



## INDOOR RESIDUAL SPRAYING FOR MALARIA CONTROL

# **Supplemental Environmental Assessment: Indoor Residual Spraying for Malaria Control in Liberia, 2013 - 2018**

## **Indoor Residual Spraying (IRS) Indefinite Quantity Contract (IQC) TO4**

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Prepared for:  
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## ACRONYMS

ACTs	artemisinin-based combination therapies
ADS	Automated Directives System
AFR	Africa
AI	active ingredient
ANC	antenatal care
BCADP	Bong County Agriculture Development Project
BCC	behavior change communication
BEO	Bureau Environmental Officer
BMP	Best Management Practice
CARI	Central agriculture Research Institute
CDC	Center for Disease Control
CHT	County Health Team
CFR	U.S. Code of Federal Regulations
COP	Chief of Party
DDT	dichloro-diphenyl-trichloroethane
DEOH	Department of Environmental Occupational Health
DfID	Department for International Development
EC	emulsifiable concentrate
ECO	Environmental Compliance Officer
EMMP	Environmental Mitigation and Monitoring Plan
EPA	Environmental Protection Agency
EPML	Environmental Protection and Management Law
FAO	Food and Agriculture Organization
FDA	Forest Development Authority
FY	Fiscal Year
GFATM	Global Fund for AIDS, Malaria and Tuberculosis
GH	Global Health
GHI	Global Health Initiative
GOL	Government of Liberia
GPS	Global Positioning System
HCA	hand catches by aspiration
HFS	Health Facility Survey
HMIS	Health Management Information System
IBA	Important Bird Area
IEC	Information, Education, and Communication
IPM	integrated pest management
IPTp	Intermittent preventive treatment for pregnant women
IRS	indoor residual spraying
ITN	insecticide-treated net
IUCN	International Union for Conservation of Nature
IVM	integrated vector management
LADD	lifetime average daily dose
L-MEP	Liberia Monitoring and Evaluation Program
LIBR	Liberia Institute for Biomedical Research
LLIN	long-lasting insecticidal net

LTC	light trap collection
NMCP	National Malaria Control Program
M&E	Monitoring and Evaluation
MDGs	Millennium Development Goals
MEO	Mission Environmental Officer
MHO	Mission Health Officer
MIS	Malaria Indicator Survey
MOA	Ministry of Agriculture
MOHSW	Ministry of Health and Social Welfare
MOP	Malaria Operational Plan
MSDS	material safety data sheet
NGO	nongovernmental organization
NEMA	National Environmental Management Authority
OP	organophosphates
PEA	Programmatic Environmental Assessment
PERSUAP	Pesticide Evaluation Report and Safer Use Action Plan
PMI	President's Malaria Initiative
POPs	persistent organic pollutants
PPE	personal protective equipment
PSCs	pyrethrum spray catches
RBM	Roll Back Malaria
REA	regional environmental advisor
RTD	rapid diagnostic tests
SAMFU	Save My Future Foundation
SCMP	Supply Chain Management Plan
SEA	Supplemental Environmental Assessment
SOW	Scope of Work
SSW	Supervisors, team leaders, storekeepers, spray operators, and washpersons
TOT	Training of Trainers
TWG	technical working group
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
UNMIL	United Nations Military in Liberia
USAID	U.S. Agency for International Development
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USG	United States Government
VCU	Vector Control Unit
WHO	World Health Organization
WHOPES	WHO Pesticide Evaluation Scheme
WP	wettable powder

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## SUMMARY OF FINDINGS

### Malaria Burden in Liberia

Liberia has been classified as a country with hyper-holoendemic malaria, perennial intense transmission, and considerable immunity outside of childhood. The climate is favorable for mosquito breeding of major vectors for malaria: *Anopheles gambiae* s.s, *An. funestus*, and *An. melas*. The major parasite species causing disease are *Plasmodium falciparum* (>90%), *P. ovale*, and *P. malariae*. Information on the frequency of co-infections, while known to exist, is not available.

According to results from the 2005 Malaria Indicator Survey (MIS), in 2005 the prevalence of malaria parasitemia in children under five was 66%. Prevalence rates have since fallen to 27.8% according to the recent 2012 MIS (positive result by microscopy, 2011 data).

The entire population of more than 3.47 million is at risk of the disease. Children under five and pregnant women are the most affected groups. According to data from the 2009 Health Facility Survey (HFS) malaria accounts for 35% of outpatient department attendance and 33% of in-patient deaths.

The National Malaria Strategic Plan focuses on malaria prevention and control in four main activities: case management of malaria, management of malaria in pregnancy, integrated vector management, and advocacy and behavior change interventions. In addition, the plan aims to strengthen the NMCP program by improving program management, operational research, monitoring and evaluation, and overall health systems strengthening (NMCP, 2011).

All WHOPEs approved insecticides, except malathion and bifenthrin, are registered in Liberia. Currently the malaria vector control program is using pyrethroids and carbamates, the latter due to resistance issues with pyrethroids. As new entomology studies are completed the program may need the flexibility to use pyrethroids, carbamates and organophosphate as appropriate in future campaigns.

### PMI Support in Liberia

The President's Malaria Initiative (PMI) is a core component of the Global Health Initiative (GHI), along with HIV/AIDS, and tuberculosis. Programming of PMI activities follow the core principles of GHI: encouraging country ownership and investing in country-led plans and health systems; increasing impact and efficiency through strategic coordination and programmatic integration; strengthening and leveraging key partnerships, multilateral organizations, and private contributions; implementing a woman- and girl-centered approach; improving monitoring and evaluation; and promoting research and innovation.

Liberia launched PMI-supported activities in 2008. Liberia's health infrastructure was severely damaged during the long civil war and only about 45% of the population has access to essential health services. The entire population of just over 3.5 million is at risk for malaria. Liberia is in the third year of a 5-year, \$37 million malaria grant from the Global Fund to Fight Aids, Tuberculosis and Malaria (Global Fund), which is paying for personnel, technical assistance, infrastructure development and commodities. Several other international and local non-governmental organizations also provide major support to malaria prevention and control efforts through importation and distribution of insecticide-treated nets (ITNs) and antimalarial drugs together with training of healthcare workers and community health volunteers. The National Malaria Control Program (NMCP) recently revised its National Malaria Control Strategy for the year 2010 – 2015.

## Adverse Health and Environmental Impacts from IRS / Mitigation Measures

Based on USAID's experience with implementation of IRS in 17 other sub-Saharan African countries under the President's Malaria Initiative (PMI), the most likely potential adverse health impact of the IRS intervention is unintentional pesticide exposure, leading to acute but mostly transitory health impacts on beneficiaries and spray operators. However, the health effects from toxic exposure to organophosphates may not be transitory, and so should be guarded against with greater vigilance. If the use of organophosphates is planned, additional efforts must be made to train and sensitize all IRS personnel to the risks involved, the symptoms of organophosphate toxicity, and the medical treatment protocol. It may also be necessary to develop a cholinesterase-monitoring program for operators and others in potential close contact with these pesticides.

To mitigate risks of exposure, all individuals involved in the implementation of spraying – from spray operators to washpersons to storekeepers – will be provided with appropriate and adequate personal protective equipment (PPE), and will be trained in the best management practices contained in the President's Malaria Initiative IRS Best Management Practices Manual. Community members will be informed on how to minimize direct and indirect exposure to insecticides (e.g., removing furniture and food from houses prior to spraying, keeping animals away, staying out of houses sprayed for two hours, sweeping dead bugs and properly disposing of them, etc.).

The highest risk to the environment is likely contamination to water resources, with subsequent die-off of fish and other aquatic life, since all the IRS insecticides are hazardous for aquatic life, with the exception of malathion, and risk to bees, which are extremely sensitive to all WHO-recommended pesticides for malaria control. Liberia has numerous water bodies considered sensitive to IRS implementation including lakes, rivers and wetlands, with five wetlands listed as important Ramsar sites. It also has one National Park and nine protected areas. Houses found within 30 meters of sensitive areas should be noted by mobilizers, marked (physically, as well as by the use of GPS if available), and not sprayed.

The PMI IRS Best Practices Manual specifies that all washing areas and soak pits must be constructed according to specific guidance in order to protect human and animal health as well as prevent environmental damage. Additional mitigation measures include utilization of PPE, best practices in pesticide storage and management, re-use/disposal of contaminated water from operations, and strong supervision and oversight at all levels.

As required by USAID's Automated Directives System (ADS) 204.5.4, USAID will actively monitor ongoing activities for compliance with the recommendations in this Supplemental Environmental Assessment (SEA), and modify or end activities that are not in compliance.

## Safer use Action Plan

During implementation, USAID/PMI/Liberia and its implementing partners will adhere to the conditions detailed in this SEA, which are summarized below, and in more detail in the Environmental Monitoring and Mitigation Plan (EMMP) **Annex 1** of this report.

### ***General implementation conditions: Project-level implementation procedures***

The following project-level implementation procedures are recommended as a general condition for approval of this SEA. Contingent upon such approval, their implementation will therefore be mandatory.

They are intended to assure that the SEA findings and conditions are implemented in project work plans, monitoring and reporting requirements:

USAID/Liberia IRS team shall undertake the following for implementation of IRS in Liberia:

1. The prime contractor for the project (“the contractor”) or his designee will develop this SEA that specifies the conditions under which IRS may be implemented.
2. The contractor or implementing partner(s) will follow the prescriptions of the EMMP contained herein, including monitoring to assure appropriate implementation and the sufficiency of environmental compliance measures.
3. The contractor or implementing partner(s) shall integrate these environmental compliance measures into the project work plan and report on them in the normal basis of project reporting. The PMI/IRS team shall assure that this integration occurs.
4. The contractor will ensure that training is provided to all IRS staff and workers as prescribed by the EMMP and Automated Directives System (ADS) 204.5.4 manual.
5. The contractor or implementing partner will notify PMI/IRS of any work plan activities outside the scope of the SEA, and the PMI unit will independently audit the work plan against the requirements of the SEA.
6. Any activities not addressed within the SEA must be addressed with an SEA amendment that must be approved by the GH and AFR BEO before the activities in question can go forward.
7. The PMI/IRS team shall ensure that the contractor’s or implementing partner’s responsibilities will be incorporated into contracts, grants or any other sub-agreement and SOWs.
8. For projects currently in implementation, USAID/Liberia-PMI unit, with the assistance of the Mission Environmental Officer and/or the Regional Environmental Advisor as necessary, will discuss SEA conditions with the contractor; and where necessary, come to appropriate agreement regarding the process for implementing these conditions as a mid-project adjustment.
9. As devising and implementing environmental compliance approaches should be an integral part of work plan development, these procedures place this responsibility principally on prime contractors. PMI/IRS Team’s primary role is thus to review and monitor, as with the execution of any other part of the work plan. Where such review and monitoring indicates unforeseen environmental impacts or that mitigation and control measures are insufficient, the PMI/IRS unit will consult promptly with the Regional Environmental Advisor (REA) at USAID/ West Africa in Accra, Ghana, to revise and adapt the environmental mitigation measures as necessary.

***Policy, Planning and Institutional Requirements***

- Prohibit the use of IRS insecticides in sensitive ecosystems (i.e. 30 meters from flood zones, wetlands, National Parks, biodiversity preserves, rivers, dams, lakes, fish farms, beekeeping areas, etc.). In line with the established best practices for IRS, and relevant national and USAID policies, the implementing partner will establish and implement mitigation measures to assure adequate protection of these sensitive ecosystems.
- Develop and implement vector resistance management. Appropriate measures will be undertaken to prevent/manage resistance and to ensure the continued effectiveness of insecticides used for IRS.
- Promote inter-sectoral collaboration frameworks and institutional arrangements to facilitate a comprehensive approach to vector control and associated pesticides management. Coordination between the malaria control program and major stakeholders will be strengthened. This will include collaboration with:

- Ministry of Agriculture – The *National Quarantine and Environmental Services* bureau is responsible for regulating the importation and use of agricultural chemicals, including fertilizers and pesticides. It issues permits for the importation of agricultural chemicals and implements international conventions governing pesticides and chemicals.
- The Environmental Protection Agency of the Republic of Liberia is the principle authority for implementing the national environmental policy and sustainable management law for the protection of natural resources in Liberia.
- The Ministry of Health and Social Welfare is responsible for activities pertaining to the protection and improvement of public health and social welfare. The National Malaria Control Program (NMCP) has the mandate to plan, implement and coordinate malaria control activities in Liberia. The County Health Teams deal with all diseases including malaria at the district level.

### **Operational Requirements**

The IRS implementing contractor will work closely with NMCP to access relevant country level authorization and support needed for successful IRS implementation:

- Quality assurance for commodity procurement and IRS operations, to minimize risks to human health and the environment. This will include ensuring legitimate procurement sources, verifiable chain of custody of commodities, and representative sampling and analysis of pesticide, as well as effective quality compliance inspections of IRS activities in the field.
- Ensure compliance with national regulations on pesticides and USAID Best Management Practices for registering, importing, transporting, labeling, handling, use, storage, and disposal of pesticides.
- Train relevant categories of workers involved in IRS operations (e.g. district program managers/coordinators, spray operators, storekeepers, pesticide transporters, washpersons, and supervisors) on best practices in accordance with national pesticides regulations and recommendations/guidelines of WHO and this SEA. Criteria for reprimanding non-observance of best practices by these workers will be established.
- Ensure use of appropriate personal protective equipment and best practices, including effective field supervision of spray operations, for adequate protection of spray operators and other handlers of pesticides or pesticide-contaminated waste.
- Train health workers in the management of insecticide poisoning. This will include program-specific guidelines on poison treatment; designation of district hospitals or health clinics within the target areas for appropriate treatment of insecticide poisoning; training of IRS workers to recognize early danger signs of poisoning and taking appropriate action.
- Enforce protection of fetus and suckling-children against exposure in spray operations. Exclude pregnant women and breast-feeding mothers from direct handling of pesticides (e.g. spray operations, washers). Before each spray season, and every thirty days thereafter during operations, pregnancy testing will be established for potential female handlers of pesticides.
- Carry out IEC activities for targeted communities and households to reduce exposure. Provide information on the removal of food, cooking and water utensils, covering of unmovable furniture with impermeable plastic prior to spraying; exclusion of spraying rooms used by pregnant women or sick individuals who are unable to leave their homes; preventing the reentry

of sprayed rooms for at least two hours after spraying; sweeping of floor residues before reentry of children or animals and disposal cleaning wastes including dead insects in pit latrines.

- Establish strict practices to reduce environmental contamination. This will include comprehensive auditing of pesticide stocks and usage, as well as enforcing best practices related to the handling, washing and disposal of containers; progressive use of waste/wash water and ablution blocks.
- Establish best practice for the transport of spray operators. This includes providing trucks with benches for transport of spray operators, and ensuring that spray operators are not transported with insecticides. Contract specific insurance for covering spray operators during spray operation. Strengthen training of drivers to limit risk of accident.
- Provide training support, as necessary, to strengthen the supervisory capacity of Environment Protections Agency at National, County and District level for day-to-day monitoring of environment compliance of IRS activities.

In coordination with AIRS, NMCP, EPA and MOA will carry out routine compliance inspections of all IRS districts, including unannounced spot inspections, to verify compliance with all relevant national regulations. PMI will also conduct inspections of IRS activities and facilities in the IRS districts.

PMI contractor (Abt Associates) will work with the NMCP to ensure that IRS Training of Trainers IRS, County Health Teams training and Training of Spray Operators includes use of local language on minimizing environmental contamination of IRS by: a) ensuring appropriate language in community mobilization efforts about sweeping houses and burying materials in latrines or dug holes, and b) training of spray operators, team leaders, and supervisors on proper maintenance of spray pumps to prevent spray pump leakages.

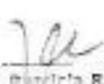
**APPROVAL OF ENVIRONMENTAL ACTION RECOMMENDED:**

The United States Agency for International Development's Global Health Bureau has determined that the proposed indoor residual spraying effort, as described in the Supplemental Environmental Assessment: Indoor Residual Spraying for malaria control in Liberia, December 2012, responds to the needs of the community and country as it relates to managing malaria in Liberia as well as conforms to the requirements established in 22 CFR 216.

This document does not mandate the execution of the proposed IRS, rather, documents the environmental planning and impact analysis executed by the IRS team in preparation for the proposed action. The design and standards of operation of the IRS program are established to avoid and reduce any potential impact. USAID has concluded that the proposed action, when executed as described in the Supplemental Environmental Assessment and the Programmatic Environmental Assessment, is consistent with USAID's goal of reducing malaria incidence in Liberia while minimizing negative impact to environmental and human health.

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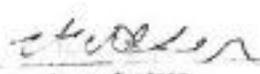
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## PURPOSE OF THIS DOCUMENT

Under the U.S. Code of Federal Regulations (22 CFR §216), malaria vector control activities supported or planned by USAID must undergo environmental examination. To assist USAID missions in planning malaria vector control interventions, USAID prepared a Programmatic Environmental Assessment (PEA), *Management Programs for Malaria Vector Control: Programmatic Environmental Assessment* (USAID, 2012), that provides a broad view of the human health and environmental impacts that could result from implementation of malaria vector control interventions. However, the PEA cannot account for inter-country and interregional variation regarding issues such as the capacity to manage pesticides used for vector control and the environment likely to be impacted. For this reason, Supplemental Environmental Assessments (SEAs) must be developed to describe in-country impacts of interventions and describe country-specific activities to minimize those impacts.

Whenever an in-country malaria vector control activity involves “assistance for the procurement or use, or both, of pesticides,” SEAs supplementing the PEA must address the pesticide procedures found in 22 CFR 216.3(b) (**Annex 4**). The pesticide procedures list 12 factors to address in SEAs and are described in the Pesticide Procedures section of this document.

In sum, the SEA should be looked upon as the overall picture within the country. The SEA should address the human health and environmental impacts that may occur as a result of USAID support of malaria vector control activities.

The purpose of a malaria program is to save lives and reduce illness and suffering. The purpose of the SEA is to optimize these goals by ensuring malaria control programs use only safe and efficacious pesticides and use them in the way that will minimize inadvertent poisonings and intoxications; by ensuring the natural resources on which people depend for their daily food production and nutrition are not damaged; by ensuring that long term development is promoted by avoiding disruption of agricultural exports by avoiding misuse of malaria pesticides on agricultural crops; and, by participating in international environmental agreements such as the Stockholm Convention on Persistent Organic Pollutants, among others.

This is the second SEA that has been prepared for the PMI IRS program in Liberia. The initial SEA was approved in November 2009, and was valid for three years. This SEA update is in response to the expiration of that SEA, and also addresses changes in the IRS program and provides an environmental review of all 15 Counties in order to cover the potential expansion or changes in program area over the next five years. As per the previous SEA, this document also considers and proposes the use of three classes of WHO-approved pesticides (pyrethroids, carbamates, and organophosphates) for IRS activities in Liberia for a period of five years (2013-2017).

After 2013, a Letter Report will be submitted to USAID annually that will discuss the IRS program in detail and all affected geographic areas for that particular year’s spray campaign. The preparation of this SEA update renders the preparation of a Letter Report unnecessary.

## BACKGROUND

### Background to the Proposed Action

Malaria prevention and control are major foreign assistance objectives of the U.S. Government (USG). In May 2009, President Barack Obama announced the Global Health Initiative (GHI), a comprehensive effort to reduce the burden of disease and promote healthy communities and families around the world. The President's Malaria Initiative (PMI) is a core component of the GHI, along with HIV/AIDS, tuberculosis, maternal and child health, family planning and reproductive health, nutrition and neglected tropical diseases.

The PMI was launched in June 2005 as a 5-year, \$1.2 billion initiative to rapidly scale up malaria prevention and treatment interventions and reduce malaria-related mortality by 50% in 15 high-burden countries in sub-Saharan Africa. With passage of the 2008 Lantos-Hyde Act, funding for PMI has now been extended through Fiscal Year (FY) 2014, and the program has expanded to 19 countries. Programming of PMI activities follows the core principles of GHI: encouraging country ownership and investing in country-led plans and health systems; increasing impact and efficiency through strategic coordination and programmatic integration; strengthening and leveraging key partnerships, multilateral organizations, and private contributions; implementing a woman- and girl-centered approach; improving monitoring and evaluation (M&E); and promoting research and innovation.

Liberia launched PMI-supported activities in 2008. Liberia's health infrastructure was severely damaged during the long civil war and only about 45% of the population has access to essential health services. The entire population of just over 3.5 million is at risk for malaria. The 2009 Malaria Indicator Survey (MIS) showed that net use is still low at about 33%, while parasitemia, determined using rapid diagnostic tests (RDTs), was 37%.

Liberia is in the third year of a 5-year, \$37 million malaria grant from the Global Fund to Fight Aids, Tuberculosis and Malaria (Global Fund), which is paying for personnel, technical assistance, infrastructure development and commodities. Several other international and local non-governmental organizations also provide major support to malaria prevention and control efforts through importation and distribution of insecticide-treated nets (ITNs) and antimalarial drugs together with training of healthcare workers and community health volunteers. The National Malaria Control Program (NMCP) recently revised its National Malaria Control Strategy for the year 2010 – 2015.

### Malaria Burden in Liberia

Liberia covers 43,000 square miles in West Africa and is bounded by nearly 350 miles of Atlantic Ocean coastline off the southwest and by the neighboring countries of Sierra Leone (northwest), Guinea (north) and Côte d'Ivoire (east and southeast). Liberia is administratively divided into 15 counties and 95 districts.

Most of the country lies at altitudes below 500 meters. The coastal areas are characterized by mangrove swamps, which give way to tropical rain forest that gradually thins out northwards to be replaced by deciduous forest. All geographic areas of Liberia are favorable to malaria transmission.

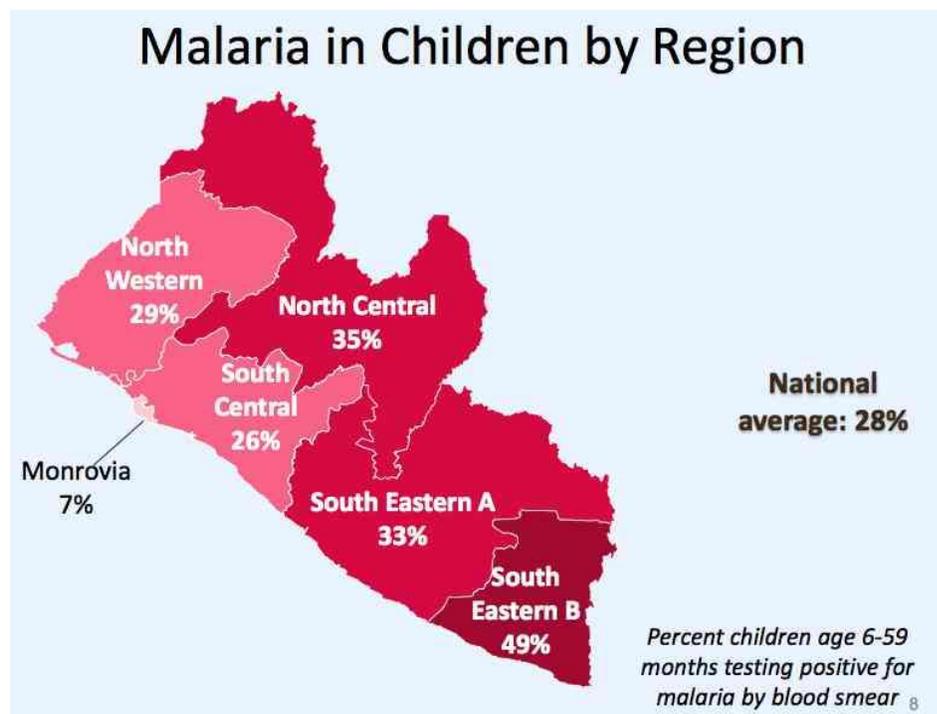
Results from prevalence studies prior to Liberia's civil wars (1989 – 1996; 1999 – 2003) classified Liberia as a country with hyper-holoendemic malaria, perennial intense transmission, and considerable

immunity outside of childhood. The climate is favorable for mosquito breeding of major vectors for malaria: *Anopheles gambiae* s.s, *An. funestus*, and *An. melas*. The major parasite species causing disease are *Plasmodium falciparum* (>90%), *P. ovale*, and *P. malariae*. Information on the frequency of co-infections, while known to exist, is not available.

According to results from the 2005 Malaria Indicator Survey (MIS), in 2005 the prevalence of malaria parasitemia in children under five was 66%. Prevalence rates have since fallen to 32% according to the recent 2009 MIS.

The entire population of more than 3.47 million is at risk of the disease. Children under five and pregnant women are the most affected groups. According to data from the 2009 Health Facility Survey (HFS) malaria accounts for 35% of outpatient department attendance and 33% of in-patient deaths.

Figure 1: Malaria prevalence in Liberia 2011



(Map courtesy of the MIS 2011 report)

### **Socio-economic impact**

Even though the socio-economic impact of malaria has not been assessed, the cost of treatment to families and the cost of lost days of work can be considerably high. The effects of malaria on the community may include substantial financial loss due to the payment of treatment/consultation costs, antimalarial drugs and vector control measures at the household level. Due to the Global Funds round 3 Grant to Liberia, some of the economic burden of malaria in terms of cost of treatment was reduced for some time (August 2005-May 2007). Sickness may cause further losses due to an inability to work or the need to look after other family member thereby preventing attendance at work. Other impacts include

absenteeism and general overburdening of the already over-stretched health service. Overall productivity for the country as a whole is significantly affected.

## History of Malaria Control

From 1958-61, UNICEF and WHO sponsored a malaria eradication project in Liberia to ascertain whether transmission could be interrupted with IRS. The project covered the central province of the country, an area of ~14,000 km<sup>2</sup>, using DDT at 2 gm/m<sup>2</sup> with one application per year. Entomological investigations showed an apparent disappearance of vectors immediately after spraying which persisted for up to two years. Bio-assays on walls demonstrated activity 12 months after spraying. Conclusions drawn from this study were that anopheline vectors in the area were highly susceptible to single annual application of DDT and that interruption of transmission was technically feasible in the forest areas of Liberia. Population movement and the lack of trained spray personnel, equipment and facilities to support the program were identified as major limiting factors for IRS-based vector control at that time.

### Progress to Date

The activities that the PMI has and will continue to support conform to the Ministry of Health and Social Welfare (MOHSW) National Malaria Strategic Plan, and support investments made by the NMCP, Global Fund, UNICEF, WHO, and other donors to improve and expand malaria-related services. Several international and local non-governmental organizations (NGOs) also provide major support to malaria prevention and control efforts through importation and distribution of insecticide-treated nets (ITNs), antimalarial drugs and training of healthcare workers and community health volunteers.

Since August 2005, as part of the previous National Malaria Strategic Plan and, with funding largely from the Global Fund, progress has been made in malaria control and prevention. The major achievements from August 2005 to October 2009, documented in the 2009 MIS include:

- 17% of children under five are receiving prompt and effective treatment for malaria within 24hrs from the onset of fever, up from 5% in 2005
- 45% of women are receiving two or more Intermittent Preventive Treatment during Pregnancy (IPTp) during their most recent pregnancy, up from 4% in 2005
- 47% of households have at least one ITN, up from 18% in 2005
- 27% of children under five slept under an ITN the previous night, up from 3%
- 33% of pregnant women slept under an ITN the previous night, up from 31%.

Until 2007, the Global Fund, the World Health Organization (WHO), and UNICEF constituted the major external sources of funding for the implementation of malaria control and prevention activities in Liberia. A Global Fund Round 3 grant provided \$12 million over two years for improving case management including the procurement of ACTs, sulfadoxine- pyrimethamine (SP) for IPTp, vector control, BCC activities, community mobilization, and program management, including paying salaries of NMCP staff; this grant ended in February 2007. A \$37 million Global Fund Round 7 grant was signed in April 2008, with the United Nations Development Program as the Principal Recipient. With Round 7 funding, Liberia plans to procure and distribute 7 million ACT treatments, 1.6 million ITNs to children under- five and pregnant women, and two doses of SP for more than 300,000 pregnant women. Also, Liberia is the recipient of a Global Fund Round 10 award of \$20,560,000 for two years, starting in 2012.

### Indoor residual spraying

Prior to PMI support, spraying in Liberia was limited to sporadic campaigns in camps for internally displaced persons or returning refugees, and protected a population of approximately 150,000 people. In 2009, MOHSW leadership endorsed the NMCP plan to initiate IRS using a pyrethroid insecticide. Spraying in 2007-2008 was conducted in camps for internally displaced persons and refugees, with a population of approximately 150,000 protected. With PMI funding, the Liberia IRS project commenced in June 2009 and targeted two districts in Grand Bassa (Mamba-Kaba and Owen's Grove) and one district in Margibi (District Number 1). Approximately 20,000 houses were sprayed in 2009, protecting over 163,000 people, or 5% of the population. Throughout the program, the PMI's implementing partner worked to develop the operational capacity of Liberia's NMCP, particularly the vector control unit and designated implementing partners.

In 2010, PMI expanded IRS to cover more than 48,000 houses protecting over 160,000 people, together with surveillance of vectors and insecticide resistance monitoring. In 2011, IRS expanded to approximately 80,000 houses protecting 400,000 people and training was conducted for increased capacity for surveillance of vectors and insecticide resistance. Emerging yet focal resistance dictated that a carbamate be used in three counties while a pyrethroid would continue to be used in 11 counties. IRS is currently performed in four counties, two of which require the use of carbamate.

IRS operations in 2012 were conducted in 14 districts in five counties: Grand Bassa, Margibi, Montserrado, Bong, and Nimba. Pyrethroids were sprayed in March through June in Grand Bassa County, parts of Dong County (Fuamah, Kokoyah, Panta and Kpaai Districts) and Nimba County. Carbamate was sprayed in March through June, and again in October through November in Montserrado County (Carysburg District) and Margibi County (Mamba Kaba District). Carbamate had been selected for spraying in 2012 due to an increase of resistance to pyrethroids in certain districts. Spraying was undertaken in two campaigns: a public sector spray campaign and a private sector campaign. The private sector spraying included support to spray the premises of Arcelo Mittal, an iron ore mining company located in Yekepa, Nimba County with a base in Buchanan, Grand Bassa.

Insecticide-treated nets: The Global Fund for AIDS, Malaria and Tuberculosis (GFATM) has provided almost a half million ITNs to Liberia since 2005 and the total number that have been distributed are over 660,000. Several service delivery mechanisms have been used to distribute the ITNs, including free door-to-door and other types of campaign distributions, and free distribution through antenatal care (ANC) clinics. Bed nets are available for sale through a few vendors in Monrovia, but the target groups have been expatriate workers as the price is prohibitive for the vast majority of Liberians. The NMCP has set a target of three ITNs per household, or approximately one ITN for each sleeping space. To support this target, PMI procured and distributed 184,000 LLINs in two counties (Bome and Grand Cape Mount) in 2008, and 430,000 LLINs in three counties (Nimba, Grand Bassa, and Lofa) in 2009. Other partners are procuring approximately 200,000 ITNs. The combined effort is expected to bring nationwide ownership of target groups to 60%. While coverage has increased dramatically over the last several years, usage remains low; therefore, PMI is also working with non-governmental organizations (NGOs) to support community-based information, education, and communication/behavior change communication (IEC/BCC) campaigns to increase demand for and correct usage of LLINs.

### **USAID/LIBERIA Strategic Approach**

The USG's investments in health will focus on two areas that mirror priorities in the new 2011-21 National Health and Social Welfare Plan: 1) improving service delivery thru the Essential Package of Health Services; and 2) strengthening health systems to increase institutional capacity for sustainability of service delivery.

This focus will be operationalized through a 3-tiered approach for USG support:

Tier 1: Investment nationwide

- The USG will increase investment in capacity building and technical assistance for policy formulation, strategy development and health systems strengthening benefitting Liberia as whole. In the immediate future, USG support in health system strengthening will prioritize critical areas that have been jointly identified, such as the Health Management Information System (HMIS), health financing, pharmaceutical and commodities supply chain, BCC and human resources for health.

Tier 2: Intensive investment in three focus counties

- The USG will prioritize the three target counties of Bong, Lofa and Nimba, to support the full complement of its health portfolio for maximum impact in improving delivery of quality services, behavior change, utilization of available preventive and curative services, and capacity building of the MOHSW's County Health Teams (CHTs). Specifically, the USG, with resources from several USAID funding streams including maternal and child health, family planning, HIV/AIDS and PMI, will continue to provide both facility-based and community-based support under performance-based contracting with non-governmental organizations (NGOs) for specific health facilities and their catchment communities to implement the MOHSW's integrated package of health services for which malaria cases account for over 30% of patient encounters. In addition, the USG funding will provide complementary technical assistance for quality assurance, in-service training, monitoring and supervision, which will target all health facilities and communities within the three counties. PMI funds represent about one-quarter of the total USG support being provided to these three counties. This approach supports the MOHSW's desire for cohesive and efficient country-wide health network that enables the scale up of high-impact, cost-effective interventions for the leading causes of morbidity and mortality.

Tier 3: Strategic investment in six development corridor counties

- As the lead development agency, USAID is targeting six counties along the Government of Liberia's (GOL) Development Corridors and the health portfolio is focusing efforts on three of these counties, as noted above. As funding levels allow, however, the USG will make investments in Montserrado, Margibi, and Grand Bassa to complement and leverage other partner investments in critical areas such as malaria, family planning, nutrition, and immunizations. These investments will be strategically designed to extend the USG's technical expertise in areas of comparative advantage and to fill gaps in implementation of these national programs.

Under this new strategic approach coinciding with an evolution of malaria control in Liberia, which has already reduced prevalence by 50% between 2005 and 2009, donor efforts are being coordinated to efficiently consolidate gains and accelerate progress. To this end, PMI will continue to support the national malaria control program with over 70% of the MOP budget financing activities implemented at the national level, and will place extra focus in Bong, Nimba, Lofa, Grand Bassa, Margibi, and Montserrado counties, where over 75% of the population resides.

## Program Objectives

The goal of PMI is to reduce malaria-associated mortality by 70% compared to pre-Initiative levels in the 15 original PMI countries. By the end of 2014, PMI will assist Liberia to achieve the following targets in populations at risk for malaria:

- >90% of households with a pregnant woman and/or children under five will own at least one ITN;
- 85% of children under five will have slept under an ITN the previous night;
- 85% of pregnant women will have slept under an ITN the previous night;
- 85% of houses in geographic areas targeted for IRS will have been sprayed;
- 85% of pregnant women and children under five will have slept under an ITN the previous night or in a house that has been sprayed with IRS in the last 6 months;
- 85% of women who have completed a pregnancy in the last two years will have received two or more doses of IPTp during that pregnancy;
- 85% of government health facilities have ACTs available for treatment of uncomplicated malaria; and
- 85% of children under five with suspected malaria will have received treatment with ACTs within 24 hours of onset of their symptoms.

### EXPECTED RESULTS - YEAR 5

#### Prevention:

- Procure and distribute 150,000 free ITNs to vulnerable groups through door-to-door campaigns, and through routine services in health facilities to help reach approximately 85% household ownership of one or more ITNs; and
- At least 85% of houses in districts targeted by the NMCP and PMI for IRS will have been sprayed (a total of 400,000 residents will be protected by IRS covering approximately 80,000 houses)

#### Case Management:

- Procure and assist with the distribution of 2.35 million artesunate-amodiaquine (AS- AQ) treatments. This, together with training and BCC efforts related to case management supported by PMI and other partners is expected to increase the proportion of children under-five with suspected malaria who receive an ACT within 24 hours of the onset of symptoms to 60%;
- Procure approximately 150,000 treatments to supply almost all nationwide needs for drugs and supplies for management of severe malaria; Enhance laboratory capacity for microscopic and RDTs diagnosis of malaria through provision of training, equipment, and laboratory supplies;
- Procure approximately 2.5 million RDTs and provide training and ongoing supervision in their use.

## Institutional Framework for Malaria Control

### ***NMCP National Malaria Strategic Plan***

In an effort to reduce the malaria burden in Liberia, the MOHSW introduced a policy and strategic plan for malaria control and prevention. The plan was in line with the Abuja Declaration, which the government of Liberia signed in April 2000, as well as Roll Back Malaria (RBM) guidelines. Liberia's third

National Malaria Strategic Plan for 2010-2015 addresses the need to scale-up malaria control and prevention activities to achieve the RBM target of reducing malaria morbidity and mortality by half in 2010, as well as the Millennium Development Goals (MDGs) of sustaining this progress and beginning to reverse the incidence of malaria by 2015. This six-year National Malaria Strategic Plan builds on the achievements made thus far while recognizing the challenges and addressing the essential actions to be taken to reduce the malaria morbidity and mortality trends in Liberia. The third Strategic Plan addresses gaps observed in the implementation of the first and interim Strategic Plans and also puts forth a more detailed and well-assessed strategy for dealing with the malaria situation in Liberia by these target dates.

The National Malaria Strategic Plan focuses on malaria prevention and control in four main activities: case management of malaria, management of malaria in pregnancy, integrated vector management, and advocacy and behavior change interventions. In addition, the plan aims to strengthen the NMCP program by improving program management, operational research, monitoring and evaluation, and overall health systems strengthening (NMCP, 2011).

The Malaria Case Management arm of the National Malaria Strategic Plan addresses the population's poor access to health services, health professionals' reluctance to use ACT, and the high circulation of chloroquine within Liberia. Case Management activities intend to scale up the availability and promote the use of ACT, the first-line treatment for malaria. The plan will make the fixed-dose artesunate and amodiaquine combination therapy available to all health facilities, while training the health staff in their appropriate use. Moreover, the role of general Community Health Teams (CHTs) within the community will be reinforced, and CHT's will be provided with malaria control tools and training to use these tools. To make ACT more available and more affordable in the private sector, private health care providers (pharmacies and drug/medicine stores) will dispense ACT at an agreeable price. The overall goal of the Case Management activities is to increase ACT use and subsequently reduce malaria morbidity and mortality.

The Malaria in Pregnancy section of the National Malaria Strategic Plan consists of three main interventions: intermittent prevention treatment (IPTp), use of long-lasting insecticidal nets (LLINs), and effective case management of malaria and anemia among pregnant women. IPT programs recommend that pregnant women receive at least two doses of sulphadoxine-pyrimethamine (SP), with one dose received during a prenatal care visit, to protect women against malaria. The Malaria in Pregnancy interventions aim to reduce not only malaria in pregnant women but also to curb the infant's low-birth weight, which is a result of fetal malaria infection.

The National Malaria Strategic Plan also includes a three-tiered Integrated Vector Management (IVM) approach. The goal of the IVM program is to increase mosquito net ownership in the population and to protect households from contact with mosquitoes. IVM will provide LLINs through mass distribution to all family units, as well as targeted distribution to pregnant women and children under age 5 to achieve maximum results for prevention of malaria transmission. The strategy will also continue targeted indoor residual spraying (IRS) of households and will consider other vector management strategies for environmental control.

The Behavior Change Communication component of the National Malaria Strategic Plan strives to increase support for advocacy and health education at all levels of society. To effect behavioral change, the program uses television, radio, schools, and places of worship to stress the importance of ACT therapy, LLIN use, and other forms of vector management. The role of the community in malaria control

and prevention activities is emphasized.

### ***Environmental Protection Agency (EPA)***

The EPA is actively involved with the Malaria Control Program and is one of the government agencies who collaborate with the NMCP. It is the principal authority for the management of the environment, and is mandated to coordinate, monitor, supervise, and consult with relevant stakeholders on all activities in the protection of the environment and sustainable use of natural resources. EPA promotes environmental awareness, implements the National Environment Policy, the Environmental Protection and Management Law, and oversees the implementation of relevant international environment conventions. The agency recognizes the role of sectorial environmental units such as water, agriculture, maritime, energy and forestry. These units are to work in conjunction with the respective line ministries and autonomous agencies that are involved with the environment. The agency also has an environmental conservation section that will oversee international environmental conventions such as the Convention on Biological Diversity, United Nations Framework Convention on Climate Change, Montreal Protocol, and the Cartagena Protocol on Biosafety.

### **Coordination with Partners**

The NMCP developed, in collaboration with donors and technical agencies, a work plan that all partners support and use to coordinate their activities. The cost difference for implementation of activities in different counties results from varying levels of cost-sharing and leveraging of resources from other donors according to the “lead partner” designation in each county. Each donor group funds various partners to implement an array of health activities including malaria control in collaboration with the NMCP and the Global Fund to cover all 15 Counties in the country. The European Union is providing support to five counties, the Pool Fund, which represents the United Kingdom’s Department for International Development (DfID), Irish Aid, and United Nations Children’s Emergency Fund (UNICEF) is supporting seven counties, and the USG is supporting six counties, with some overlap in three counties.

The WHO has hired a National Professional Officer to provide technical assistance related to malaria. UNICEF has assisted with the procurement and distribution of ITNs in the past and distributed over 350,000 ITNs in Liberia for FY2010. NGOs such as John Snow Inc., MENTOR Initiative, EQUIP, Africare, Save the Children, and the Red Cross continue to provide significant support to the GOL and, in particular, the MOHSW, to ensure health service delivery continues.

Several mechanisms for communication and coordination between the NMCP and partners exist in Liberia and include the following:

#### **Liberia Country Coordinating Mechanism**

The Country Coordinating Mechanism is made up of representatives from the donor and NGO communities as well as technical and managerial leads from UN agencies and MOHSW senior leadership. USAID is a voting member of the Country Coordinating Mechanism. They meet to review options and plans for submission of proposals to the Global Fund and keep abreast of progress toward start-up of activities and grant implementation. The Country Coordinating Mechanism does not have any direct role in implementation of malaria activities. Liberia is consolidating the Global Fund Round 7 phase 2 and the Round 10 grants.

### Malaria Steering Committee

Recommended by RBM and in response to the current malaria situation in Liberia, a Malaria Steering Committee was formed to strengthen partnerships and coordination. The Malaria Steering Committee includes the NMCP as well as representatives of all implementing partners, including relevant government ministries and agencies, international and local NGOs, donor agencies, and multilateral organizations. It meets on a monthly basis. The Malaria Steering Committee advises and guides the NMCP and other participating partners on the content and organization of their work plan and projects.

### Donors' technical coordination forum

The PMI team initiated a donors' technical coordination forum where United Nations Development Program (UNDP), UNICEF, WHO, and PMI meet monthly to exchange information on issues of mutual interests and coordinate activities;

### Donor coordination meeting

Every month the MOHSW chairs a meeting of donors and heads of departments in the MOHSW and reviews major developments in the health sector. The PMI and other USAID health programs participate in these meetings.

NMCP, with PMI coordination and support, has developed a consolidated 2011 work plan including budget; this template facilitates follow-up of malaria control program activities on a quarterly basis.

The MOHSW has also established a National Diagnostics Unit to coordinate diagnostics activities for service delivery across Liberia. A TWG has been established by the Unit to plan and coordinate activities on diagnostics. The TWG is currently reviewing a National Diagnostics Strategic Plan that will harmonize diagnostics activities for malaria, HIV/AIDS and Tuberculosis with support from partners.

The Supply Chain Management Unit of the MOHSW will be responsible for rolling out the Supply Chain Management Plan (SCMP) developed for Liberia with technical support from PMI. A technical working group (TWG) for supply chain issues meets monthly to review progress made in the implementation of the supply chain and propose remedies for unresolved challenges.

PMI is developing a National Guideline and National Policy for malaria diagnostics in collaboration with the NMCP. These documents are expected to feed into the National Diagnostics Strategic Plan of the MOHSW currently being reviewed. The SCMP is being implemented in a phased fashion with a pilot being carried out in Montserrado County, which will subsequently be rolled out to the rest of the country. The management information system being piloted will enable data from health facilities to be collected, collated and analyzed through the supply chain system for adequate quantification and forecasting of antimalarial drugs.

### **Private Sector Partnership**

It is essential that the private sector collaborate with the NMCP for Liberia to achieve its malaria control objectives. The large populations living within the concession areas managed by private companies remain in malaria transmission foci and may not easily access effective preventative malaria services. As PMI-supported IRS activities demonstrate success, companies have expressed interest in conducting IRS as part of malaria prevention in the context of corporate social responsibility. To further the sustainability of IRS, an integral part of malaria control strategy in Liberia, private sector participation

must be expanded.

PMI is currently the only international donor funding IRS activities. The NMCP would like other donor groups and private sector collaboration in the funding of IRS. The country team guided by the NMCP and PMI will facilitate dialogue to encourage private sector participation in IRS activities. Establishing a network of private sector partners to coordinate experiences and information will help. The team will also develop a concept note on private sector collaboration to assist with private sector participation.

The second phase of the PMI IRS implementation project was rolled out during the third quarter of 2010; this was a public-private partnership initiative. During the course of the year, three large corporate entities— Arcelor Mittal Mining Company, an iron ore mining company, and two rubber plantation companies, Firestone Liberia and Liberia Agricultural Company—expressed interest in undertaking an IRS program to protect their employees. These companies compose close to 155,000 employees with 100,000 dependents residing within company premises. Initial spraying of the Arcelor Mittal Mining Company concession has taken place. NMCP is still talking to Firestone Liberia to also start IRS at its concession, but has successfully sprayed at the LIBINC Palm Oil concession area. Nine employees and nine volunteers were trained. Spraying was conducted over a 17-day period, with 1,168 structures sprayed, and 6,762 people and 1174 households protected by IRS.

PMI plans to use this partnership as an example of successful collaboration between the public and private sectors, and hope that it will lead the way for future collaboration with other private companies in Liberia.

Support from PMI for private companies will include assisting with the mobilization of communities, and providing technical training and guidance to sprayers and supervisors in line with international standards. PMI will also supply insecticides and spraying equipment and encourage daily reports, feedback, and summaries from spray teams as well as an evaluation meeting with lessons learned at the completion of the activity. Spray teams will be requested to present regular data on malaria morbidity and mortality

### International Conventions

Over the past decade, Liberia has acceded to, or ratified several international conventions relevant to natural resources management and environmental protection. They include:

- Africa Convention on the Conservation of Nature and Natural Resources
- Convention on International Trade in Endangered Species of Wildlife Fauna & Flora (CITES 1981);
- Convention to Combat Desertification (1998). Liberia has submitted her first national report on desertification to the convention secretariat. Her geographic location does not place it in any serious desertification category. Land degradation activities are, however, prevalent;
- Vienna convention for the Protection of the Ozone Layer (1996), and the Montreal Protocol on substances that deplete the Ozone Layer;
- The Convention on Biological Diversity was ratified (2000).
- In 2002, Liberia acceded to the:
  - Convention on World Cultural and Natural Heritages;
  - The United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol;
  - The Stockholm Convention on Persistent Organic Pollutants (POPs);

- The Ramsar Convention on Wetlands of International Importance, especially as Waterfowl Habitat. This convention came into force on 2 November 2003.
- Cartagena Protocol on Biosafety

### **Pesticide Regulation and Control**

The *National Quarantine and Environmental Services* bureau within the Department of Technical Services within the MOA is responsible for regulating the importation and use of agricultural chemicals, including fertilizers and pesticides. It issues permits for the importation of agricultural chemicals and implements international conventions governing pesticides and chemicals. Unfortunately, it has no scientific testing facility and limited capacity to conduct field monitoring of agricultural chemical use.

### **Waste Disposal Regulations**

The Environmental Protection and Management Law (EPML), April 30, 2003, forms the legal framework for the sustainable development, management and protection of the environment by the Environmental Protection Agency in partnership with relevant ministries, autonomous agencies and organizations. Part IV of the EPML concerns the establishment of environmental quality standards and includes Solid Waste Management Guidelines. Part V of the EPML covers pollution control and licensing. This part, in conjunction with many of the requirements in Part IV, provides for the development of programs to manage: Pesticides, Toxic and Hazardous Materials, Leaded Gasoline and Paint, Hazardous Waste, Wastewater Effluents, Solid Waste Management, and Air Pollution.

### **Malaria Vector Control Activities in Liberia**

#### ***LLINs***

The NMCP's National Strategic Plan for 2010-2015 aims to increase usage of ITNs among the whole population, especially pregnant women and children under five. PMI will continue to support strengthening the management of the national net program, improving logistics, forecasting, storage, distribution, training, and associated behavior change and communication for improve net usage.

Liberia's ITN policy is "universal coverage defined as three ITNs per household. Distribution approaches are regular mass campaigns and distribution at ANC services.

The NMCP seeks to increase use of ITN to 80% among the entire population through intense BCC campaigns at the community level. The National Malaria Strategic Plan also calls for targeting vulnerable populations such as pregnant women and children under five-years of age. Additionally, focus will be placed on reaching at least 85% of women of child-bearing age. More than one million ITNs purchased by PMI have been distributed to 12 of the 15 counties in Liberia since 2008.

To attain the universal coverage, NMCP continued ITN mass campaign distribution: 883,400 ITNs were distributed free in Montserrado, Bong, and Nimba Counties, with 480,000 of these ITNs purchased by PMI. Local and international NGOs, donors, government departments and communities contributed to the campaign. PMI trained 846 community health workers as supervisors. Mass media was reinforced by a door-to-door campaign. A total of 2,000 reminder cards and 20,000 leaflets were distributed. In September, additional mass-media messages on hanging up ITNs were broadcast through local radio along with the replacement of 350,000 ITNs to the southeastern counties of Grand Gedeh, Rivergee, Sinoe, Maryland, Grand Kru and, Rivercess. In addition, more than 60,000 ITNs were distributed free through ANC visits to enhance nets ownership among pregnant women.

## **IRS**

The 2010-2015 revised NMCP strategy includes increased use of IRS in rural districts of high prevalence, covering approximately 45% of the population, and at least 85% of houses in the target areas accepting IRS. Objectives are to: 1) improve procurement of insecticides, sprayers, protective gear and maintenance of spray pumps; 2) strengthen the CHTs capacity to implement IRS; and 3) map district-specific information on vector and malaria prevalence.

The NMCP has stated their desire to develop a strong program based on focal IRS, as part of their IVM strategy, however they have very limited malaria vector surveillance or control capacity. Although an overall IRS strategy exists, no detailed IRS plans have been developed. The NMCP has requested PMI assistance to establish an IRS program, to include the capacity to conduct vector surveillance, a baseline assessment to determine efficacy and cost, and identify the optimum parameters to include insecticide duration of efficacy for a targeted IRS program.

Households are considered to be covered if they own at least one ITN, have been sprayed by IRS at any time in the past 12 months, or both. Overall, 54 percent of households in Liberia are covered; that is, they reported either ownership of at least one ITN and/or IRS of their dwelling places. There is little difference between vector control coverage among the urban and rural populations or among wealth quintiles. The percentage of households with at least one ITN and/or sprayed by IRS in the past 12 months ranges from a low of 44 percent in the North Western region to a high of 65 percent in the South Eastern B region. IRS target areas have included Mamba-Kaba district in Margibi County; all districts in Grand Bassa except Buchanan City; Careysburg district in Montserrado County; Fuamah, Kokoyah, and Panta-Kpaai districts in Bong County; and Arcelor Mittal concession area in Yekepa, Nimba County.

Training is ongoing to increase capacity of NMCP staff for entomologic surveillance and insecticide resistance. Emerging yet focal resistance dictated that a carbamate be used in two counties while a pyrethroid will continue to be used in the other 3 counties. Under public-private partnerships, IRS will also be implemented in 14,000 households in the Liberian Agriculture Cooperative rubber plantation, LIBINC Palm Oil, and the iron ore company ArcelorMittal concessions areas.

Figure 2: Map of current IRS geographic area



(Map courtesy of AIRS End of Spray Report / L-MEP)

### **Entomological Monitoring**

The IRS program works closely with the Vector Control Unit (VCU) of the NMCP and the Liberia Institute for Biomedical Research (LIBR) to provide entomological monitoring of insecticide resistance and quality of spraying. The most experienced among the VCU technicians are engaged in some of the monitoring activities. Sentinel sites representing intervention and control site were selected to monitor mosquito densities, behavior, and insecticide resistance status. The IRS implementing partner has developed data collection tools that enabled the collection of PMI entomology indicators.

Entomological monitoring was conducted in six selected sentinel sites in four counties. Monitoring of vector densities was conducted for both pre- and post-spray periods. The pre-spray surveillance was conducted in March/ April 2012 and the post spray surveillance was conducted in June 2012. The pre-spray surveillance was conducted in three pre-selected sentinel sites while post spray surveillance was conducted in six sentinel sites

### *Monitoring Vector Resting/Feeding Behavior*

The hand catches by aspiration (HCA), light trap collection (LTC) and pyrethrum spray catches (PSC) methods were conducted to monitor host seeking mosquito vectors. Comparison of methods for indoor resting mosquitoes suggests hand collection was the most productive, catching good numbers of mosquitoes.

Hand catches through aspiration for indoor resting mosquitoes provided good results in one-location and poor results in another. However, this technique posed challenge due to lack of adequate experience with some collectors. With a requirement that sampling be conducted within a given time span, not past noon, it was not feasible to use this technique post spray. A total of 20 houses were sampled using this method.

### *Vector Susceptibility and Residual Efficacy*

Cone wall bioassays to assess the quality of spraying and decay rate of insecticides were conducted in the four intervention areas between 20 days and two months post-spraying. Both wild caught indoor resting adults and those reared from field-collected larvae were used in the bioassay. The wild caught *Anopheles gambiae* mosquitoes were collected by indoor resting hand catches in the control site. Larvae were collected in breeding habitats then transported to the insectary at LIBR and reared to adult mosquitoes, which were used for bioassay tests. Between 10 to 15 adult female mosquitoes, aged 2 to 5 days, were confined in WHO conical transparent chamber fastened on either sprayed (test exposure) or unsprayed (control exposure) wall surfaces using adhesive tapes for 30 minutes. After expiry of exposure time (30 min), the knocked down mosquitoes were counted and recorded, then transferred to holding paper cups. Then the mosquitoes were provided with 10% sugar solution soaked in cotton wool and the knocked down and dead mosquitoes counted after 60 minutes and 24 hours holding times respectively. The cone bioassay test mortalities in spray sites were above 90%, which according to WHO standard, suggests good quality spraying and that mosquitoes are susceptible to the insecticide (carbamate) used.

Mortality rates in two areas sprayed with K-Othrine and Fendona insecticides were below 20%. Low mortality could be attributed to either vector resistance to the pyrethroid insecticide used or poor quality of spraying. The results should be interpreted with caution because mosquitoes used for cone bioassay were collected from a different region of the Country. Exposure of local mosquitoes to nearby sprayed walls will give a better indication of the effect of spraying on the local mosquito population. Nevertheless, the contribution of poor quality of spraying to the observed low mortality rates could not be ruled out. Operations increased supervision and onsite training to ensure spraying was done properly.

The WHO tube test for susceptibility for mosquitoes sampled showed mortality rates of 60% and 77% against deltamethrin treated filter paper. The mortality rates were low compared to the acceptable threshold of 90% and since the diagnostic concentration has been set at twice the minimum concentration that kills 100%, the observed mortalities of 60% and 77% suggest possible resistance of local *An. gambiae* s.l. against deltamethrin, but more data points are needed to confirm resistance and determine spatial distribution. It is recommended that the IRS Task Force review these and upcoming susceptibility results annually when selecting the insecticide to be used for each spray campaign.

## DESCRIPTION OF ALTERNATIVES AND PROPOSED ACTIONS

This section describes the alternatives that were considered in the preparation of the report including those that were accepted or rejected. The section begins with the preferred proposed intervention, and the key components of this option, before discussing other alternative interventions that were considered alongside the IRS intervention. Alternative spray sites and alternative insecticide classes are also discussed in this section.

The SEA does not address the treatment of malaria that is part of the Malaria Control program, but rather vector control activities.

### Proposed Actions

The National Malaria Strategic Plan includes a three-tiered Integrated Vector Management (IVM) approach. The goal of the IVM program is to increase mosquito net ownership in the population and to protect households from contact with mosquitoes. IVM will provide LLINs through mass distribution to all family units, as well as targeted distribution to pregnant women and children under age 5 to achieve maximum results for prevention of malaria transmission. The strategy will also continue targeted indoor residual spraying (IRS) of households and will consider other vector management strategies for environmental control.

#### Distribution of Long Lasting Insecticide Nets

The NMCP seeks to increase use of ITN to 80% among the entire population through intense BCC campaigns at the community level. The National Malaria Strategic Plan also calls for targeting vulnerable populations such as pregnant women and children under five-years of age. Additionally, focus will be placed on reaching at least 85% of women of child-bearing age.

The PMI program will identify malaria control actions for Liberia annually; the following are the actions that were identified for 2012:

- Procure 150,000 ITNs for distribution, hang-up and keep-up and health facilities in selected counties. Rest of ITN needs will be covered by Global Fund Round 10
- Distribution, training of supervisors for campaigns, and BCC pre-distribution and during campaigns to promote the continued increasing net use; and
- Integrated BCC for malaria case management, ITNs, MIP, and IRS.

**Note: The focus of this SEA is to provide an Environmental Assessment on IRS activities, and does not address LLINs.**

#### Indoor Residual Spraying

The NMCP strategy includes increased use of IRS in rural districts of high prevalence, covering approximately 45% of the population, and at least 85% of houses in the target areas accepting IRS. Objectives are to: 1) improve procurement of insecticides, sprayers, protective gear and maintenance of spray pumps; 2) strengthen the CHTs capacity to implement IRS; and 3) map district-specific information on vector and malaria prevalence.

The PMI program will identify malaria control actions for Liberia annually; the following are the actions that were identified for 2012:

- Support spraying of approximately 80,000 houses in three counties (protecting 400,000 people) with an insecticide to be selected by the Malaria Task Force. The maximum number of households possible will be sprayed, with the number determined by reduced costs associated with economy of scale and class of insecticide that has to be used. Areas for IRS will be selected based on annual MIS and entomological surveillance results;
- Training, equipment, supplies, and mentoring for NMCP entomology technicians. These investments will contribute to addressing the lack of senior NMCP personnel with vector control experience, which limits efforts to establish an IRS program;
- Assist NMCP with insecticide resistance monitoring at two new sites, and continue monitoring at two existing sites;
- Technical assistance on vector control activities: CDC staff will conduct two TA visits to assist with training and to monitor planning and implementation of vector control activities. The entomology technical assistance visits will be used for capacity building, with a focus on establishing a functional insectary, and assisting with training in mosquito surveillance and insecticide resistance monitoring, in support of IRS and ITN vector-based interventions; and
- Assist NMCP in the conducting of an independent environmental monitoring and compliance inspection.

The NMCP and PMI will include IRS activities in private sector concessions if the Liberia Agricultural Company, LIBINC Palm Oil, and Arcelor Mittal Mining Company concession areas overlap with the targeted counties identified in the upcoming MIS. Funding for these concession areas will be determined as their inclusion in IRS activities is finalized.

- Support from PMI for private companies will include assisting with the mobilization of communities, and providing technical training and guidance to sprayers and supervisors in line with international standards. PMI will also supply insecticides and spraying equipment and encourage daily reports, feedback, and summaries from spray teams as well as an evaluation meeting with lessons learned at the completion of the activity. Spray teams will be requested to present regular data on malaria morbidity and mortality.

The scale up of malaria activities in Liberia will depend on a well-trained and active malaria staff particularly at the county level. PMI continues to support in-service and pre-service training for CHTs through short-term trainings and technical assistance by partners.

- Provide training to NMCP staff in applied entomology, and collaborate to provide increased entomological services at the NMCP and county level, training entomology technicians for entomologic monitoring.

### ***The Insecticide Selection Process***

The selection of type of insecticides that would be used for each IRS campaign is decided annually by the Malaria Task Force. The Task Force reviews the bioassay data presented by the implementing partner and decides which pesticide will be used in which District based on malaria prevalence, resistance and accessibility.

The Task Force is chaired by the Assistant Minister for Preventive Health (MOHSW) and the NMCP Program Manager and has members from MOHSW, MOA, EPA, Department of Environmental and Occupational Health (DEOH), PMI/USAID Resident Advisors and other partners working on malaria control in Liberia.

Insecticide selection for any PMI supported program is also subject to international procurement requirements of the US Federal laws. Requisitions for public health insecticides used in IRS must be initiated at class level, rather than for a particular insecticide (active ingredient, or AI). The selection of insecticide class for use in IRS is based on a number of considerations.

**Primary Selection Criteria:**

- Must be WHOPES approved,
- Must be registered for IRS use in the country,
- Should have a residual efficacy pertinent to transmission pattern,
- Should be suited to the main type of wall surface,
- Local vectors must show high susceptibility,
- Must be able to manage and minimize environmental impacts.

Should the economic and resistance criteria between formulations be similar (that is to say similar cost and similar vector susceptibility), then toxicity of formulations should be considered when making procurement decisions.

**Secondary Selection Criteria:**

Once the Malaria Task Force endorses a pesticide selection, then the criteria is expanded to include international procurement language in which the criteria is clearly stipulated, and then tendered out in accordance with international open competitive procurement rules. Once there are responses to the call for bids, the resulting proposals are subjected to secondary criteria including:

- Appropriate packaging for safety and standard delivery tools
- Unit cost of insecticide.
- Timely delivery of the insecticide to the preferred point of delivery.
- Local representation of supplier in host country
- Technical assistance with training and troubleshooting by supplier

Once a winning bid is selected, it is then submitted to PMI for approval and the Task Force is informed of the now-named insecticide that has been selected and the reasons for its selection for the current IRS round. Once PMI/USAID grants its approval, then procurement of the insecticide and MOA permit process is initiated.

**Alternatives Considered and Insecticide Classes Selected**

For IRS to be implemented, a pesticide approved by World Health Organization Pesticide Evaluation Scheme (WHOPES) must be selected for use. The PMI program does not allow for procurement of pesticides that are not approved for IRS by WHO and the host government. Currently, all of the IRS WHO pesticides are registered for use in Liberia, excluding malathion and bifenthrin (one product registered contains pirimiphos-methyl + bifenthrin). WHOPES is the institution that analyzes and recommends the pesticides that should be used in IRS based on their residual effectiveness, toxicity to human health and the environment.

To date WHOPES has so far approved the use of pesticides within the following four classes: pyrethroids, carbamates, organochlorines and organophosphates. **Table 1** below highlights the recommended insecticides for IRS in vector control. The proposed action includes the use of carbamates, pyrethroid and organophosphate formulations. Organochlorines, a class that includes DDT (dichlorodiphenyl-trichloroethane) are not proposed for use in any of the PMI Counties.

Table 1: WHO Recommended Pesticides

<b><i>Insecticide compounds and formulations(1)</i></b>	<b><i>Classgroup (2)</i></b>	<b><i>Dosage (ga.i./m<sup>2</sup>)</i></b>	<b><i>Mode of action</i></b>	<b><i>Duration of effective action (months)</i></b>
<b><i>DDTWP</i></b>	OC	1-2	contact	>6
<b><i>MalathionWP</i></b>	OP	2	contact	2-3
<b><i>FenitrothionWP</i></b>	OP	2	contact&airborne	3-6
<b><i>Pirimiphos-methylWP&amp;EC</i></b>	OP	1-2	contact&airborne	2-3
<b><i>BendiocarbWP</i></b>	C	0.1-0.4	contact&airborne	2-6
<b><i>PropoxurWP</i></b>	C	1-2	contact&airborne	3-6
<b><i>Alpha-cypermethrin WP&amp;SC</i></b>	PY	0.02-0.03	contact	4-6
<b><i>BifenthrinWP</i></b>	PY	0.025-0.05	contact	3-6
<b><i>CyfluthrinWP</i></b>	PY	0.02-0.05	contact	3-6
<b><i>DeltamethrinWP,WG</i></b>	PY	0.02-0.025	contact	3-6
<b><i>EtofenproxWP</i></b>	PY	0.1-0.3	contact	3-6
<b><i>Lambda-cyhalothrinWP,CS</i></b>	PY	0.02-0.03	contact	3-6

(1)CS:capsulesuspension;EC=emulsifiableconcentrate;SC=suspensionconcentrate; WG=waterdispersiblegranule; WP=wettablepowder.

(2)OC=Organochlorines;OP=Organophosphates;C=Carbamates;PY=Pyrethroids.

### ***Preferred Insecticide Classes***

Generally, pyrethroids have been the preferred insecticide of choice in Liberia. Due to increase of resistance to pyrethroids, carbamates are now being used in regions that have shown less than 90% mortality to pyrethroids. Long lasting formulations are preferred to allow for a single spray campaign during the dry season when most regions are accessible. Chemicals that have a shorter effective duration require two spray campaigns; the second would take place during the rainy season when the roads are often impassable. Organophosphates are proposed for future use throughout Liberia in order to manage vector resistance on an ongoing basis, but are the least preferred due to costs and the need to biomonitor the spray operators.

### ***Rejected Insecticide Classes***

Organochlorines, including DDT, were rejected for use on this project by PMI.

### ***Quantification of Pesticide Requirements***

An annual geographical reconnaissance and logistics assessment is done to understand and map the area so as to appropriately plan for the operation. Secondly, a logistics assessment helps to quantify IRS materials (insecticides, pumps, PPE, etc), which will then be procured as needed. The implementing partner will conduct the geographical reconnaissance, logistics assessment and all the planning for the field operation in the Districts that have been selected by the Malaria Control Task Force.

Upon purchase from the United States from a reputable supplier, the insecticides first will be freighted to Monrovia. A permit will have been obtained from the National Quarantine and Environmental Services of the MOA to allow the importation and use of the pesticide. The insecticides will then be transported directly to the principal warehouse in Margibi County before being dispatched to different districts where spray operations will be concentrated. Transportation of insecticides should be done in compliance with program and National environmental compliance requirements. During geographical reconnaissance and logistics assessments, the need for rehabilitation of principal warehouses at county level and district level to meet PMI BMP requirements for pesticide storage will be assessed. Existing storage facilities meet PMI BMP requirements, but will be re-evaluated between spray campaigns..

#### **Qualification of warehouses (Storage Facilities)**

The procured pesticides are categorized as hazardous and toxic and can potentially cause adverse impacts to human health, animals, and the natural environment if not properly stored according to the international guidelines and USAID/BMP (2011) for storing insecticides. Before insecticides are procured or transported to the spray areas, suitable warehouse(s) must be assessed and ensure that they meet the FAO or USAID/BMP standards for insecticides storage. Those standards include among others:

- Spacious enough to store insecticides in bulk and to store other materials separately
- Located as far as possible from; flood plains, wetlands, markets, schools and residential areas
- Well ventilated and allowing for air circulation
- Built of concrete or other solid material
- Adequate roofing that is not susceptible to leaks
- Adequately secured
- At least 2 exits for emergency purposes
- Guarded 24 hrs/day
- Fire extinguishers are available.
- Double locking padlocks are provided.
- Pallets are available for proper storage of insecticides

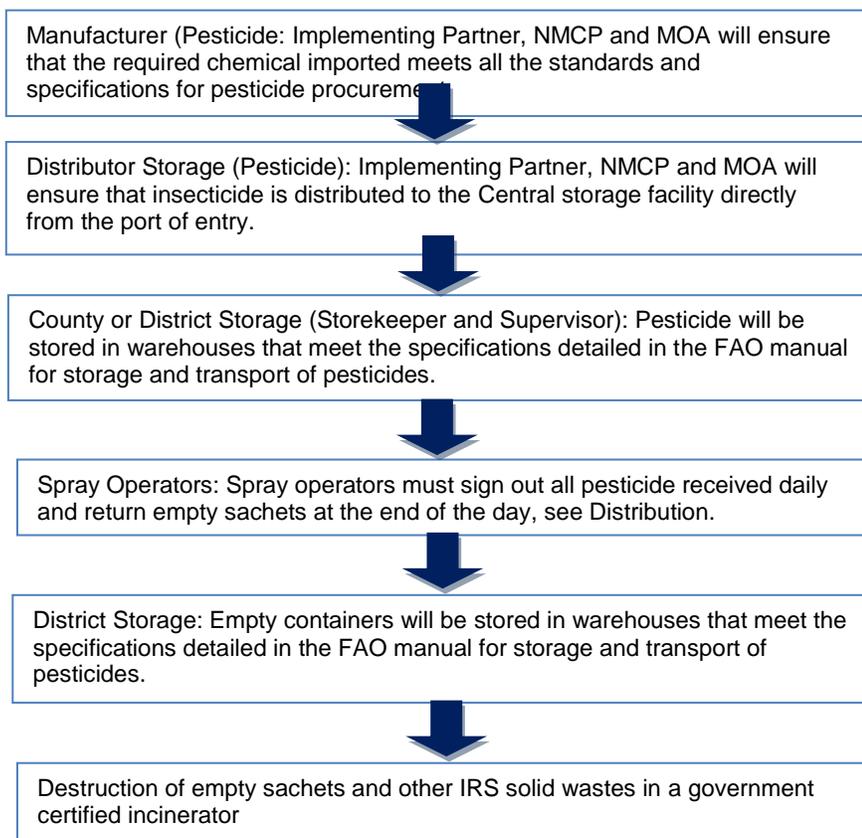
During the logistical needs assessment, the implementing partner working with County Environmental Health Team will identify appropriate warehouses at the county level and at the districts level that meet the above-mentioned requirements. They may require minor rehabilitation especially aimed at enhancing security by repairing/upgrading locking systems, floor, roof, doors, ventilation system etc.

All facilities used for storage, distribution, and transportation of insecticide products should comply with relevant requirements of the Environmental Protection and Management Law and any other relevant Liberia standards on pesticides use and management. To that end, the following section and the EMMP describe the program requirements for storage, distribution, and transportation.

#### **Supply Chain and Disposal Options**

The implementing partner will work with the relevant authorities and will employ the following pesticide chain management in its Liberia IRS programs to ensure control.

Figure 3: Pesticide Chain of Custody and Management



### Health and Safety in the Warehouse

The following measures are required in all warehouses in order to reduce cases of pilferage, exposure through leakages and theft, and to ensure the health and safety of those accessing these facilities:

- Warehouse must be double-padlocked and guarded at all times.
- All the storage facilities must have thermometers installed for temperature recording.
- Soap and clean water for washing must be available at all times.
- Trained storekeepers must be present and wear appropriate PPE when in the pesticide area of storage.
- Pesticide stacking position and height in the warehouses must not be above 2 meters in height.
- The central warehouses must have at least two exit access routes in case of fire outbreak.
- Fire extinguishers must be available in the storage facilities and all workers trained on how to use them.
- Hazard warning notices must be placed in the outside of the store in pictorial form (skull and crossbones).
- First-aid kits must be available in all the central warehouses and secondary stores

### Insecticide Distribution and Management Process at District and Lower Levels

The implementing partner will develop standard requisition, tracking, and monitoring forms to be used for inventory, record, and track all the insecticides distributed and returned. These forms will be used in the program at all levels, and the store managers will receive training on how to use these forms. The

steps below highlight the insecticide distribution process proposed including recording and tracking methods:

- At reception at the provincial warehouse, lot numbers of insecticide and quantities are registered on shelf inventory card.
- District requisitions are approved at the program office, where copies are maintained.
- Requisition goes to district warehouses where distribution takes place and is signed for, based on sachet numbers. Insecticides are distributed on a “first-in, first-out” system, so the insecticide that arrived first is distributed first. This avoids accumulation of expired stock.
- On reception at lower storage levels, all sachets are counted and stamped with the relevant stamp and registered on a stock card.
- Every morning before the spray operations begin, spray operators receive from the store manager only enough sachets for the day’s work (between 8–10 sachets), and must sign for all pesticide received daily in a log book.
- At the end of the day, empty and full sachets are returned and numbers checked against what was signed out. Returned empty and full sachets are logged into the logbook by the storekeeper or supervisor.
- Supervisor examines spray operator performance by comparing number of structures sprayed to sachets used to determine whether there is an over or under application.
- Store keeper must submit the following to the central office for data entry on a daily basis: 1) insecticide stock balances; 2) sign-in/sign-out results; and 3) structures sprayed per spray operator.
- The next day, all previously signed for but unused sachets are reissued and signed for by the relevant spray operator.
- At the end of each day and at the end of the spray round, stock remaining must equal the stock at start of the day minus the number of sachets distributed. Number of sachets distributed should be equal to number of sachets used if there is no returned full sachet.

### **Personal Protective Equipment (PPE)**

Each spray team will consist of five spray operators and one team leader. Each spray operator will be provided with the following safety equipment to be used during the spraying, in accordance with WHO and FAO specifications:

- Broad-rimmed hat/helmet;
- Face shield or goggles (face shield preferable);
- Dust mask or filtered mask;
- Two or more cotton overalls per spray operator (appropriately sized);
- Nitrile rubber, neoprene, or butyl rubber gloves, without inside lining, and long enough to cover the forearm; and
- Rubber boots.
- Cloth to protect the neck

In accordance with WHO health and safety regulations, all persons working on IRS must be adequately protected against potential harm due to exposure from pesticides. All persons with potential direct contact or exposure to pesticides during handling, transportation, storage, use and cleaning of pesticides or pesticide contaminated materials must wear appropriate personal protective clothing in accordance with the safety instructions on the pesticide label or material safety data sheet (MSDS).

For spray operators, safety precautions will depend on the proper use of PPE, and personal hygiene, including washing and daily changing of spray clothes. A schedule for carrying out and supervising

personal hygiene, regular washing of protective clothes and cleaning of equipment will be organized along the following lines (WHO 2006):

- Spraying staff will be provided with at least two uniforms to allow for frequent changes.
- Washing facilities with sufficient water and soap will be made available in the field at appropriate locations.
- All working clothes must be removed at the end of each day's operations and a shower or bath taken—in circumstances where a full-body shower or bath is not feasible, face/neck and hands must be washed with soap and water.
- Working clothes will be washed daily.
- Particular attention will be paid to washing gloves, and avoiding contamination of the inside of the gloves.
- Spray operators will wash before eating, drinking or smoking at the end of the daily spray operation.
- Eating, drinking and smoking during work will be strictly forbidden at all times during the operation. If spray operators need to drink water in the course of the operation, they must clean their hands thoroughly to avoid any exposure, or receive assistance from the homeowner, such that they do not need to handle water containers with gloves or other PPE that has been exposed to pesticides during spray or make-up activities.

#### **Procurement of Other IRS Equipment**

The following IRS equipment will be procured alongside with the insecticides and PPEs including;-

- **Spray Nozzles**  
The program in Liberia will procure 8002E nozzles for the spray pumps, which are the standard size, recommended by World Health Organization for mud wall.
- **Spray pumps**  
Spray operators use Hudson X-PERT compression sprayers with shoulder-suspended tanks to apply a measured amount of insecticide on the interior walls of houses and structures. A water-soluble insecticide is added to the sprayer containing a pre-measured amount of water, the sprayer is pressurized, and the material is then applied to the interior walls of targeted house (Structure). After the day's spraying is complete, spray operators must clean the sprayer following the manufacturer's recommendations to ensure their proper operation and calibration.

#### ***Training***

The objective of the trainings is to build the capacity of the host government at the national and district levels to implement a well-organized IRS program. Training is organized in two parts, the training of trainers (TOT) and the training of spray operators and community mobilizers.

#### **TOT Training:**

The training, which included both theoretical and practical sessions, was co-facilitated by officers from the NMCP (the Head of the IEC/BCC Unit & IRS Coordinators), the EPA and MOA. Training topics include introduction to IRS; spray pump handling, use, assembly and maintenance; insecticide use, handling, and safety; and environmental compliance.

### **Training of Spray Operators**

Spray operators will initially be chosen based on their completion of primary school and must pass written and practical tests of their ability to read, write and record critical spray information, and make calculations. They will then undergo medical exams to determine their physical capability for providing appropriate application of the insecticide. All the female spray operators and washers will be subjected to a mandatory pregnancy test before training and recruitment as spray operators or washers. Pregnant operators must not be included in the spray operations because of the possible effects the pesticides to the fetus. Every month until the operations are concluded, a pregnancy test must be obtained from the female candidates selected.

Graduates of the TOT training conducted the spray operator training with the support of implementing partner, and facilitators from the NMCP and CHTs. The training had both theoretical and practical sessions.

The individuals recruited for IRS campaigns will receive intensive training on the use, operation, calibration and repair of the spray pumps, including practical exercises during a 5-day period prior to the beginning of the spraying campaign. They will also receive training to understand proper hygiene, to recognize the signs and symptoms of poisoning, and to understand the referral procedure for any incidents involving poisoning. This training is conducted in accordance with WHO's "Manual for Indoor Residual Spraying" (WHO 2002) and PMI IRS BMPs.

From the post IRS training test and on the basis of performance during training, graduates of this training will then be assigned to various categories of work including;

- Spray operators
- Supervisors
- Team leaders
- Washers
- District managers
- Pumps technicians
- Storekeepers
- Washers

The above teams will then receive additional specialized training in accordance with the area of assignment.

### **IEC Mobilizer Training**

The majority of mobilizers are community health volunteers with a strong visibility and extensive experience raising health awareness in the community. The selected community mobilizer received a refresher training, which was conducted in each of the region. In coordination with the implementing partner and NMCP IEC/BCC officers, all mobilizer supervisors who attended the TOT training facilitated the refresher trainings. The training modules that were covered include:

Introduction to IRS

- Communication basics and strategies
- Community entry approaches
- Overview of malaria parasite, transmission and control
- Data collection and reporting

- IRS messages (i.e. household preparation, handling of animals during spraying, safety measures and steps to take in case of exposure to insecticide)

Mobilizers are trained to conduct house-to-house mobilization during the first cycle of each IRS campaign.

### Clinician Training

The clinicians in the health center facilities at ward level will be given refresher courses on how to handle acute exposure incidents that may occur when using pesticides. When new pesticides will be used, additional training specific to the symptoms and treatment for that chemical will be provided. Acute exposure can happen through dermal contact, which could lead to absorption into the blood stream as well as skin and eye irritation, or ingestion, which could also lead to poisoning. The health facilities must have relevant anti-dotes for poisoning incidences in their store (see **Table 2, 3 and 4**).

Table 2 : Drugs Recommended for Treatment of Pyrethroid Exposure

Name of drug	Active ingredients
Promethazine	Promethazine Hydrochloride
Panadol	Paracetamol
Diazepam	Benzodiazapine/Diazepam
Lorazepam	Lorazepam
Calamine cream	Calamine, zinc oxide, glycerol, phenol, purified water, sodium citrate, betonite,
Vit E	Tocopherol, fragrance, mineral oil, deionized water, sodium hydroxide, stearic acid
Hydrocortisone cream	1% hydrocortisone
Salbutamol	Salbutamol 100 mcg, suspended inert aerosol
Salbutamol tablets	Salbutamol sulphate 4 mg
Activated Charcoal	Activated Charcoal

Table 3 : Drugs Recommended for Treatment of Carbamate Exposure

Name of drug
Atropine Sulfate
Activated Charcoal
Pralidoxime
Furosemide
Diazepam

Table 4 : Drugs Recommended for Treatment of Organophosphate Exposure

Name of drug
Atropine Sulfate
Obidoxime choride
Pralidoxime

## **Driver Training**

All the drivers recruited for the operations will also receive training on safe transport of pesticides, use of PPE, and steps to respond to spills or accidents.

## ***Supervisory Actions during IRS***

To ensure adequate supervision, the spray operators are organized into teams of five or six spray operators and a spray leader to ensure strict supervision during the implementation phase. A team of six will be under the management of one supervisor. Supervisors will observe spray teams to ensure spraying occurs according to best practices. Supervisors will travel between spray teams and will observe spray operators and team leaders in pesticide preparation, spray technique, and sprayer and PPE clean up during the IRS campaign, as well as compile all data collected by their respective teams. District teams will provide oversight to ensure the goal of day-to-day achievement of environmental compliance.

In general, IRS activities will be centralized in each district at the district storage facility. On the same property as the storage facility, will be constructed soak pit and washing bays in an appropriate fenced area. The site will be identified during the logistical assessment phase and will be based on BMP recommendations, accessibility and access to water. It is preferable to be located near the government health facility.

At District level, activities are coordinated by the County Health Team. Each district will maintain an operational spray plan (progress calendar), produced during the micro-planning and validated by the health team at the district level, indicating all communities to be sprayed during the spray operations.

At the end of each day, spray leaders at each operational site will meet with their manager to discuss the day's events, challenges faced, and recommendations for resolving problems. At the end of each spraying month, IRS partners' coordination meetings will be held with the IRS project, IEC implementers, and the district health team, chaired by the District Chief Medical Officer or designate. During these meetings, the partners will assess the progress of spray operations, ensure that the planned work schedule is strictly adhered to, and make recommendations as necessary to the IRS project or IEC implementers.

The IRS district coordinator will hold a weekly meeting with the district chief medical officer and the IRS managers to discuss operational issues and their solutions. The implementing partner will maintain records of program performance reports which will be able to demonstrate adherence to WHO technical standards, quality of training and supervision, procurement activities, and environmental compliance. Such reports include the pre- and mid-spray environmental compliance report, reports on core IRS indicators and end-of-spray evaluation reports.

Supervisors will monitor the effectiveness on beneficiary populations of Information Education and Communication (IEC) campaigns by visiting sprayed houses to discuss beneficiary impressions, and visiting unsprayed houses to discuss with heads of families why spraying is important. Regarding spray technique and spray operator discipline, monitoring will involve visiting the sprayed compounds and interviewing beneficiaries to ensure that spray operators respect household members, spray all eligible rooms, record the essential data in the relevant form, mix and apply insecticides at the right dosage, and pass the relevant health information to the household.

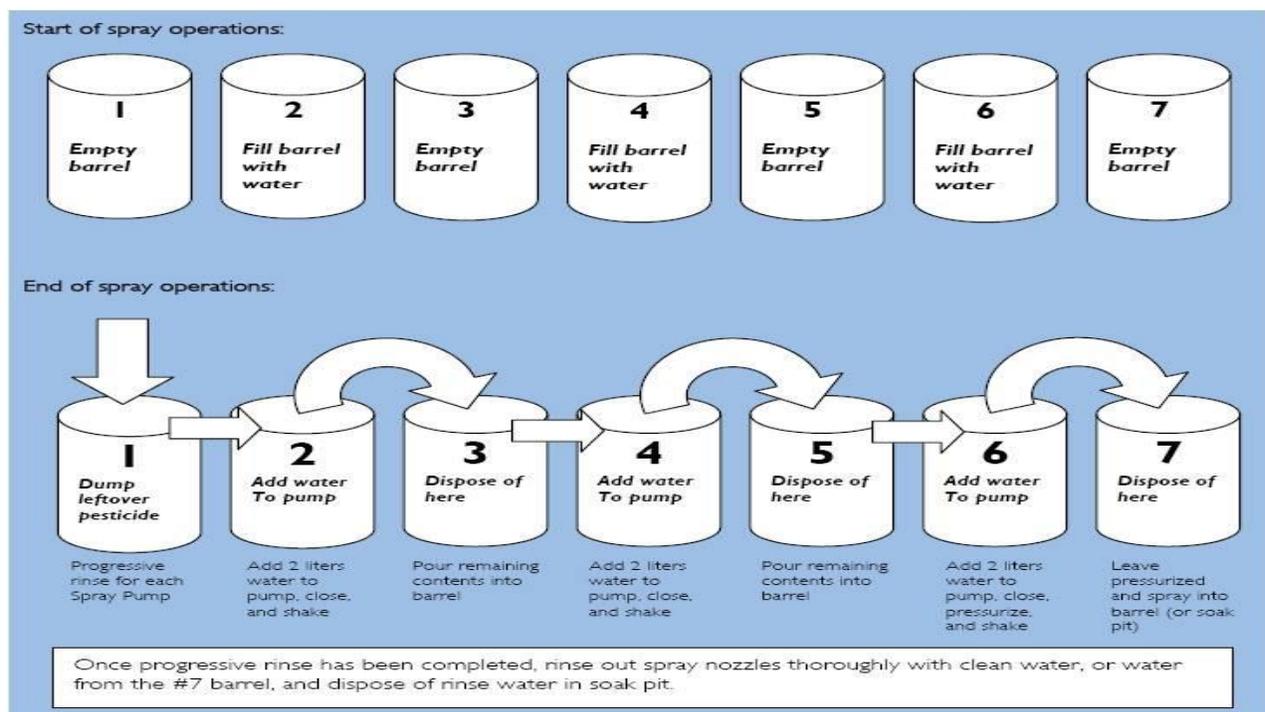
Good supervision will also require observing each spray group at work, spray group leaders, spray team leaders, and spray operators, and checking spray team habits to ensure best practices for insecticide storage and solid waste management. Since the reports of the operators are the basis for all reporting and data collection, supervisors will ensure that they are completed accurately and promptly at the end of the spraying day.

### Equipment for decontamination

USAID’s IRS BMP Manual recommends that water used to rinse out spray pumps at the end of each day must be re-used at the beginning of the next day’s work to save water and reduce the potential for pollution from leftover pesticide or contaminated rinse-water. The best practice for rinse-water re-use is called “progressive rinse.” With this rinse method, seven barrels/drums/containers of approximately 200-litres each are placed in a line. Every other container is filled with water (e.g. the first container is empty, the second is filled with water, the third is empty, fourth is filled with water, fifth is empty, sixth is filled with water and the seventh container is empty) (**Figure 4**). During the end-of-day cleanup, the remnants of a pump charge from the field are emptied into the first container. This will be a limited volume, which should be much less than half of this container, as most sprayers will be returned empty from the field. It is important to train operators to manage this goal of minimizing leftover at the end of the day. The spray operator will then fill the sprayer less than half-full with a cup of water from the second container, close and shake the sprayer, and dump the sprayer water in the third container. The spray operator will repeat those steps with the fourth and fifth containers, then with the sixth and seventh containers, making sure to rinse the outside of the sprayer only at the sixth container (although not in the sixth container). The following day, spray pumps are filled with liquid from containers in the same sequential order: container one, then container three, then container five. Any remaining liquid in the fifth and seventh containers are quite dilute and will be disposed in a soak pit.

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Figure 4: Progressive rinsing (BMP Manual)

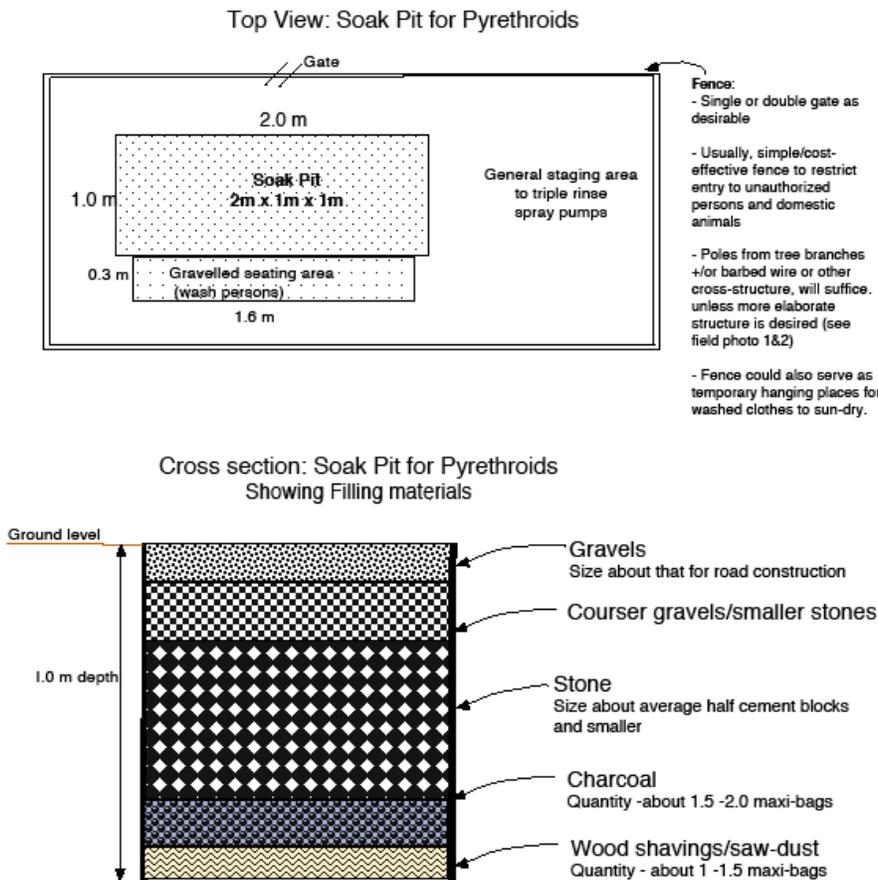


**Effluent disposal facility: soak pits and washing areas**

The site for the soak pits in each storage facility will be selected jointly with the assistance of the representative of EPA and NMCP at the district level. The soak pit site must be away from water bodies, bore holes and schools wherever possible. The size of the soak pit depends on the number of spray operators that the soak pit supports. On average, and according to the USAID/BMP Manual, the soak pits are 2 meters by 1 meter, excavated to a depth of one meter. What is important is that the bottom of the pit is packed with sawdust followed by hard coal or charcoal, stone aggregates and gravels (**Figure 5**). The entire soak pit area is fenced complete with a lockable access door to prevent unauthorized entry by children or animals.

The soak pit as described can be used for all three classes of proposed pesticides. It is not appropriate for DDT, however. The overall principle of the soak pit, also referred to as a bio-bed, is to absorb the toxic chemicals in the pesticide through a filtration process so that the wastewater that finally reaches the underground has been purified and no longer contains the chemical components. The organic chemical contaminants (pesticides) are held by the charcoal, where they are acted upon by environmental forces, including bacterial action. Research has shown that pesticides on the coal are degraded within three months in the soak pit. Unless the soak pit becomes clogged with foreign matter and will not drain, the soak pit should remain effective for three years, at which time it can be excavated so that the sawdust and coal can be replaced. As long as the foreign matter can be separated from the stone, the three stone layers can be reconstituted re-using the same material.

Figure 5: Soak Pit (BMP Manual)



In order to minimize possible ground contamination from washing spray equipment and PPE, all staging areas are required to have an impervious wash area that drains to the soak pit. This will ensure that all contaminated wash water is properly treated in the soak pit.

Wash-persons will be hired and provided with protective gear. Wash persons will wash overalls at a central location in tubs used exclusively for overall washing. Spray operators must completely wash themselves after each day's operations using washbasins or shower areas constructed near the soak pits. Spray operators should never wash themselves, their overalls, or their PPE in any water bodies, or delay washing until they are home. Washing must be performed at designated sites, and all wash-water must be disposed of in a soak pit. Where necessary, construction of infrastructure for proper disposal of contaminated water will be financed by PMI.

### **IRS Solid Wastes Disposal**

IRS solid wastes, which include empty insecticide sachets, masks and torn gloves and boots, will be collected from the field and brought back to the central warehouse. All require disposal in an environmentally and internationally accepted manner as prescribed by FAO/WHO with regards to disposal of pesticide wastes. Incineration under specific conditions is highly recommended by the United Nations Environment Program (UNEP) and WHO/FAO in relation to mask and sachet disposal. Incineration is not recommended for PVC or other chlorinated wastes such as gloves and boots.

Generally, according to WHO/FAO<sup>1</sup>, incinerators recommended for disposal of non-DDT wastes meet the following key requirements:

- The recommended combustion temperature is between 1,100°C and 1,300°C.
- An after-burner is required, with a residence time of at least two seconds.
- The incinerator should have emission control, including particulate matter filters.
- Ash and slag produced by high-temperature incineration of pesticides are, in principle, considered inert, unless determined otherwise and can be disposed as normal waste, preferably in a dug out pit.
- An alternative disposal method is using a Sanitary Landfill, which has impermeable lining underneath and a system of leachate collection.

Currently, there is only one incinerator that meets the requirements for disposal of contaminated waste. This is the United Nations Military in Liberia (UNMIL) incinerator at Starbase UNMIL logistic center at Freeport in Monrovia. UNMIL has two Medi Burn Portable Medical Waste burning units at this facility. Access to this incinerator is limited and its usage must be coordinated with other waste disposal needs. MediBurn is capable of disposing of up to 8 cubic feet (0.22 cubic meters) batch-loads of infectious and pathological waste with a burn rate of 18 to 20 kg per hour. The incinerator has dual chamber combustion and high exhaust temperatures in excess of 1000°C (1832°F). There is a concern that when UNMIL departs in the near future they may decommission the incinerator. There is an incinerator at the JFK Hospital, but it is not functional at this time and would need to be rehabilitated. Another option is to import a mobile incinerator as other PMI IRS projects in other countries have done. This effort would

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<sup>1</sup> Food and Agriculture Organization of the United Nations (2008). International Code of Conduct on the Distribution and Use of Pesticides: Guidelines on Management Options for Empty Pesticide Containers. Rome: FAO. Accessed June 2, 2008  
[http://www.who.int/whopes/recommendations/Management\\_options\\_empty\\_pesticide\\_containers.pdf](http://www.who.int/whopes/recommendations/Management_options_empty_pesticide_containers.pdf)

require approval and collaboration with PMI Liberia.

Figure 6: Photo: UNMIL incinerator



*(Photos courtesy of the Elastec American Marine Incinerator Product website)*

Solid waste from the campaign, including packaging materials, empty insecticide sachets, torn gloves and used disposable nose masks, were packaged in black bin liners, and stored in the central warehouse awaiting incineration. The Environmental Compliance Officer supervised the retrieval of materials used by spray operators that were contaminated with insecticides (empty sachets, hand gloves and nose masks) to ensure that all environmental compliance procedures were followed. A post spray environmental compliance assessment was also completed and documented. The Implementing Partner Chief of Party (COP), Implementing Partner Environmental Compliance Officer (ECO) and an EPA official supervise the transportation of the waste. UNMIL staff then burns the waste in the presence of the ECO and EPA official. UNMIL disposed the waste bit by bit as the incinerator become available for use. The implementing partner is then notified when all waste was incinerated and receives a certificate of disposal.

### ***Alternative IRS Geographical Sites Considered***

The IRS districts are selected based on Liberia's strategic approach to give priority to rural communities where the malaria burden is high, and also factor in technical and epidemiological considerations, and geographical and logistical information for cost effective operations. The Ministry of Health and Social Welfare (MOHSW) policy on IRS strategy outlines three criteria for consideration in the selection of IRS sites:

- Areas with the highest malaria burden
- Under-served areas, in terms of access to health services
- Areas with relatively easy physical or geographical access

This SEA covers all the 15 counties in Liberia for the period of 5 years. Annual Letter Reports will provide updated entomological information for each county and district that has been selected for IRS activities for that particular spray round. Areas considered as malaria risks according to the MIS include all 15 counties of the country. However, the current IRS activities have focused on five Counties: Margibi, Montserrado, Grand Bassa, Bong and Nimba. Over 5 years, IRS implementation will depend on the malaria status of each area as determined by entomological studies. According to entomological resistance results, the Malaria Task Force, can decide to change insecticides or overall strategy. Unauthorized areas, however, including all special habitats such as wetlands, within 30 m of water bodies, and areas of sensitive habitats such as bee keeping areas, national forests, parks and other all protected habitats, may not be sprayed.

## Potential Other Vector Management Strategies

### ***Environmental Management Alternative***

Environmental management methods for mosquito control are not a developed component of the malaria control program in Liberia. However, to help reduce breeding sites around homes and communities, beneficiaries could be instructed to remove any potential breeding sites by consistently emptying all containers and filling in or leveling depressions in the land that are prone to retain water.

### ***Larviciding Alternative***

Larviciding is not a developed component of the malaria control program in Liberia. It does however, have potential in reducing breeding sites at locations near homes such as latrines, which is a concern of the beneficiaries. It also could be a requirement of the mining industry for contained mosquito-breeding sites created due to the mining activities. As Liberia has numerous water bodies and swamps, a comprehensive larviciding program is not feasible. Also due to the frequency and duration of rains, larviciding would be flushed out of most water bodies limiting their effectiveness.

Larviciding and environment management should not be considered as an alternative to IRS, but rather as part of an integrated vector control program.

### **No Action Alternative**

IRS is a critical intervention in the control of malaria because it attacks the indoor resting malaria vector and drastically reduces the vector population. As a result, it prevents or reduces transmission, hence minimizing morbidity that would need to be addressed through a curative approach. A no action scenario would mean the status quo of the malaria situation in Liberia.

Malaria is the leading cause of attendance in outpatient departments and is also the number one cause of inpatient deaths. Hospital records suggest that at least 33 percent of all inpatient deaths and 41 percent of inpatient deaths among children under age 5 are attributable to malaria (NMCP, 2009). This problem was exacerbated by 15 years of civil conflict that displaced populations and damaged health systems. Although curable and preventable, malaria remains a major public health problem in Liberia, where it takes its greatest toll on young children and pregnant women.

In 2005, the National Malaria Control Program (NMCP) at the Ministry of Health and Social Welfare (MOHSW) implemented a nationally representative, household-based Malaria Indicator Survey (MIS). One of the most important findings of the survey was the fact that 66 percent of children under age 5 were infected with the malaria parasite *Plasmodium falciparum*, as measured by the rapid diagnostic test Paracheck PfTM, at the time of the survey; in addition, 87 percent of children under age 5 were anemic (NMCP, 2006).

A second Malaria Indicator Survey was conducted in 2009 by NMCP in collaboration with LISGIS, the laboratory at the China-Liberia Malaria Center, and USAID as part of the President's Malaria Initiative (PMI) and the MEASURE DHS project at ICF International. The survey results documented substantial improvements in key malaria prevention and treatment indicators. Despite these real gains, the survey found anemia and malaria remained widespread among young children; among children age 6-59 months, nearly two-thirds (63 percent) were found to have some level of anemia (less than 11 g/dl), and blood smears taken from nearly one-third tested positive for malaria in the central laboratory (NMCP et al., 2009).

One of the most encouraging findings of the latest (2011 data) survey was the fact that 44.7 percent of children under age 5 were infected with the malaria parasite *Plasmodium falciparum*, as measured by the rapid diagnostic test Paracheck PfTM, down from 66 percent in 2005. According to the 2012 MIS (2011 data), 7.7 percent of children under age 5 were anemic (hemoglobin below 8.0 g/dl), NMCP, 2012).

## AFFECTED ENVIRONMENT

### Country Overview

Liberia, officially the Republic of Liberia, is located in West Africa and is bordered by Sierra Leone on the west, Guinea on the north, Côte d'Ivoire on the east and the North Atlantic Ocean to the southwest. Liberia covers an area of 111,369 km<sup>2</sup> (43,000 sq mi) and is home to about 3.7 million people. English is the official language, while over 30 indigenous languages are spoken within the country.

Figure 7: Map of Liberia



(map courtesy of ezilon.com)

The landscape is characterized by mostly flat to rolling coastal plains that contain mangroves and swamps, which rise to a rolling plateau and low mountains in the northeast. Tropical rainforests cover the hills, while elephant grass and semi-deciduous forests make up the dominant vegetation in the northern sections. The equatorial climate is hot year-round with heavy rainfall from May to October

with a short interlude in mid-July to August. During the winter months of November to March, dry dust-laden harmattan winds blow inland, causing many problems for residents.

Liberia's watershed tends to move in a southwestern pattern towards the sea as new rains move down the forested plateau off the inland mountain range of Guinée Forestière, in Guinea. Cape Mount near the border with Sierra Leone receives the most precipitation in the nation. The country's main northwestern boundary is traversed by the Mano River, while its southeast limits are bounded by the Cavalla River. Liberia's three largest rivers are St. Paul exiting near Monrovia, the river St. John at Buchanan and the Cestos River, all of which flow into the Atlantic. The Cavalla is the longest river in the nation at 320 miles (515 km).

There are basically four topographical regions with each having its own distinct physical features and height above sea level. Along the Sea Coast is the Coastal Plain of 350 miles (560 km), an almost unbroken sand strip, which starts from the lowest elevation up to 30 meters above sea level. Next to the Coastal Plain is the Belt of inundated plateau followed by the Belt of high lands and rolling hills in the north and northwest. The highest point within Liberia is Mount Wuteve at 4,724 feet (1,440 m) above sea level in the northwestern Liberia range of the West Africa Mountains and the Guinea Highlands. However, Mount Nimba near Yekepa, is higher at 5,748 feet (1,752 m) above sea level but is not totally within Liberia as Nimba shares a border with Guinea and Côte d'Ivoire (Ivory Coast) and is their tallest mountain as well.<sup>2</sup>

Despite the small size of Liberia, it exhibits significant biodiversity. There are over 2000 flowering plants (225 timber species), 600 bird species, 150 mammals and 75 reptiles. Liberia contains 42% of the Upper Guinea Forest of West Africa. The once continuous tracts of forests are now isolated from each other and fragmented into blocks largely due to shifting cultivation and human settlements. Logging and road infrastructure have also contributed to the fragmentation. There are two distinct blocks of forest remaining in Liberia, and these blocks represent the only forest blocks within the Upper Guinea Forest Region. They are the evergreen forest block in the southeast and the semi-deciduous block in the north. There is a distinct transitional zone of disturbed forest vegetation mostly along the Nimba-Monrovia corridor, which is becoming further dissected by the advances of shifting cultivation.<sup>3</sup>

## Climate

The climate of Liberia is hot, and humid, with an average annual temperature of 80°F (27°C). Relative humidity is generally high throughout the country; along the coastal belt, humidity does not drop below 80% and on average is above 90%. There are two major seasons in Liberia, dry (November to April) and rainy (May to October). Annual rainfall along the coast averages 200 inches (510cm) and in inland areas averages 85 inches (220cm) rain per year. Grand Bassa is among the wettest counties of Liberia with an annual average rainfall of about 400 mm per year.

Rainfall is caused by the South Atlantic sub-tropical high wind called the southwest Monsoon of the Maritime Tropical Air between April and October. For the rest of the year, the Inter-Tropical Front moves south, and most of West Africa comes under the influence of the low pressure from the Sahara Desert. At this time low humidity prevails usually from the end of December to January, and sometimes until February. This dry wind sweeps across the continent and reaches Liberia between December and February bringing considerable amounts of fog and dust with low cool temperatures during the night.

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<sup>2</sup> [wikipedia.org/wiki/Liberia](http://wikipedia.org/wiki/Liberia)

<sup>3</sup> Liberia National Biodiversity Strategy Action Plan, 2005

Since the soils in Liberia have low moisture storage capacity, the amount and frequency of rain during the dry season becomes a limiting factor for crop cultivation. Despite the heavy torrential rainfall, it does not rain continuously during the rainy season. It is common to have sunny days even during months when rain is heaviest.

## Agriculture

The agro-ecosystem of Liberia contains four major zones, namely: the coastal plain, hilly zone, mountain and plateau zone, and the northern highland zone. Thirty percent of the land area is arable, while 2.5% is pastureland.

Major crops grown are rice, cassava, maize, cocoa, oil palm, coffee, rubber and sugar cane. About 90% of the locally produced rice is grown upland. Most of the upland soils are lateritic, acidic, infertile, and low in humus. The swamp soils are comparatively better in nutrients and hummus; but are waterlogged from May to October. Traditional farming with its low technologies still dominates the agriculture sector.

## Livestock

Livestock production in Liberia has always been the least prioritized as compared to crops. It plays a minimum role in the agriculture industry. The high annual importation of livestock and livestock products is indicative of this. Cattle, goat, sheep, pig, rabbit, guinea pig, chicken, duck, and guinea fowl are the main animals used in Liberia livestock agriculture. Although local breeds are well adapted to the local conditions, their productive capacity is lower than the exotic breeds. Local breeds have been recorded as producing stunted babies and the maturity period is longer. Research in animal husbandry is very weak. Livestock feeding housing and health are major problems in the sector.

## Mountain Ranges

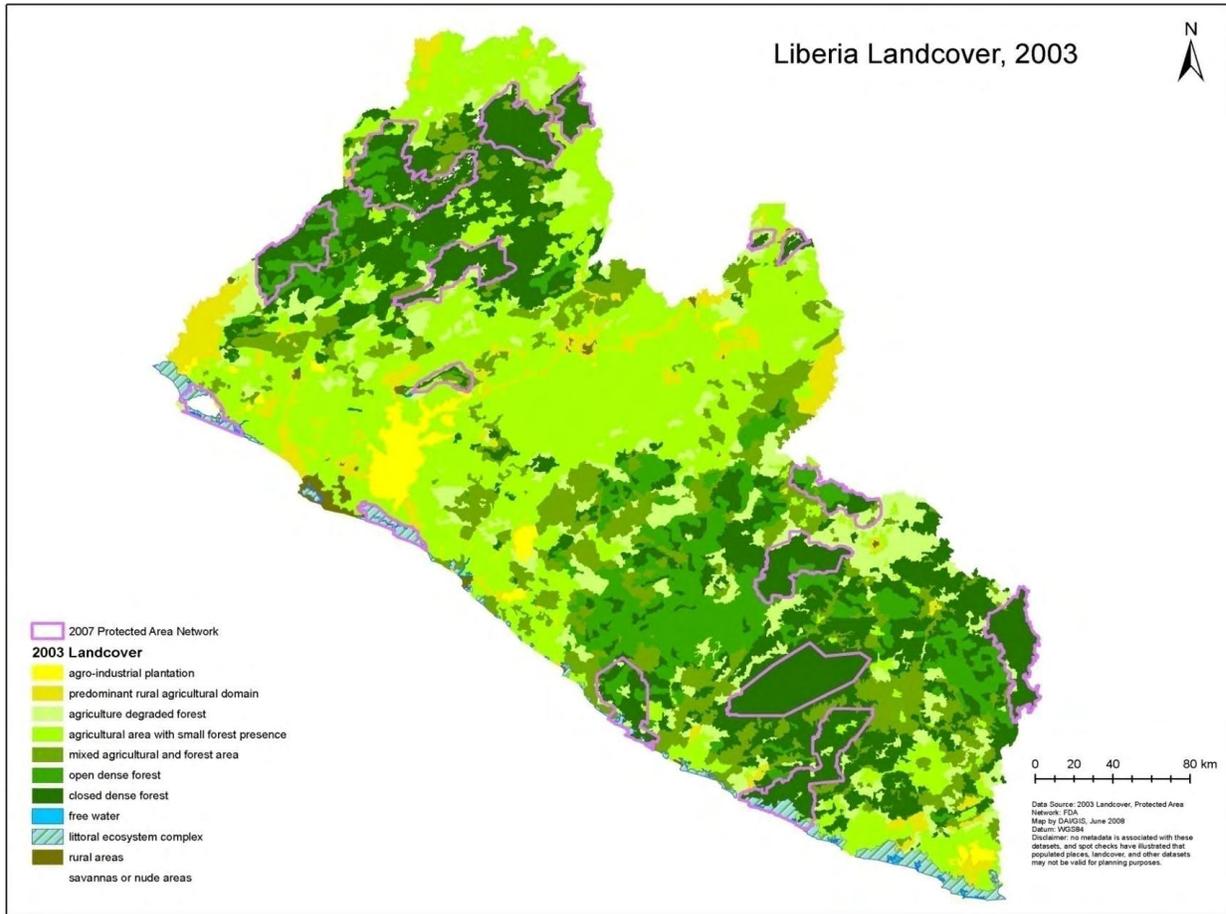
Four of the mountains ranges have been exploited for iron ore, they are the Bong Range, Mount Nimba, Bomi and Mano Mountains. There are also valuable plant and animal species, which are representatives of biodiversity found in the tropical rainforest regions of the world. Their status began to change for the worse when mining, shifting agriculture, commercial logging, and uncontrolled burning progressed in mountain communities.

## Forests

Liberia is situated in the fragmented band of forest known as the 'Upper Guinean Forest'. The total Liberian land area is 9.59 million hectares, of which forests cover about 4.39 million hectares equivalent to 45 percent of the land area, including 2.42 million has classified as closed dense forest, 1.02 million ha classified as open dense forest, and .95 million ha classified as agriculture degraded forest.

It is believed that Liberia is the only country in West Africa that once was covered entirely with rain forest. The forest of Liberia is being reduced at the rate of 1-2% per annum. More than 50% of the forests have been destroyed over the years. The two remaining dense forest areas are now found in the northwest and southeast of the country separated and isolated from each other by a corridor extending from Monrovia to Nimba County. These two forest blocks are further fragmented and dissected by the advances of shifting cultivation along existing roads and by the construction of logging roads.

Figure 8: Liberia Land use map



(map courtesy of the ETOA report)

Other vegetation types result from human degradation of forest and from local soil or hydrological conditions that prevent forest growth. There are three general types of forests; the evergreen or mixed evergreen/semi deciduous moist forests of western Liberia where there is a distinct dry season (under 100mm rain/month), and the wet evergreen forests of eastern Liberia where the dry season is very short or absent. The highest hills in Liberia support the third forest type, submontane (or montane) forest above about 800-1000m, though this zone is of limited extent and poorly-differentiated from the contiguous lowland forests. There are however, some notable endemic species, making this zone important for conservation. An extensive zone of degraded forest occurs near the coast and extends inland in central Liberia, separating the moist and wet forest blocks. The degraded forest is mostly managed for shifting cultivation, and typically shows a mosaic of fields with scrubby and forested fallows. More intensively farmed areas in this zone have plantations with little natural vegetation at all. Finally, there is a coastal zone, often heavily impacted by settlements and agriculture, with a mosaic of sandy and rocky shores, mangroves and fresh-water swamps, grass/shrub savannas on sand, and coastal forests.

### National Forests

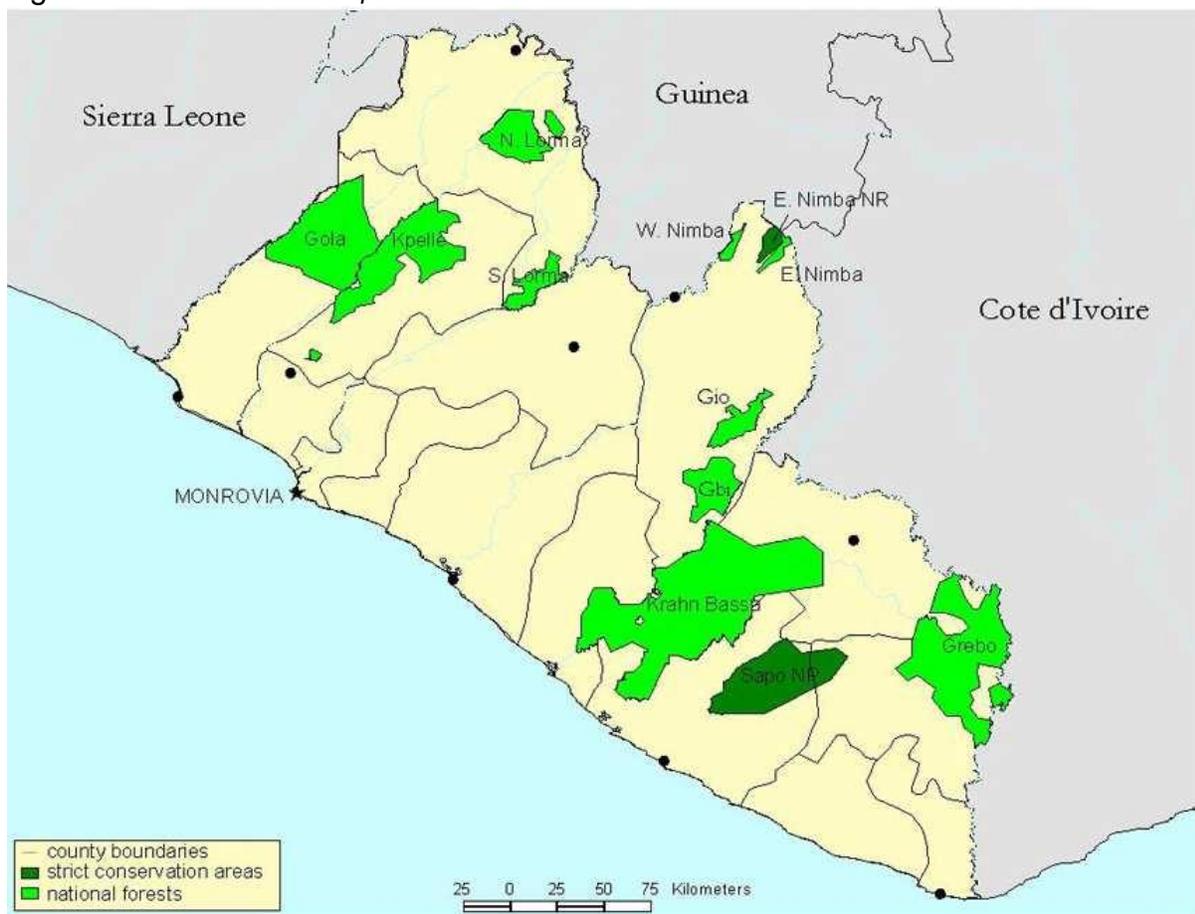
There are eleven national forests currently under partial protection. These forests are set-aside as production forests. Conservation activities such as wildlife management are permitted, but farming,

hunting and human settlements (except logging camps and similar activities) are not permitted.

Table 5: Liberia National Forests

NATIONAL FOREST	AREA IN ACRES	AREA IN HECTARES
Krahn-Bassa	1,270,000	513,962
Grebo	643,603	260,462
Gola	510,168	206,995
Kpelle	432,000	174,828
Yoma	6,456	2,649
Lorma	176,000	71,226
South Lorma	107,503	43,506
Gbi	81,370	32,930
Gio	165,480	66,969
East Nimba	71,650	28,966
West Nimba	32,000	12,950
TOTAL	3,496,230	1,415,443

Figure 9: National Forest map



(map courtesy of Forest Sector in Liberia report)

## National Parks and Nature Reserves

Conservation efforts to protect the forests of Upper Guinea have focused on the establishment of protected areas at priority conservation sites. Liberia is committed to including 30% of its forest (about 1.5 million hectares) in a protected areas network, including both strictly protected areas and production forests. In addition to the existing Sapo National Park and East Nimba Nature Reserve, three new areas have been selected to form the second tranche of strictly protected areas, and there is an unofficial list of nine or ten additional sites of high biodiversity importance in the Liberia Protected Area Network Strategic Plan. Together, these sites cover a full range of Liberia's ecosystems, including the drier forests of the west, the wetter forests of the east, mountains and coastal sites.

Currently, only 4% of Liberia's forests are contained in two strictly protected areas: Sapo National Park and East Nimba Nature Reserve.

Sapo National Park. Created in 1983, Sapo is Liberia's first national park. The approval of the Sapo National Park Act (*An Act for the extension of the Sapo National Park*) on October 10, 2003 expanded the size of the park to 180,363 ha constituting an increase of more than 37%. The act recognized the park as being "at the core of an immense forest block of the Upper Guinea Forest Ecosystem that is important to the conservation of the biodiversity of Liberia and of West Africa as a whole". The park is located in the south-central portion of Liberia, and includes lowland rainforest, wetlands, and riparian forests, and represents one of - if not the most - intact forest ecosystem in Liberia. Notable fauna within the park include forest elephant (*Loxodonta africana cyclotis*), *Jentink's (Cephalophus jentinki)* and Zebra Duikers (*C. zebra*) and large primate populations, including the Diana monkey (*Cercopithecus diana*), red colobus (*Procolobus badius*), black and white Colobus (*Colobus polycomos*) and the western chimpanzee (*Pan troglodytes verus*). Also found within the park are several populations of the endangered pygmy hippopotamus (*Hexaprotodon liberiensis*).

East Nimba Nature Reserve. Created in October 2003, the East Nimba Nature Reserve is dominated by a semi-montane and deciduous forest, and is one of the 14 centers of plant endemism within the Upper Guinea Hotspot. The Mount Nimba Massif is located within the Sanokole quadrangle and is found on the northeastern border of Liberia. Hill and mountain vegetation are the favorite migration and wintering sites of Palearctic migrants such as European pied flycatcher (*Ficedula hypoleuca*), spotted flycatcher (*Muscicapa striata*) and Garden warbler with rock thrushes found in rocky areas. The Nimba slopes between 500 and 700 meters contain a large number of plant species, representing not fewer than 82 genera of trees and brushes. *Piptadeniastrum spp.*, *Heritiera spp.*, and *Lophira spp.* are common. Between 700 and 900 meters *Parinari spp.* becomes increasingly common, as well as *Parkia spp.* and associated species. East Nimba is an important bird area and a designated world heritage site.

Under the World Bank/GEF's Consolidation of Liberia Protected Area Network Program (COPAN), to begin in late 2008, three additional national parks will be added to the protected area network for an additional 176,462 ha. These include:

Lake Piso (48,593 ha). Biodiversity richness includes migratory bird species, sea turtles, hippos, manatees, primates, fish species and medicinal plants, plus a wide variety of habitats and ecosystems such as coastal, marine, forest, mangrove, brackish water, island, and freshwater habitats. The main opportunities for conservation here are based on: i) the very unique marine biodiversity here and the presence of mangroves that provide a breeding ground for important marine species; ii) the existence of enough baseline data for establishing a PA and iii) a potential for funding from tourism, research and fishery sectors as well as high interest for investment in the area including some private US funds. Lake

Piso has also been designated as a Ramsar site. The main threats are deforestation of mangroves, unregulated fishing, hunting, farming and settlements on hills, high population due to the presence of a town and the vicinity of Monrovia, port development, erosion of dunes (sand mining) and offshore mining for oil.

Gola Forest (97,975 ha). Gola Forest is endowed with significant biodiversity richness (endemic amphibians, elephants, hippos, birds, plants, etc) and a number of unique habitats such as forests, gallery forest, swamp forest and fram (*Terminalia superba*) bushes. Opportunities include: i) good funding potential based on charismatic fauna (elephants, hippos), transboundary conservation potential, security of border area and eco-tourism potential; ii) lessons learned from Gola in Sierra Leone in terms of management experience, biological data, community exchanges and fund raising experience; and iii) potential effectiveness of transboundary/peace park management leading to coordinated response to threats. The main threats include: i) the possibility for forest concessions to be reinstated; ii) diverse land uses such as hunting, mining, logging, farming, and transboundary migration of people from Sierra Leone and elsewhere in the region; iii) possibility of opposition from locals and others whose livelihoods might be threatened by PA's establishment (boundaries issues); and iv) lack of FDA capacity in the area.

Wonegizi Forest (29,894 ha). Biodiversity richness includes chimps and other primates, elephants and pygmy hippo. Wonegizi is a unique habitat for rock fowl (*Picathartes spp.*). Conservation opportunities include: i) opportunity for additional funding support from IUCN, Birdlife, and Great Apes programs; ii) research attention; iii) ecotourism potential (species, culture, scenery); iv) corridor (Wologizi) into Guinea and transboundary nature (peace park); and v) scattered farming communities offer opportunity for integrating community land use practices into protected area management. The most important threats include: i) mining for iron ore with the possibility of the extension of the Wologizi deposit entailing possible erosion and contamination of water bodies; ii) returning refugees that could increase population density and result in land use change (farming expansion) especially in the next 5 years; iii) legal and illegal logging; and iv) commercial hunting.

## Hydrology

Liberia has six major rivers: the Mano, Lofa, St. Paul, St. John, Cestos and Cavalla Rivers. These rivers flow from mountains in the north and empty into the Atlantic Ocean. Most are navigable up to 20 miles from the coast, except for the Cavalla, which is navigable up to 50 miles. There are also numerous micro-watersheds and sub-watersheds. There is a total of 1800 kilometers of river, most of which is shallow, rocky and with cataracts and fallen logs.

Figure 10: Watershed map



(map courtesy of Wikimedia.org)

Figure 11: Map of Liberia Rivers



(map provided by L-MEP)

Liberia’s two major lakes are Lake Piso (the country’s largest) and Lake Shepard. Lake Piso in Grand Cape Mount County near the city of Robertsport, covers an area of approximately 30 square miles and is the largest lakes in Liberia. It is a saltwater lake with an open connection to the Atlantic Ocean. Lake Shepard is located in Maryland County and is part salt water and part fresh water. A third lake, Blue Lake Bomi located in Bomi County, is an important lake from a tourist perspective.

There are approximately 600,000 hectares of freshwater swamplands, with about 20,000 hectares (3%) under cultivation to augment upland rice production.

**Fresh Water Biodiversity**

The aquatic ecosystem, freshwater as well as coastal wetlands and near-shore marine communities are clearly affected by upstream changes in terrestrial environments. There are about 166 species of freshwater fish which provide about 65% of the protein needs of the country, and of this number, one species, barbus trispoloides (bass) is endemic, and another species, oreochromis macrochir (longfin tilapia) was introduced. The remaining 164 are native species such as catfish.

## **Wetlands and Mangroves**

Mangroves characterize the wetlands of Liberia, and cover a small area along the coast from Cape Mesurado to Cape Palmas, at the edges of lagoons, riverbanks and river estuaries and in widespread areas of swamps. Wetlands cover 0.5% (500 km-wide belt extending along the total length of the coastline) land surface of Liberia. The most common mangrove species is *Rhizophora racemosa*; but six (6) other species occur in the country. Mature mangroves, reaching heights up to 30m were found along the lower Sankwein and neighboring rivers where species such as *Rhizophora harrisonii*, *Rhizophora mango*, and *avicennia* occur together with impressive tracts of *pandanus*. Except for few places in the central part of the country, primary mangrove forest has been replaced by secondary ones. Much of the mangrove destruction appears to be concentrated along the edges of creeks, and particularly more widespread around the larger towns and cities, such as Monrovia, Robertsport, Buchanan, Greenville and Harper. Mangroves are degraded due to urban expansion, collection of fuel-wood and construction of makeshift homes and establishment of unplanned human settlements. Although the Margibi forest reserve and the Marshall and Mesurado Ramsar sites contain extensive areas of mangrove, there is no active program for mangrove management and conservation.

## **Significant Wetlands**

The Convention on Wetlands -- called the "Ramsar Convention" -- is an intergovernmental treaty that embodies the commitments of its member countries to maintain the ecological character of their Wetlands of International Importance and to plan for the "wise use", or sustainable use, of all of the wetlands in their territories.<sup>4</sup> Liberia has a number of brackish wetlands, the largest of which have been declared Ramsar sites, and one of these—Lake Piso—has also been designated as a National Park. The following is a description of each:

Lake Piso (76,091 ha - 06°45'N 011°13'W) is situated in Grand Camp Mount County. The open coastal lagoon is located near Robertsport to the west of Monrovia, and is the largest such inlet on the Liberian coast, surrounded by forested hillsides (including one of the rarest tropical rainforests in the region) and fed by a number of creeks and rivers; these latter drain a series of swamps above the lagoon, the lower ones of which are tidal and support mangroves. Other mangrove swamps occur behind the dune ridge on the west side of the lake mouth and at other creek mouths. A series of small lakes with swampy margins occurs on the sandy-forested spit that separates the lake from the sea. Some 38 communities, totaling about 7000 people, depend upon Piso for transportation, commercial and non-commercial fishing, and sand for construction, and farm-to-market infrastructure was well-developed prior to the civil crisis of the past decade. The site is important both as a nursery and spawning ground for fish and sea turtles and as feeding and roosting places for large numbers of shore and sea birds. Mammals such as antelopes, duikers, monkeys, bushbucks, and a few crocodiles are also found in the area.

Gbedin Wetlands (25 ha - 07°16'N 008°48'W) is situated in Nimba county in the northern region of Liberia. The area is largely a swamp, but also consists of a man-made wetland with irrigation system that includes channels, ditches, dams and drainages. The paddy fields provide a good feeding ground for many bird species including Palearctic and Nearctic migrants as well as resident breeders such as the Plover *Charadrius dubius*, Bar-Godwit *Limosa lapponica* and the Forbes' Plover *C. forbesi*. The endemic otter shrew *Micropotamogale lamottei* also occurs in the area. The suitability of the swamp for rice cultivation prompted the government in 1960 to solicit technical assistance to introduce modern agricultural methods to local rice farmers in order to discourage shifting cultivation. The project, the Gbedin Swamp Rice Project, has employed a large number of local people, especially up to the onset of

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<sup>4</sup> [http://www.ramsar.org/cda/en/ramsar-about-about-ramsar/main/ramsar/1-36^7687\\_4000\\_0\\_\\_](http://www.ramsar.org/cda/en/ramsar-about-about-ramsar/main/ramsar/1-36^7687_4000_0__)

the civil war in 1990. The site is currently used for subsistence farming (rice), hunting and fishing, while the surroundings are used for logging and mining, as well as multiple crop farming. The use of fertilizers and pesticides are potential threats.

EPA's declaration of Gbedin as a Ramsar site has resulted in considerable conflict between the Gbedin community and EPA. The ETOA team was informed by the community that they learned that the site had been declared a Ramsar site over the radio. Moreover, they were informed via the radio that they were to cease rice cultivation on the site—something they had been doing since 1963. Additionally, no one knows where the exact boundary for the Ramsar site (only 25 ha) but the community was led to believe that they were to stop production on the entire site (some 1000 ha). After protest to the MOA, the community was allowed to continue rice cultivation on about 400ha. The irony of the situation - even as recognized by the community—is that the only reason the site had migratory birds was because they are attracted to the rice.

Kpatawee Wetlands (835 ha - 07°07'N 009°38'W) is situated in Bong County. The Kpatawee waterfall falls is located within the rainforest zone of Liberia, as a branch of the St. John River, one of the six major rivers in the country. While the river erodes the valley in its upper sections, it accumulates sand and gravel downstream, leaving patches of bare land along its course, which provide wintering grounds for large numbers of common Sandpipers and Palearctic migrant species such as Little Ringed Plover and Greenshanks. The endangered Three-cusped Pangolin and Water Chevrotain occur at the site, too. The villagers value this area as a picnic ground, for hosting meetings, workshops and retreats, but the area and its resources are also used for palm wine production, hunting, fishing, basket making, bathing and other domestic uses. Within the site, the governments of Liberia and China undertook the Kpatawee Rice Project with the objective of introducing new rice farming methods to farmers, to discourage shifting cultivation. Threats to the site include the potential development of a hydropower scheme. The site is an ideal nature reserve and tourist attraction but has not officially been recognized for this purpose.

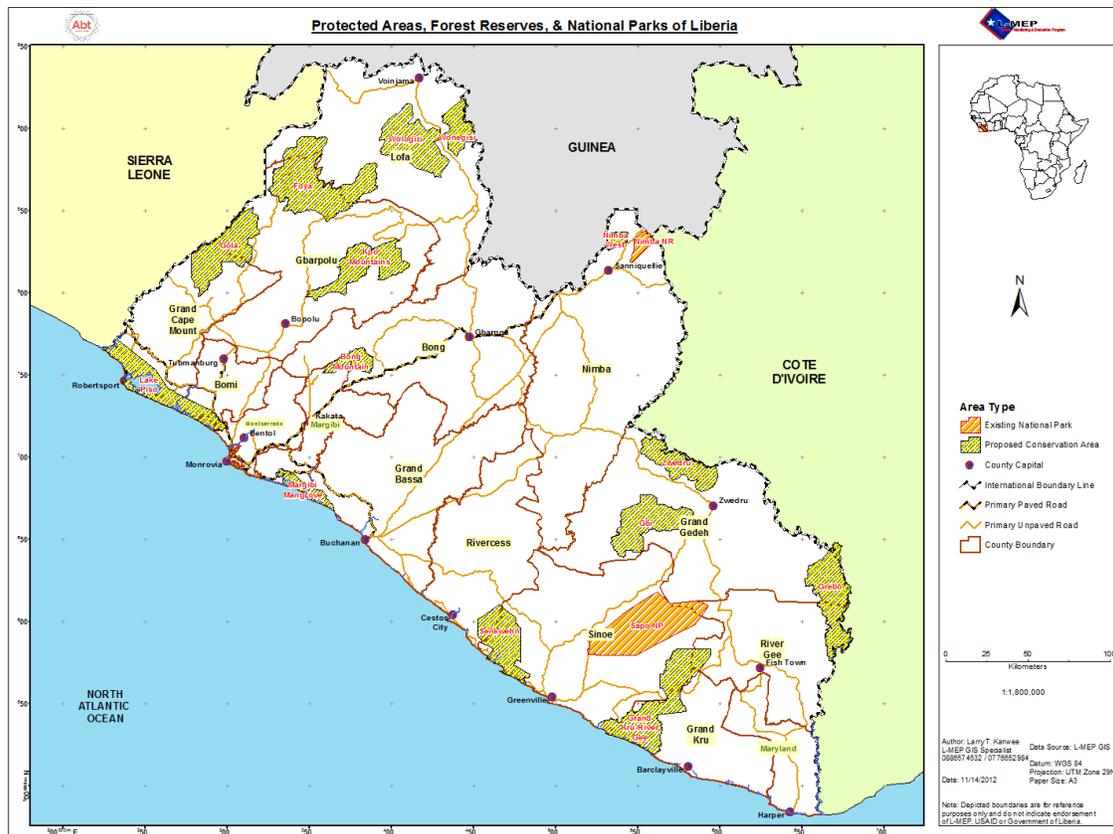
Marshall Wetlands (12,168 ha - 06°08'N 010°22'W) is situated in Margibi County and is comprised of three small rivers and their surrounding mangrove forests. The area has sandy and rocky shores along the coast and the inflowing streams are surrounded by mangrove forests while the vegetation found further inland is characterized by secondary forests and savannah woodland. The wetland is chiefly a mangrove type with mature trees reaching up to 30m. In addition to the Red Colobus monkey, a number of bird species listed by the Convention on Migratory Species appear in the area, such as the Glossy Ibis, Lesser Kestrel and Common Pratincole. The site provides control against flooding and underground water recharge and is a sediment trap. The very large stands of mangroves, fish population and wildlife are valuable resources for inhabitants in the area. The three rivers are navigable and are used for transport from one village to another. The uncontrolled harvesting of the mangrove forest and overfishing by both local and regional fishermen are serious threats to the ecological character of the site. Pollution from the Firestone rubber factory used to be a problem until EPA forced Firestone to install a wastewater treatment facility. In addition, the presence of *Chromolaena odorata*, an invasive alien species which provides host to harmful agricultural insects such as the variegated grasshopper *Zonocerus variegatus*, is a serious problem for farmers. Research on chimpanzees for human vaccines against Hepatitis B and C has also been carried out at the nearby New York Blood Center's Vilab II laboratory and the animals were released on islets in the mangroves after the closure of the research facility in 2006. The New York Blood Center currently provides for the feeding and maintenance of the chimpanzees and has obtained partial funding for an endowment to provide care for the animals indefinitely.

*Mesurado Wetlands* (6,760 ha - 06°18'N 010°45'W) is located in the capital city Monrovia and Montserrado County (the largest administrative region of the country with 1 million people), the site is important for the protection of three mangrove species (*Rhizophora harrisonii*, *R. mangle* and *Avicennia africana*), which are threatened by intense charcoal burning and fuel wood collection. It provides a favourable habitat and feeding ground for several species of birds including the African spoonbill *Platalea alba*, Common Pratincole *Glareola nuchaltis* and Curlew *Numenius arquata*. It also hosts the vulnerable African dwarf crocodile, the Nile crocodile and the African sharp-nosed crocodile and plays an important role in shoreline stabilization and sediment trapping. The site is currently used for fuel wood collection, as a dumping site, for car washing, and fishing, with fish and crustaceans sold to the population of Monrovia. An additional threat comes from unregulated fishing, as well as from pollution from the industries around the site, including an oil refinery, paint factories and medical waste discharge from the Monrovia Hospital.

### Protected Area Management

The Forest Development Authority (FDA) is responsible for managing all national parks, nature reserves and national forests, while the Environmental Protection Agency (EPA) is responsible for managing the Ramsar sites.

Figure 12: Protected Area map



(map provided by L-MEP)

Table 6: Liberia Protected Areas

Liberia's Protected Area Network				
Name	Designation	Ecosystem	Area (ha)	Management
Sapo	National Park	Wet Evergreen	150482	FDA
Wonegizi	Proposed National Park, Partially in North Loma National Forest and Partially not protected	Mixed evergreen/semi deciduous, plus (sub) montane	29894	FDA
Gola	Proposed National Park located largely in Gola National Forest	Mixed evergreen/semi deciduous	97975	FDA
Lake Piso	Proposed National Park / Ramsar Site and not part of an existing National Forest	Coastal Marine and wet evergreen	33914	FDA / EPA
East Nimba	Nature Reserve	Mixed evergreen / semi deciduous, plus sub) montane	13569	FDA
Kpo Mountains	Located partially within Kpelle National Forest	Mixed evergreen / semi deciduous, plus sub montane	83709	FDA
Wologizi	Largely within North Loma National Forest	Mixed evergreen / semi deciduous, plus (sub) montane	107533	FDA
Grebo	Largely part of Grebo National Forest	Wet evergreen	97136	FDA
Gbi	Largely part of Krahn Bassa National Forest	Mixed evergreen / semi deciduous	88409	FDA
Nimba West	Largely part of West Nimba National Forest	Mixed evergreen/ semi deciduous, plus montane	10482	FDA
Gbedin Wetlands	Ramsar Site	Freshwater	25	EPA
Kpatawee Wetlands	Ramsar Site	Freshwater	835	EPA
Marshall Wetlands	Ramsar Site	Coastal / marine	12168	EPA
Mesurado Wetlands	Ramsar Site	Coastal / marine	6760	EPA
Important forests being considered for the Protected Areas network				
Foya	Not part of an existing National Forest	Mixed evergreen / semi deciduous		FDA
Bong Mountain	Not part of an existing National Forest	Mixed evergreen / semi deciduous, plus sub montane		FDA
Margibi Mangrove	Not part of an existing National Forest	Coastal/ marine		FDA
Senkwehn	Not part of an existing National Forest	Wet evergreen		FDA
Grand Kry-River Gee	Not part of an existing National Forest	Wet evergreen		FDA
Zwedru	Not part of an existing National Forest	Wet evergreen		FDA

### Specie Biodiversity

Biologically, Liberia's forest and coastal marine ecosystems are exceptionally diverse, with high rates of endemism and many species that are nearly extinct outside the country. Liberia is home to approximately 2000 flowering plants including 240 timber species, 125 mammal species, 590 bird

species, 162 native fish species, 74 known reptiles and amphibians and over 1000 described insect species. A general description of the types of biodiversity is presented below.

### **Larger Mammals and Reptiles**

This group is relatively well known in terms of their distribution within Liberia. Along with birds, their protection forms the core of the Liberian conservation strategy. These are the pygmy hippopotamus, Liberian mongoose, Nimba otter shrew, Diana monkey, red colobus monkey, and chimpanzee. Threatened species such as the forest elephant and the Jentink's and zebra duikers (both Upper Guinea endemics), are also important in the conservation strategy.

### **Birds**

Birds, like larger mammals, are the flagship of Liberian conservation. There are a number of rare, endemic bird species in Liberia's forests including the Gola malimbe, the Liberian greenbul and the rufous fishing owl, all listed as endangered, plus a number of threatened species such as the white-breasted guineafowl, the Nimba flycatcher and the white-necked rockfowl. In addition, the coastal wetlands are important overwintering habitat for migratory water birds.

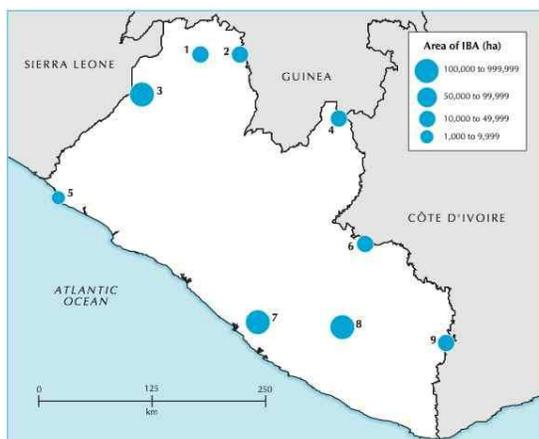
### **Important Bird Areas (IBA)**

There are nine important bird areas (IBA) located in Liberia. IBA are key Biodiversity Areas that are used by threatened species.

1. Wologizi Mountains (Lofa County)
2. Wenegizi Mountains (Lofa County)
3. Lofa-Mano (Lofa County)
4. Nimba Mountains\* (Nimba County)
5. Cape Mount\* (Grand Cape Mount County)
6. Zqedru\* (Grand Gedeh County)
7. Cestos Senkwehn (River Cess and Sinoe Counties)
8. Sapo National Park (Sinoe County)
9. Cavalla River (River Gee County)

*\*also meet Ramsar site qualifications*

Figure 13: IBA map



*(map courtesy of Important Bird Areas in Africa – Liberia report)*

### **Costal and Marine Species**

The Liberian coast is critical habitat for four endangered species of sea turtle of which three nest on the beaches (Green, Leatherback and Olive Ridley), and one in estuaries (Hawksbill). The USFWS with SAMFU have been active in marine turtle protection, which involves long-term collaboration with fishermen and coastal communities. Estuaries are also important habitat for threatened manatees. Protection for these species along the coastline and in Liberian territorial waters presents complex problems for law enforcement.

The coastline of Liberia is 560km (350 miles) long and about 58% of its population lives along this coast. With a continental shelf of 14,894 km<sup>2</sup> and a territorial sea of up to 159,200 km<sup>2</sup>. It produces 7,616 metric tones of fish and 126 metric tones of mollusks and crustaceans annually. The coastline consists of swamp related vegetation, which includes mangrove forests and savannah related vegetation, extending up to 25 km inland. The coastal and marine environments are subjected to a variety of pressures: erosion due to sand mining, oil pollution, waste dumps, human settlement and the discharge of municipal waste water. Although fishing has not exerted significant pressure on the fish population, no stock assessment has been undertaken for the country to make informed decisions on the management and utilizing of the resources.

Table 7: Liberia's Threatened or Endangered Animals

<b>Scientific Name</b>	<b>Common Name</b>	<b>Habitat</b>	<b>IUCN</b>
<b>Mammals</b>			
Cephalophus jentinki	Jentink's duiker	forest	VU
Cephalophus zebra	Zebra duiker	forest	VU
Cercopithecus diana	Diana monkey	forest	EN
Hexaprotodon liberiensis	Pygmy hippopotamus	forest	EN
Hippopotamus amphibius	Hippopotamus	rivers	VU
Liberiictis kuhni	Liberian mongoose	forest	EN
Loxodonta africana cyclotis	Forest elephant	forest	VU
Micropotamogale lamottei	Nimba otter shrew	rivers	EN
Pan troglodytes verus	Chimpanzee	forest	EN
Piliocolobus badius	Red colobus	forest	EN
Trichechus senegalensis	Manatee	rivers	VU
<b>Reptiles and Amphibians</b>			
Amnirana occidentalis	(frog – Ranidae family)	forest	EN
Caretta caretta	Loggerhead turtle	coastal	EN
Chelonia mydas	Green sea turtle	coastal	EN
Conraua alleni	(frog – Ranidae family)	forest	VU
Eretmochelys imbricata	Hawksbill turtle	coastal	CR
Kinixys homeana	Home's hingeback turtle	forest	VU
Lepidochelys olivaceus	Olive Ridley turtle	coastal	EN
Phrynobatrachus annulatus	(frog - Petropedetidae family)	forest	EN
Phrynobatrachus villiersi	(frog - Petropedetidae family)	forest	VU
<b>Birds</b>			
Agelastes meleagrides	White-breasted guineafowl	forest	VU

Scientific Name	Common Name	Habitat	IUCN
<i>Bleda eximius</i>	Green-tailed bristlebill	forest	VU
<i>Campephaga lobata</i>	Western wattled cuckoo-shrike	forest	VU
<i>Criniger olivaceus</i>	Yellow-throated olive greenbul	forest	VU
<i>Malimbus ballmannii</i>	Gola malimbe	forest	EN
<i>Melaenornis annamarulae</i>	Nimba flycatcher	forest	VU
<i>Phyllastrephus leucolepis</i>	Liberian greenbul	forest	CR
<i>Picathartes gymnocephalus</i>	White-necked rockfowl	forest	VU
<i>Scotopelia ussheri</i>	Rufous fishing-owl	forest	EN

(CR=critically endangered, EN=endangered, VU=vulnerable/ threatened)  
Source: IUCN (2007)

## Fishing

Fishery is an important economic activity for a significant proportion of the Liberian population, mainly for those who live along the coast. Besides the five (5) fishing enterprises, only four (4) companies are reporting fish production statistics. Fishing is also done by artisan fishermen, whose harvest is predominantly subsistence-oriented. The fishing resources off the Liberian coast in 1984 were believed to be considerable and included such well-known food fish as croaker, grunter, sea bream, mackerel, snapper, sole, graper, tuna, and various sardines. Shrimps, rock lobsters, crabs, and oysters were also caught. Inland subsistence fishing is carried out on the lagoons, swamps, streams, and rivers throughout the country.

### *Inland Fisheries*

Freshwater bodies cover 15,050 km<sup>2</sup> (14%) of the total area of Liberia. These include rivers, lakes, lagoons, creeks and streams that drain to the Atlantic coast. Inland fisheries contribute approximately 25% of fish consumed by rural dwellers.

Inland fisheries activities take place in all Liberian fresh water bodies, particularly Liberia's six major rivers and Lake Piso, an inland lagoon connected to the sea in the north of the country. Inland fisheries in Liberia are conducted from shore and dugout canoes at the artisanal level only, using a variety of fishing gear, including:

- Hook and hand line
- Fishing net
- Traditional trap

Major species targeted in the inland fisheries of Liberia include:

- Talapia
- African cat fish *spp*
- *Hecterites*

### *Aquaculture*

Aquaculture was established in Liberia in the early 1950s. Institutions involved in aquaculture include

the Central Agriculture Research Institute (CARI), Bong County Agriculture Development Project (BCADP), and the Klay Agriculture Fishery. These institutions were all functional in constructing breeding facilities and supplying local indigenous fingerlings such as tilapias and clarias to local fish farmers in aquaculture production. Presently, they are all in ruins due to the civil crisis. Although the Klay Fishery was rehabilitated by the Lutheran World Service in 2000, it was later destroyed. Aquaculture production contributed immensely in providing protein for rural families also contributed to poverty reduction.

Aquaculture in Liberia is currently very limited, occurring for the most part as small, freshwater ponds. There are approximately 1050 small-scale fish farmers. There are three fish hatcheries currently under the supervision of the Division of Aquaculture and Inland Fisheries:

- Klay Fish Hatchery & Farmers Resource Center in Bomi County
- Duoyee Fish Hatchery in Grand Gedeh County
- Tasah Fish Hatchery in Bong County

In addition the use of floating cages emerged in 2009 on the lower St. Paul River through the initiative of a private entity. This operation is growing *Tilapia spp* for the local market. There are currently approximately 15 cages of this type, each approximately 5 x 10 metres, and holding up to 500 fish.

### *Artisanal Fisheries*

Artisanal Fisheries are a key sector of marine capture fisheries in Liberia, providing food and livelihoods to coastal communities throughout the country. Recent surveys indicate that there are approximately 3300 canoes and more than 11,000 fishers operating actively from 114 fish landing sites along the 579-kilometer coastline. The artisanal fleet comprises the indigenous Kru canoe (1–3 person crew), operated by Kru fishermen using paddles or sail. These are small dugout canoes up to about 7 m, deploying mainly hooks, long lines and gillnets which target barracudas, croakers, grunters, grappers and also target crabs and lobsters. Fanti canoes are larger (12–15 m), built with planks and powered by 15–40 hp engines; they operate with a crew of up to 15. Their gears are ring and purse nets used for small pelagic species, with larger gillnets specifically adapted for different species and seasons. While some Fanti canoes are permanently based in Liberia, others migrate along the coast from countries such as Ghana. Similar canoes migrate down from northern West Africa, some coming from as far as Senegal.

### *Industrial Fisheries*

The industrial fishery in Liberia involves bottom trawlers targeting demersal fish and shrimp, purse seiners and long liners targeting off shore tuna resources, crab vessels and on-shore cold storage facilities. Fishing vessels, as well as vessels importing fish, are required to land their catches under inspection at the fishing pier in the Free Port of Monrovia; transshipment must also take place in port under inspection.<sup>5</sup>

### **Beekeeping**

NGO's and Missionary Groups are working with local farmers to help develop a bee keeping cottage industry. Bee keeping is mainly with the honeybee *Apis mellifera adansonii*, which are kept for honey and bees wax production. Top-bar hives are widely used in these programs. Hunting for wild honey is also wide spread throughout rural areas.

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<sup>5</sup> liberiafisheries.net

## County Descriptions

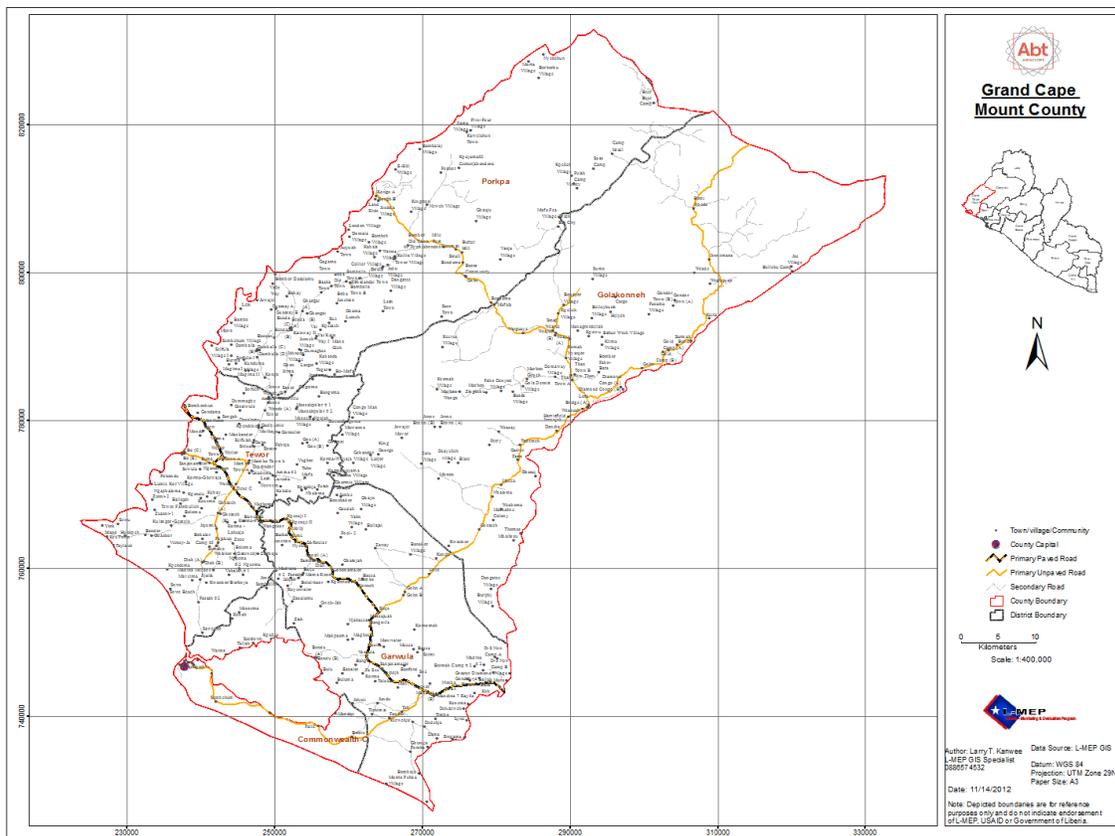
A detailed description of the environmental and social conditions for each of Liberia's 15 Counties are included in this SEA to allow the flexibility to expand the IRS program or change the geographic location based on malaria prevalence and other considerations Malaria Task Force employ for selecting the districts that are considered priority for that particular spray campaign.

### North Western Region

#### Grand Cape Mount County

Grand Cape Mount is a border County found in the Western Region of Liberia, specifically the south-western corner of Liberia along the coastal belt. It is bounded in the Northeast by Gbarpolu County, in the East by Bomi and Lake Piso, in the South by the Atlantic Ocean and in the West by Sierra Leone, with a total land area of 5,827 square kilometers. The town of Robertsport serves as the capital. The County is sparsely populated with concentrations in commercial, mining and fishing areas. As of the 2008 Census, it had a population of 127,076, making it the eighth most populous county.

Figure 14: Grand Cape Mount map



(map provided of L-MEP)

In 1461, Pedro De Sintra, a Portuguese Navigator on a mission to the West Coast of Africa, saw the beauty of the cape and mountains and named the area Cape du Mont, a Portuguese word meaning the Cape of the Mount, from which the name Grand Cape Mount County was derived.

## **Districts**

The districts of Grand Cape Mont County include (population):

- Garwula (26,936)
- Golakonneh (23,518)
- Porkpa (42,615)
- Commonwealth (6,547)
- Tewor (27,460)

## **Demographics**

The Comprehensive Food Security and Nutrition Survey of October 2006 measured an average household size of 4.6 persons and a dependency ratio of 1.33, as compared to Liberia's national figures of 5.6 and 1.37 respectively. Like the rest of Liberia, the local society is predominately patriarchal, with 83% of households headed by men, 16% of households sampled were headed by an elderly family member, 9% of the population is chronically ill/disabled, and .03 % are orphans.

The five major ethnic groups in the County are the Vai, Gola, Mende, Mandingo and Kissi. Other minority ethnic groups include Bassa, Gbandi, Kpelleh, Grebo, Kru, Lorma, and Mano. The Vai vernacular is widely spoken, followed by the Gola, with percentage distributions of 60% and 23% respectively. Mende, Mandingo and Kissi languages are also spoken by sizeable minorities. The Vai script, introduced by Bokeleh, serves as means through which many locals are able to communicate and keep financial transactions and other records. Culturally, inter-marriages among the tribes are permissible and common. This leads to cultural assimilation that creates a bond of unity.

## **Climate**

The climate of the County is humid and tropical with two distinct seasons: the wet season and the dry season. The wet season begins in April and ends in October with an average rainfall of 400 cm and temperatures ranging from 28 degrees and 34 degrees Celsius, while humidity goes as high as 90 to 100 percent. The dry season is from November to March. Cape Mount, being a coastal County, has high annual average rainfall because the coastline runs approximately from Southeast to Northwest and at right angles to the prevailing southwestern rain-bearing winds.

## **Topography**

Grand Cape Mount has a large natural lake called Lake Piso, which forms a confluence with the Atlantic Ocean with beautiful shores that attract tourists. The County is also endowed with mountains such as the Bie Mountains in Porkpa and Gola Konneh Districts, which contains a large deposit of iron ore. Cape Mount County is served with a good network of rivers such as Maffa, Mani, Konja, and Lofa, which separates Bomi from Cape Mount, and the Congo Mano River, separating Sierra Leone and Liberia. These rivers contain rich deposits of gold and diamonds and provide food and livelihoods for many communities.

## **Geology**

The County is richly endowed with natural resources, mainly iron ore in Porkpa and Gola Konneh Districts, and diamonds and gold in Porkpa, Gola Konneh and Tewor District. It was reported during the CDA consultations that there may be valuable deposits of oil around Bobojah in Garwular District, though a geological survey has yet to confirm this claim.

## **Vegetation**

The County's coastal belt is rich with coastal mangrove, farmland, coastal savannah and secondary

forest. Tewor, Porkpa and Gola Konneh Districts are mostly covered with semi- deciduous and rainforest. A portion of the Gola Forest runs through the County, with a variety of wildlife species such as elephants, monkeys, chimpanzees, pottos, genets, pigmy hippopotamus, zebra duiker, leopards, egrets and owls, among others.

### **Institutional Structure**

Grand Cape Mount County is sub-divided into four administrative districts, namely, Tewor, Garwular, Porkpa and Gola Konneh Districts, and the Commonwealth comprising of Tombey Chiefdom, Tallah Township and the capital city, Robertsport. Robertsport is the seat of the County Administration and the home of the City Corporation. At the County level is the Superintendent as the head of County Administration assisted by the Assistant Superintendent for Development, Administrative Assistant and other officials.

### **Natural Resources**

The County is heavily endowed with abundant and rich natural resources including economically viable rivers, creeks, forests, rich mountains, Lake Piso and the Atlantic Ocean with its beautiful beaches that makes its attractive to eco-tourism and fertile land suitable for agriculture. It also has mineral resources such as diamonds, gold and iron ore with likelihood of oil deposits, particularly in Garwular, Gola Konneh and Porkpa Districts. The proper utilization of such natural and mineral resources has the propensity to positively drive the socio-economic recovery process. Within the County, Porkpa and Gola Konneh Districts are known as the County's breadbasket because of the rich deposits of minerals such as iron ore (especially Canga and Limonite in Mano River and Magetite+, Haemite+ and Limonite in Bea Mountains), gold and diamonds. The Ministry of Lands, Mines and Energy has divided the County into five mining agencies - Varguay, Bangoma, Kawellahun, Keita and Camp Freeman.

#### *Iron*

Recently, Delta Mining Company has won the bid for the extraction of the Western Cluster iron ore. The finalization of the iron ore concession agreement between the Government and the Company will see the revamping of iron ore mining activities within the next couple of years, which has great economic revitalization potential.

#### *Diamonds*

Diamonds are found along the Mano and Lofa Rivers covering Porkpa, Gola Konneh and Garwular Districts. These rivers host extensive areas of artisanal workings and have potential for diamondiferous kimberlites.

#### *Gold*

In 2007, Mano River Resources announced that it had identified a resource of about million tons of gold at a grade of approximately 5 grams per metric ton. Some Mining Companies have received either exploration rights or mining licenses and these include African Aura Resources, Mano River Resources, Texas International Mining Group, KBS Mining Group, Diasoma Mineral Incorporated and Montserrado Mining Company, in addition to other individual gold mining license holders.

#### *Timber*

The cancellation of logging concessions limited commercial logging activities in the County. However, unregulated pit-sawing is still being carried out, mostly in Gola Konneh and Porkpa Districts. The transportation of over-loaded trucks of timber is a contributing factor to the deterioration of roads and damage on bridges. Regulation of pit-sawing for the benefit of local communities and protection of the

environment cannot be overemphasized as it provides many resources for the County including medicinal herbs, raffia, bush meat, charcoal and firewood and creates employment opportunities.

### **Agriculture**

According to the 2001 agricultural baseline survey, 78% of the rural households in Cape Mount are engaged in agricultural activities at subsistence scale. Formal employment accounts for as little as 4% of incomes, with the majority serving as casual workers at best. Most locals are instead engaged in petty trading.

In general, Cape Mount has fertile soils that favor the cultivation of a variety of cash crops including oil palm, rubber, cocoa and coffee, and food crops such as rice, cassava, yams and vegetables including pepper, bitter ball, okra, potato leaves, cabbage, and others. Agricultural productivity remains low due to limited access to extension services, crude methods of farming, late supply of seeds, lack of capital and credit, lack of tools and other inputs, a flawed land tenure system, and few post-harvest facilities.

#### *Food Crops*

The main food crops produced in the County include rice, cassava and groundnut. However, many women are engaged in the production of other crops such as corn, okra, pepper, bitter ball, and other vegetables. In most cases the production of vegetables is done by women through the establishment of small backyard gardens. With cessation of hostilities and the return of the displaced communities to their land, rice and cassava production and food crops in general is steadily increasing.

#### *Cash Crops*

##### Rubber

Rubber is one of the country's major cash crops and serves as a major revenue engine. According to the LDTSI report, after the war, rubber accounts for about 90% of Liberia's exports. The biggest rubber farm in the County is the Guthrie Plantation, which also extends into Bomi County. However, private rubber farms abound in the County, especially in Garwular and Gola Konneh Districts. There are large uncultivated lands and fertile soil to allow for rubber farm expansion. Although production was disrupted during the war period, the Interim Management Team of Guthrie is producing between 400-600 wet tons of rubber per season.

One key constraint to the development of the sector is the muted output growth during the long gestation period of new plantings. With the occupation of the plantations by rebel militias, a significant proportion of the trees were subjected to excessive tapping, which has killed many trees. Other constraints include the communal land system, which does not easily avail large parcels of land for the expansion of the sector.

##### Palm Oil

The availability of vast fertile land throughout the County provides the basis for expansion and greater growth of the oil palm sector with comparative advantage over many other West African countries. Palm oil cultivation is of great economic value to the rural communities, and the products are widely locally consumed. The largest palm oil plot is located in Wangekor, with a cultivated area of 10,000 acres. Smaller holdings are found in Sinje, Gola Konneh and Porkpa Districts. The Wangekor farm provides not only employment but also substantial revenue for local communities, who use crude extraction methods, producing as low as a 4-8 ton ffb/ha ratio, according to the LDTIS report.

## **Fishing**

Grand Cape Mount is endowed with many rivers and creeks, as well as the large Lake Piso and the Atlantic Ocean, where a variety of fish abound. About 11% of households were engaged in ocean fishing in 2005, while 15% fished in rivers, 81% in creeks and 2% in swamps.

However, the fishing industry remains underdeveloped. Fishing provides employment to about 30 percent of the population of Robertsport and its environs. Currently most fishing is carried out by Fanti and Kru people, who have trained many local youth. Lack of cold storage facilities and bad roads, coupled with a lack of capital continue to constrain growth in the sector. There is a strong need to organize fishing cooperatives and provide inputs to local fishermen to engage in commercial fishing as well as drying and cooling of the catch in Bo, Tahn, Sinje and Robertsport.

## **Healthcare**

There are 33 functional health facilities, which include one hospital, one health center, 30 clinics and one health post. The hospital (St. Timothy Government Hospital) and three of the clinics (Fanti Town, Sembahun and Tallah) are found in the Commonwealth. Garwular District has functional clinics located in Jundu, Madina, Bomboja, Bendu, Kpeneji and Kanga, one health center in Sinje, one health post in Division 8, Guthrie (Private) and one non-functional clinic in Zarway Town. In Tewor District there are 11 facilities, in Tienni, Bo Waterside, Diah, Kulangor, Mambo, Gondama, Gonelor, Jenewonde, Fahnja, Than Mafa and Bangorma. Five clinics are operational in Porkpa, in Bamballah, Bendaja, Kongo and Kawellahun, and four more in Gola Konneh District, namely Mbaloma, Lofa Bridge, Tahn and Varguay. The African Humanitarian Agency (AHA), Medical Teams International (MTI) and International Medical Corps are playing a pivotal role in supporting the health sector.

## **Water and Sanitation**

Only 20 % of the communities in Grand Cape Mount have access to clean water facilities. The poor water and sanitation situation has contributed immensely to the poor health of the inhabitants of the County. The Government, in collaboration with NGOs, is constructing and rehabilitating hand pumps, wells and latrines in various communities. World Vision Liberia (WVL), the Norwegian Refugee Council (NRC), Christian Children's Fund (CCF), German Agro Action (GAA) and local NGOs are actively engaged in the rehabilitation of wells/hand pumps and construction of toilets. An estimated 35 percent of the pre-war wells and hand pumps have been rehabilitated to date, and NGOs are also giving institutional water and sanitation support to many schools.

## **Roads and Bridges**

The physical damage to roads and bridges, particularly following the rainy season, continues to limit the ability of humanitarian agencies to provide critical support and it obstructs access to markets, thereby impeding economic productivity and self-sufficiency. The County has only one paved major road, leading from Monrovia to Bo Waterside, and seven major feeder roads, Madina–Robertsport, Sawelor-Tienni, Tienni-Kawellahun, Congo Mano River-Tahn, Tahn-Sinje, Teh–Bomboja, and Daniels Town-Tallah. There also exist several farm-to-market or secondary feeder roads. With the exception of the paved road, all these roads have deteriorated to an extent that makes accessibility very difficult. WVL/Japan Platform rehabilitated the Tienni- Damballah road, while German Agro Action (GAA) has constructed five bridges in Gola Konneh District and has undertaken a feeder roads assessment for possible intervention in the District. District and Clan youth groups have been mobilized to assist in the rehabilitation of roads. Texas International Mining Company is rehabilitating the 43 km road from Sinje to Tahn. Deterioration of roads is attributed to lack of maintenance and the absence of qualified technicians, which has warranted the rehabilitation of bridges by masons and carpenters. As such the repairs and constructions

are not sustainable. UNMIL, in collaboration with the Ministry of Public Works, has formed a Road Task Force (RTF) to assess and recommend on the state of the roads and bridges. The RTF has done some assessments of feeder roads to be rehabilitated by communities with food-for-work support from WFP.

Accessibility to some areas during the rainy season is virtually impossible due to damaged bridges, specifically Konja and Kalia bridges, which link the rest of Porkpa District, and Jagila and Diah bridges, which link many towns in Tewor District. UNMIL Pakistani Engineers have worked to ensure that the Madina-Robertsport road is passable, but the geographical location of Robertsport has created a contact gap between the County Administration and the locals.

**Education**

A total 124 functional educational facilities exist in Grand Cape Mount. Of this number, 107 are elementary schools, 14 are junior highs and three are senior high schools. Enrollment is estimated at 26,748 including 13,888 boys and 12,860 girls, with a teacher population of 341, of which 311 are male and 30 are female.

**Environmental Issues**

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people’s access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

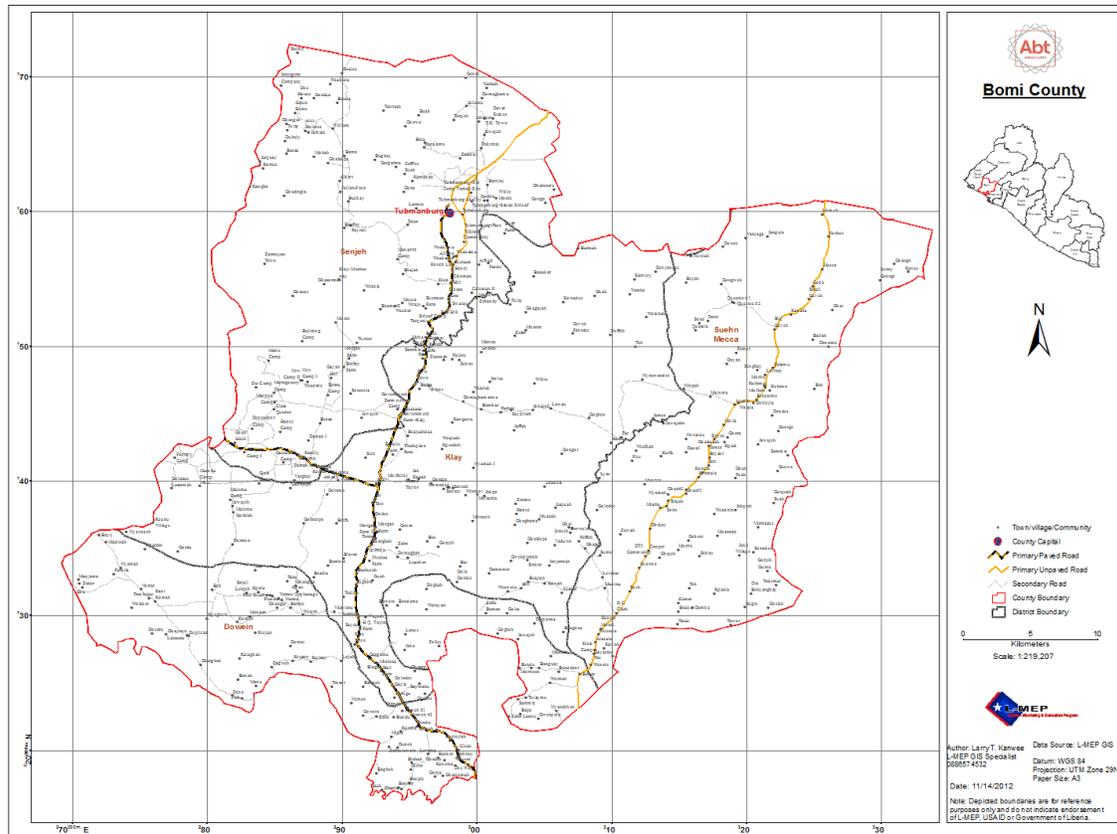
**Sensitive sites**

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
Gola	Gola	Lake Piso	Lake Piso	Cape Mount

**Bomi County**

Bomi County is situated in the Northwestern region of Liberia and bordered by Gbarpolu County in the North, Grand Cape Mount County in the West, Montserrado County in the East and the Atlantic Ocean in the South. The capital city is Tubmanburg. There are four Administrative Districts (Klay, Dewien, Suehn Mecca and Senjeh), comprising five Chiefdoms and 18 Clans. Bomi County has an area of 755 square miles. As of the 2008 Census, it had a population of 84,119, making it the twelfth most populous county in Liberia.

Figure 15: Bomi County map



(map provided of L-MEP)

Before the war, Bomi County enjoyed a vibrant socio-economic life, and it is still one of the richest in Liberia, boasting ample natural resources. The proximity of Bomi to Monrovia rendered it vulnerable during the war as the various fighting groups struggled at various times to take control of the capital. The County suffered extensive damage to infrastructure and basic social services as well as mass displacements and loss of life.

Bomi County, formerly known as Bomi Territory, was annexed from Montserrado County by decree during the military regime of Samuel Doe in 1983 and later recognized by an act of legislation. Bomi means “light” in the Gola language, symbolizing the County’s uniqueness as the first cradle for iron ore mining in Liberia. Before the national crisis, iron ore mining flourished in Bomi County, starting in the 1950s. Rubber has also long been an important export from Bomi, and the second largest rubber plantation in Liberia, the Guthrie plantation, is situated here.

### Districts

The districts of Bomi County include (population):

- Dowein (13,188)
- Klay (23,398)
- Senjeh (30,027)
- Suehn Mecca (17,507)

### **Demographics**

Bomi County is a predominately Gola-speaking region, though there at least 15 different dialects or languages spoken. The population is predominantly made up of four ethnic groups, namely Gola, Dei, Mandingo and Kpelle, though all of Liberia's 16 major groups are thought to be represented. Some 70% of the active workforce is engaged in agriculture.

### **Climate**

Bomi County is generally warm throughout the year. It has two seasons: the rainy season beginning in April and ending in October, and the dry season covering the months of November to March. The average annual rainfall of Bomi County is approximately 80 inches.

### **Topography**

Bomi County is generally hilly with a few plains and valleys. The County is endowed with ample water resources to supply fish and other livelihood options, including the Atlantic Ocean and the Po, Wlein, Mahei, Lofa, and St. Paul Rivers, among others. Many of the rivers are suitable for mini hydroelectric generation to supply electricity to citizens and industry.

### **Geology**

In general, Bomi County has a sandy clay soil type.

### **Vegetation**

There are many valuable commercial timber species found in the County. However, currently there exists no large-scale logging activity. Timber processing and pit sawing are carried out only at a small scale. Bomi County is a fertile land with rolling hills. Approximately, 45% of the land is covered by grassland.

### **Institutional Structure**

The Superintendent's Office and at least 17 other Government Ministries are operating in the County, though few of them are adequately resourced or capacitated. The District Development Committees (DDCs) were formed two years ago under elected leadership, and are supported by UNDP. Bomi County's Housing and Properties Committees have been functional since 2004. The existence of these structures means that it is not necessary to refer many cases related to housing to the court system. Disputes are instead mediated by these local committees comprising of the Superintendent, Land Commissioner, Tribal Governors, Elders and CSOs.

### **Natural Resources**

#### *Forestry, Rubber, and Mining*

Several valuable timber species are available for exploitation in Bomi County. As a part of its reform program, the Government cancelled all forest concession agreements across the country, and consequently there exists no large-scale or formal forestry activity in Bomi.

An important cash crop in the County, rubber was being harvested by some 21% of households in 2005.

Bomi is home to Liberia's well-known Guthrie Rubber Plantation, which was reclaimed by the Government with the assistance of UN peacekeepers after it had been illegally occupied and exploited by ex-combatants for about 3 years. The plantation has potential to be a major employer of Bomi County residents and workers from neighboring Grand Cape Mount County. Some residents of the two counties complain that workers have been imported from other parts of Liberia.

While mining has historically been an important economic activity in Bomi, the 2005 CFSNS found only 2% of households working in the sector.

#### Rubber

Traditionally, rubber is one of the main sources of income for the County. But nearly all rubber farms, including traditional smallholder farms, Liberian-owned commercial farms and the foreign-owned Guthrie plantation were badly affected by the war. Prior to the war, the Guthrie plantation provided basic social and infrastructure services to workers and inhabitants of surrounding areas. Nearly all of the estimated 34,000 people residing on the plantation are presently unemployed, and little has been done to revitalize the farm.

#### Palm Oil

The County's palm farms, too, were badly affected by the war and farmers have so far been unable to rehabilitate/replant them. Palm oil is a staple of the local diet, but it is only produced at a small scale today. While before the war Bomi had its own functioning oil mill, consumers now depend on imports from other counties.

#### **Agriculture**

Before the civil war, Bomi was essentially an agricultural zone, with 70% of the population actively engaged in subsistence agriculture and related activities. As the farming population gradually returns to the county, farmers are being encouraged to cultivate various food crops such as rice, cassava, sweet potatoes, plantains and vegetables.

#### Rice

The people of Bomi consume more rice than any other food, and farmers throughout the County grow rice at a subsistence level. About 85% of rice is grown upland, and international and local NGOs are promoting increased production of lowland (swamp) rice.

#### Cassava

Cassava is second only to rice in volume of production and consumption in Bomi County. With the high commercial value of fufu, farina or garri, which are produced from cassava, many farmers are now engaged in the mass production of this food crop. Many of the county's cassava products come from the Dewien District and parts of Klay District.

#### Sweet Potatoes/Eddoes

These tubers are grown by farmers mainly for their own consumption. Few have engaged in production of these crops for market purposes, due to inadequate knowledge and appropriate technology for processing and preservation.

#### Plantains

Like sweet potatoes and eddoes, plantain production is constrained by a lack of farmer knowledge and appropriate technology for processing and preservation.

### Vegetables

These food crops are grown throughout the county, tended mainly by women and girls, and used mainly for household consumption. Despite the potential for production of a wider variety of vegetables, output is mainly limited to tomatoes, peppers, potato greens, and a few more.

### **Livestock**

Prior to the civil war, Bomi farmers raised livestock mostly for domestic consumption, including local-breed fowl, goats, and sheep.

### **Fisheries**

Many fine rivers, streams and creeks meander through Bomi County, rich with a variety of local species of fish. The local population uses traditional methods of fishing such as sisal nets, water fences and basket setting. Artisanal marine fishery is also practiced along the beaches in Dewien District, south of Klay District. Lutheran World Service/World Federation and the Fisheries Department of the Ministry of Agriculture collaborated to construct fish ponds in Klay Town to train farmers from all over the County in fish farming methods.

### **Healthcare**

Currently, less than 15% of the County's population has access to health care. The County Health Team is led by the Ministry of Health and Social Services. One hospital and 16 functional clinics are providing services: nine of the clinics are run by World Vision Liberia (WVL), three by Save the Children UK (SCUK) and two by African Humanitarian Action (AHA). Part of the hospital is also occupied by the Pakistani UNMIL battalion, who assist in rendering medical services to the community. There is one government doctor at the hospital, who is assisted by a gynecologist from St Luke's private clinic on an on-call basis. There is no proper pharmacy and only seven medicine stores to service the entire County.

### **Water and Sanitation**

Access to water and sanitation is totally inadequate to meet the rising demand, especially because Bomi is among the counties of highest return for displaced persons and refugees. The situation has contributed immensely to the poor health of the inhabitants of the County. NGOs operating in this sector include NRC, Peace Winds Japan, WVL and CCF. UNHCR through its Community Empowerment Projects have assisted with hand-pumps, wells and latrines, mostly in areas of high return.

### **Roads and Bridges**

The physical damage to roads and bridges, particularly following the rainy season, continues to limit the ability of humanitarian agencies to provide critical support, hinders the displaced/refugee return process and obstructs access to markets, thus impeding economic productivity and self-sufficiency. The problem is especially bad in the Suehn Mecca district. The Road Task Force has been instrumental in the assessment of about 30 farm-to-market (feeder) roads and has mobilized communities to rehabilitate these roads with WFP assistance. NGOs involved in road and bridge rehabilitation and construction include WVL, GAA and Peace Winds Japan.

There is currently a free flow of transportation between Monrovia and Tubmanburg due to the good condition of the road. Transportation to other parts of the County is often severely hampered by the bad road conditions. Taxis and other commercial transport are nearly always overloaded, posing a hazard to human life.

### **Education**

Currently there are 105 functioning schools, of which 95 are primary and 10 are secondary level. During

the war, some of these schools were burned to the ground, while others were looted and have only recently been rehabilitated. According to the County Education Officer (CEO), approximately 50% of primary schools have neither latrines nor safe drinking water.

**Environmental Issues**

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people’s access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

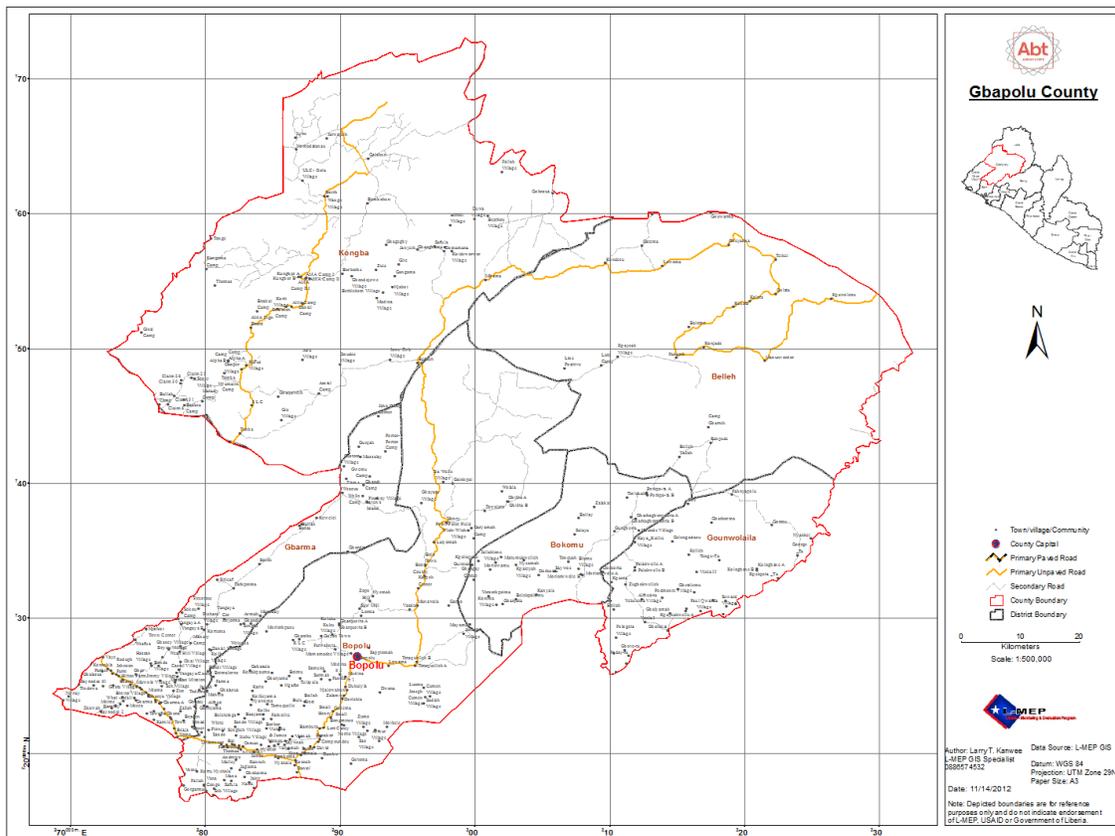
**Sensitive Sites**

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
<i>None</i>	<i>Lake Piso</i>	<i>None</i>	<i>None</i>	<i>None</i>

**Gbarpolu County**

Created in 2001 when it was split from Lofa County, Gbarpolu is the youngest county in Liberia. The county is bordered by Grand Cape Mount County to the west, Bomi County to the southwest, Bong County to the south, and Lofa County to the east and north. The northwest part of Gbarpolu borders the nation of Sierra Leone. As of the 2008 Census, it had a population of 83,338, making it the eleventh most populous county in Liberia. The majority of Gbarpolu County consists of forest. Mining was the primary economic activity prior to the Liberian Civil War, in addition to subsistence farming.

Figure 16: Gbarpolu County map



(map provided of L-MEP)

The County seat of Bopolu City is famous as the home and final resting place of King Sao Boso of the Kingdom of Suehn-Bopolu, who resolved the conflict between the settlers of the Mississippi Colonization Society and the natives, paving the way for their co-existence in the coastal areas. Bopolu also served as a stop along the route for the trans-Saharan trade. In spite of an illustrious history that far predates the arrival of the settlers from America, over the decades Bopolu and its environs slowly became an isolated and impoverished place. It was also one of the worst affected by the war, suffering extensive damage to infrastructure and basic services as well as mass displacements and loss of life.

### Districts

The districts of Gbarpolu County include (population):

- Belleh (15,257)
- Bokomu (9,557)
- Bopolu (17,719)
- Gbarma (15,851)
- Gounwolaila (11,512)
- Kongba (13,492)

### Demographics

Households in Gbarpolu County are said to have an average size of 5.49 persons, higher than the

national average of 5.6. The County's dependency ratio is 1.20. Households are headed primarily by men (91%), again higher than the national average of 87%. Elder-headed households account for some 8%, about the same as the national average.

The Kpelle form the majority ethnic group, with Belle and Gola making the next two largest groups. Kpelle and Gola are the main dialects spoken in the County.

### **Climate**

Like most of Liberia, Gbarpolu enjoys a tropical climate with a long rainy season between March and October. The average temperature is 28 degrees Celsius and the prevailing wind is from the Southwest.

### **Topography**

The County has two main mountain ranges, Kpo and Fanyea, and three main river systems, the Lofa and St. Paul that form the boundary with Lofa, Bong and Bomi counties, and the Mahe River. It has many large creeks and streams that are tributaries of these main rivers, and two large waterfalls: Goma and Zalakai.

### **Geology**

There are various mineral resources in Gbarpolu County; gold and diamonds are the most commonly exploited. Gold deposits are found in Henry's Town, Weasua, and Belekpalamu, while diamond deposits are found in Tarkpoima, Sirleaf Town, Smith Camp, and other sites. Iron ore has been discovered, and unconfirmed reports point to the existence of potentially valuable lead, manganese, silver, fluorite, graphite and copper deposits.

### **Vegetation**

Gbarpolu contains significant portions of the Upper Guinea Forest. Most of this forest is deciduous and mountain in nature, covering all three main forest classes: class 3.1– forest with small agricultural; class 3.2–open dense forest; and class 3.3–closed dense forest.

### **Institutional Structure**

Gbarpolu's relative newness as a County, its remoteness and its geographic isolation from the seat from which it was previously administered (Voinjama in Upper Lofa) led to a relative lack of administrative institutions being founded. The County has eleven (11) chiefdoms and twenty-seven (27) clans.

### **Natural Resources**

The County has a rich resource base, with significant amounts of timber, gold, diamonds and iron ore. Timber and mineral exploitation have played a significant role in the economic fortunes of Lower Lofa, and properly managed, these resources can be the prospective strategic drivers of the country's economic revitalization.

#### *Timber*

The forest provides many resources for the County. As a part of the forestry reform program, the Government of Liberia (GOL) cancelled all concession agreements across Liberia. Consequently, there exists no large skill or formal forestry activity in the County, though small-scale pit sawing is evident in many areas. Apart from logs, people depend on the forest for raffia and medicinal herbs, charcoal and fire wood. Despite the economic importance of the forest, it continues to be depleted by shifting cultivation and unregulated logging.

Gbarpolu forests are deeded forests, meaning that the communities are the outright owners of the land.

As this could have an impact on the exploitation of the forest reserves, the Forestry Development Authority has carried out a series of sensitization workshops on the New Forestry Law. Pit-sawing is having a negative impact on the potential yield from timber production. Most of the proceeds go to local chiefs who control the forests in their regions. There are also reports from FDA on illegal cross-border trade in timber and forest products from Kongba District. This has a negative impact on County's revenue and security. Other negative impacts are unregulated timber felling for charcoal and firewood, and slash & burn agriculture, which renders the forests ecologically unsustainable.

### *Mining*

Gold and diamonds are the most commonly exploited mineral resources in the County. Unregulated artisanal gold wells are present in Henry's Town, Weasua and Belekpalamu in Bopolu, Gbarma and Gou-Nwolala Districts, among others. There are also unregulated artisanal diamond mines in Tarkpoima, Sirleaf Town, Smith Camp, Ballah Camp and Weasua in Gbarma District; and Kumgbor, Camp Alpha, and Camp Kamara in Kongba District. The company American Mining Associates hopes to revive its diamond mining operations in Kumgbor, while the South African owned Mano River Resources Company has set up its diamond mining headquarters in Weasua. Two Liberian-owned mining companies with foreign backing, Liberty Gold Group of Companies and African Erica Resources Company, are hoping to establish gold mining in Henry Town, Bopolu District, and in Belle District. BHP-Billiton and Mittal Steel are exploring the possibility of establishing iron-ore mining operations in Gongbeya and Bondi-Mandingo Clan areas of Bopolu District.

### **Agriculture**

Agriculture, especially rice farming, is the chief occupation of locals in Gbarpolu. Households grow vegetables, eddoes, bananas, plantains, sweet potatoes and cassava as food crops. Rubber, oil palm, coffee, cocoa, and plantain/banana constitute the major cash crops of the County. Palm nuts are processed into the staple palm oil for sale and domestic consumption.

Two other important sources of income are hunting and fishing. About 63% of households were engaged in inland fishing in rivers, creeks and swamps in 2005.

### **Healthcare**

In spite of some recent advances, access to healthcare in the County is limited and the quality of care is generally low, as the infrastructure was devastated in the war. Many facilities are in need of upgrading and rehabilitation, and staffing with adequate qualified personnel is a chronic problem. The recently completed Chief Jallah Lone Health center is the only hospital in the County. The County Health Team operates the hospital and 11 clinics with the assistance of Africa Humanitarian Action (AHA) and Save the Children UK (SC-UK). Bopolu District hosts the hospital and has clinics in Henry's, Bamboo and Gbayarma Towns. There are clinics in Gbarma District in Gbarma, Yangaryah and Tarkpoima Towns, while in Kongba District the clinic is in Kumgbor Town; Belle District has the Badee clinic; Bokomu District a clinic in Gbangay; and Gou-Nwolala District has a newly opened clinic in Kpayeakwelleh.

### **Water and Sanitation**

Access to safe drinking water is very poor in all parts of Gbarpolu. The majority of inhabitants depend solely on creeks for drinking and household use, and are therefore susceptible to water-borne diseases. The sanitary condition is equally desperate, as there are few proper latrine facilities in most communities.

### Roads and Bridges

The road network in the County is also very poor, becoming extremely difficult to traverse in the rainy season. Road access to Fassama in Belle District is possible only during the dry season, and due to the condition of the bridges on the route. There is no road access to Bokomu or Gou-Nwolala. President Ellen Johnson-Sirleaf indicated during a visit to Bopolu and Belle Yalla this year that a road would be constructed from Bopolu to Belle Yalla during her administration, which would open up access to Belle and Bokomu Districts.

### Education

Like the health sector, the education sector in Gbarpolu was devastated by the civil crisis. Most schools were destroyed and are not yet fully functional. There is also a chronic lack of trained teachers. The Bopolu Central high school in Bopolu and Zuo Mission high school in Gbarma are the only senior high schools in the County. There are junior high schools in Gbarma and Belle Districts, and twenty-four elementary schools in Bopolu, nineteen in Gbarma, fourteen in Kongba, seventeen in Belle, sixteen in Bokomu and ten in Gou-Nwolala.

### Environmental Issues

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people's access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

### Sensitive Sites

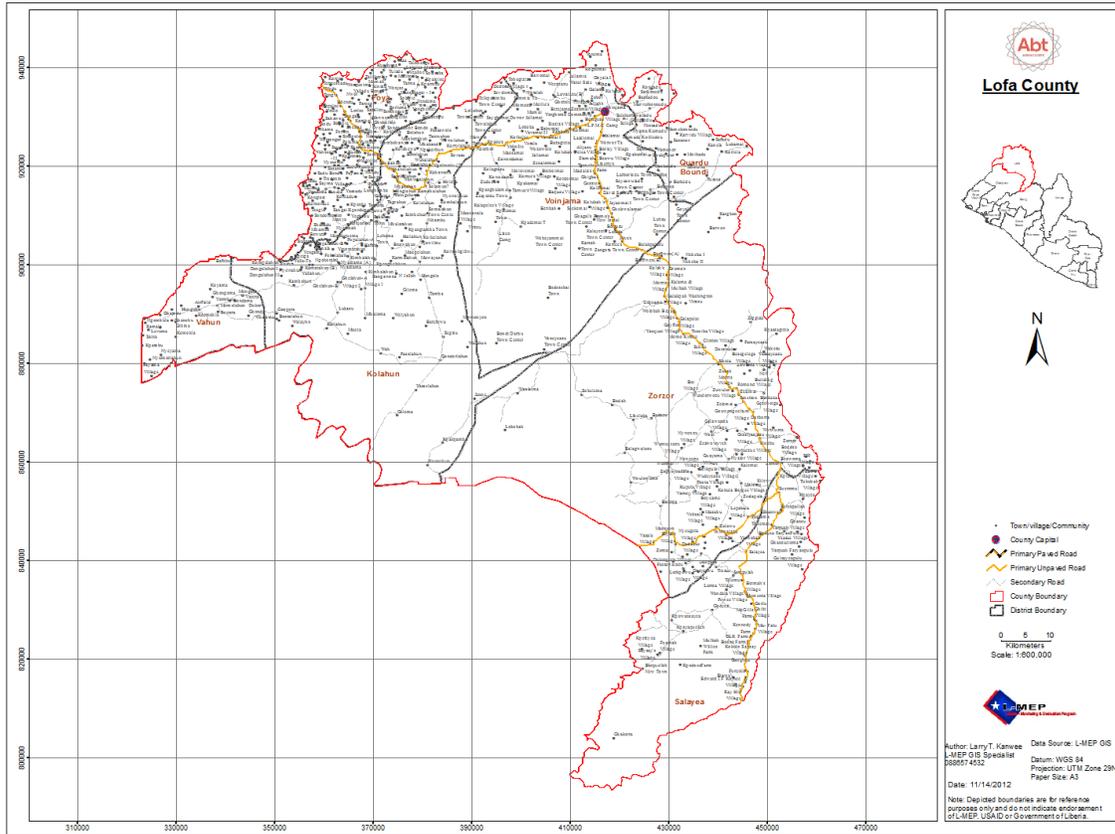
National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
Kpelle	Kpo Mountains	<i>Foya</i>	<i>None</i>	<i>None</i>
Yoma				

## **North Central Region**

### **Lofa County**

Lying in the northwestern corner of the country, Lofa County is now the second largest County in Liberia with an area of 9,982 square kilometres (3,854 sq mi). It is bounded on the east and the north by Guinea, on the west by Sierra Leone and on the south by Gbarpolu and Bong Counties. The largest city and county capital is Voinjama. Mount Wuteve, the highest mountain in Liberia, lies in the north-central part of the county. Before the war, Lofa was considered the "breadbasket" of Liberia as a result of its high level of food production, especially of rice, the national staple food.

Figure 17: Lofa map



(map provided of L-MEP)

### Districts

The districts of Lofa County include (population):

- Foya (73,312)
- Kolahun (60,557)
- Quardu Bondi (18,785)
- Salayea (23,578)
- Vahun (17,137)
- Voinjama (42,790)
- Zorzor (40,704)

### Demographics

At least six of Liberia's tribes (Lorma, Kissi, Gbondi, Mende, Mandingo and Kpelle) are resident in Lofa County. Traditional culture remains strong in Lofa with the Poro and Sande societies still playing a critical role in the education and initiation of boys and girls. The two largest tribes are the Lorma and Gbandi, which are largely Christian and Muslim respectively. The two coexisted peacefully prior the conflict, but current issues of land ownership, traditional practices and power sharing have led relations to deteriorate.

## **Climate**

The climate in Lofa County is tropical, hot and humid. Based on the prevailing precipitation, two seasons are differentiated. The rainy season lasts from mid- April to mid-October. The dry season begins in November and ends in April. The temperature normally ranges annually from 24C to 30C (75F to 85F). Data on winds in Lofa County is incomplete, but wind generally blows from the Northeast during the dry season and from the Southwest during the rainy season. The total wind mileage is greatest in the rainy season from July to September and lowest in the dry season during December and January.

Lofa County has an average rainfall of around 115 inches (2,900mm). Three principal types of rainfall can be distinguished. First, heavy downpours occur at the beginning and at the end of the rainy season. Second, longer periods of precipitation with less turbulence occur, covering larger areas. The intensity of this kind of rainfall is increased through the drop of temperature during the afternoon and the night hours. Third, "Relief Rains" are produced by the friction between the topography and air masses, which reach the county from the sea. Relief rains occur at mountain ranges and other relief features.

## **Topography**

The plateaus and mountain ranges lie behind rolling hills. Plateaus reach heights of up to 1000 ft-2000 ft (609.6 m) and mountain ranges are found up to 2000 ft. (600 m). Important ranges are the Wologisie, Wutivi and Wanigisi. The greatest width of this zone is 80 miles (130 km) between the Lofa and St. Paul Rivers. The belt of rolling hills parallel to the east zone has elevation in the order of 300ft (90 m). There are numerous hills, valleys and water courses in this zone.

## **Geology**

All three kinds of soil produced by different conditions of climate and vegetation in Liberia are found in Lofa: clay loam, sandy clay loam, and loam.

## **Vegetation**

Vegetation in Lofa is composed of tropical rain forest including high forest, broken forest and low bush. The type of forest most common to Lofa County is known as Moist Semi- Deciduous Forest. Some of the most common trees are the nesogordonia papaverifera, the limba (or terminalia superb), and the obechi (or triplochiton scleroxylon).

## **Institutional Structure**

Lofa County was for decades the largest county in Liberia, with eleven administrative districts and a population made up of at least eight of the sixteen major tribal groups in Liberia. While the presence of local government officials in Lofa County has gradually increased, in particular since the establishment of the new government in 2006, public sector capacity remains weak. The county's ministries and agencies are operating from temporary locations pending the rehabilitation of the County Administration building by GoL and USAID. The appointment of a superintendent in 2006 served as a catalyst for deployment of other ministry officials at the county and district levels.

## **Natural Resources**

Even though Lofa County still retains a good portion of its forest, there are no large-scale forestry activities presently taking place in the County. Forest-related activities are mostly limited to burning and sales of charcoal and firewood, and pit sawing. These activities combined constitute only 1% of total household income. Rubber is not produced or processed in Lofa County in significant quantities, unlike in Margibi, Sinoe, Bong and Nimba Counties. Timber and mining do not feature in the County's economy

but have high potential. The Wologisie Mountain has not yet been exploited for minerals, but potential exists. Deposits of iron ore, gold, diamonds and other minerals are mined only illegally in Lofa, and the authorities lack the resources to control the problem. Some international companies including BHP Billiton have been assessing the mining possibilities in Lofa, which could lead to a major concession and significant investment and jobs creation.

### **Agriculture**

70% of Lofa's population is engaged in agriculture. In the 1980s, it was widely believed that Lofa County alone could provide enough food for the entire country. Today, Lofa has the highest number of food insecure people in Liberia, with 70% having poor or borderline food consumption levels according to the Comprehensive Food Security and Nutrition Survey conducted by the Government. Last year, Lofa produced its first proper harvest since the end of the war. The County Agriculture Office has indicated that food production will double this year in comparison to the previous year, based on county-wide farm inspections. The main crops cultivated in 2005 included cassava, rice, sweet potatoes/eddoes, plantain/banana, corn, other vegetables (14%) and pulses (11%).

Lofa County's history of producing enough to export can now be realized again with strong support from the Government and other investors. The gradual shifting from traditional farming to mid-scale mechanized agriculture is critical to the creation of a sustainable economy for the County. The Foya and LISCO areas have over twenty thousand (20,000) acres of previously mechanized rice cultivation lands that can be reactivated to boost the national rice supply and reduce reliance on imports.

#### *Food Crops*

The chief food crops in Lofa County are rice and cassava. Rice was cultivated by 95% of households in 2005 while 17 % of households cultivated cassava. Vegetable cultivation was put at 17% during this same period, while pulses were cultivated by 11% of households. Sweet potatoes, plantain/banana were cultivated by 6% of households while corn was grown by 7% and groundnuts by 1% of households.

#### *Cash Crops*

In 2005, some 37% of households produced crops for cash. Of those households, coffee and cocoa are produced by 53% and 82% respectively. Other important cash crops included plantain/banana (produced by 12% of households), palm/nuts oil (10%), Cola nuts (5%), pineapple (3%) and rubber (1%). The palm nuts and palm kernel are processed into oil and sold mostly in neighboring Guinea and in Monrovia.

### **Fisheries**

Lofa is a landlocked county and all fishing is fresh-water. Fishing is not now conducted on a commercial basis, though fisher folks do carry their surplus catch to market to supplement the community fish protein requirement. There is potential to develop the fresh-water fishing business for riverside communities, and the availability of abundant swamp lowland can also be exploited to develop commercial fish, shrimp, and frog farming.

### **Healthcare**

The Ministry of Health through the County Health Team coordinates management and provision of health services, flanked by WHO and UNICEF with major support from INGOs. During the war, all 53 of Lofa's health facilities (4 hospitals, 6 health centers and 41 clinics) were destroyed. 49 of these facilities have been rehabilitated and are currently managed mainly by international organizations. Progress in health service coverage and quality has been made but the capacity of the Government to take over

management of the clinics is still limited. The need for qualified medical staff cannot be understated, especially as international actors are scaling down their operations. Swiss Development Cooperation (SDC) has reconstructed Lofa's main referral hospital, in Voinjama. According to a MOU signed between SDC and the government, the hospital will be run by International Medical Corps (IMC) and the County Health Team for two years. Within this time, IMC plans to extend the capacity of the hospital from the present 50 beds to 150 beds. The hospital will open in April 2008.

### **Water and Sanitation**

Boreholes with pumps, unprotected wells and creeks are the main sources of drinking water for the people of Lofa County. Improving access to reliable water sources is a key activity of many international organizations. There are an estimated 800 water points (the majority of which are unprotected and unusable during the dry season) and 500 proper latrines in the County. Efforts to ensure the sustainability of existing water points have been made, including the establishment of Community Water Committees (CWC) with the help of INGOs. These CWCs have responsibility for making minor repairs, carrying out hygiene promotion events and taking overall care of water pumps. LRRRC is currently steering the coordination efforts of the WATSAN sector, and the Ministry of Public Works will increasingly take over this responsibility.

### **Roads and Bridges**

There is a lack of good primary and feeder roads in Lofa, and the existing roads are in disrepair.

### **Education**

Educational services in Lofa rely heavily on external support. The County Education Office, in cooperation with UNICEF, coordinates sector support activities. These include emergency school feeding programs; renovation of schools; provision of furniture, stationery and textbooks; and strengthening the managerial capacity of the Ministry. By the end of May 2007, there were 297 schools in Lofa County registered with the Ministry of Education, with a total enrolment of 48,164.

With a rapidly growing school-going population, Lofa faces a shortage of trained and qualified teachers. As a result, the student-to-teacher ratio is unfavorably skewed, resulting in a poor quality of service to the student. Rehabilitation of the Zorzor Teacher Training Institute has been pledged by USAID, while the Japanese government will fund rehabilitation of the Voinjama Multilateral High School. School feeding with support from WFP is ongoing in 172 schools.

### **Environmental Issues**

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people's access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty-environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

### **Sensitive Sites**

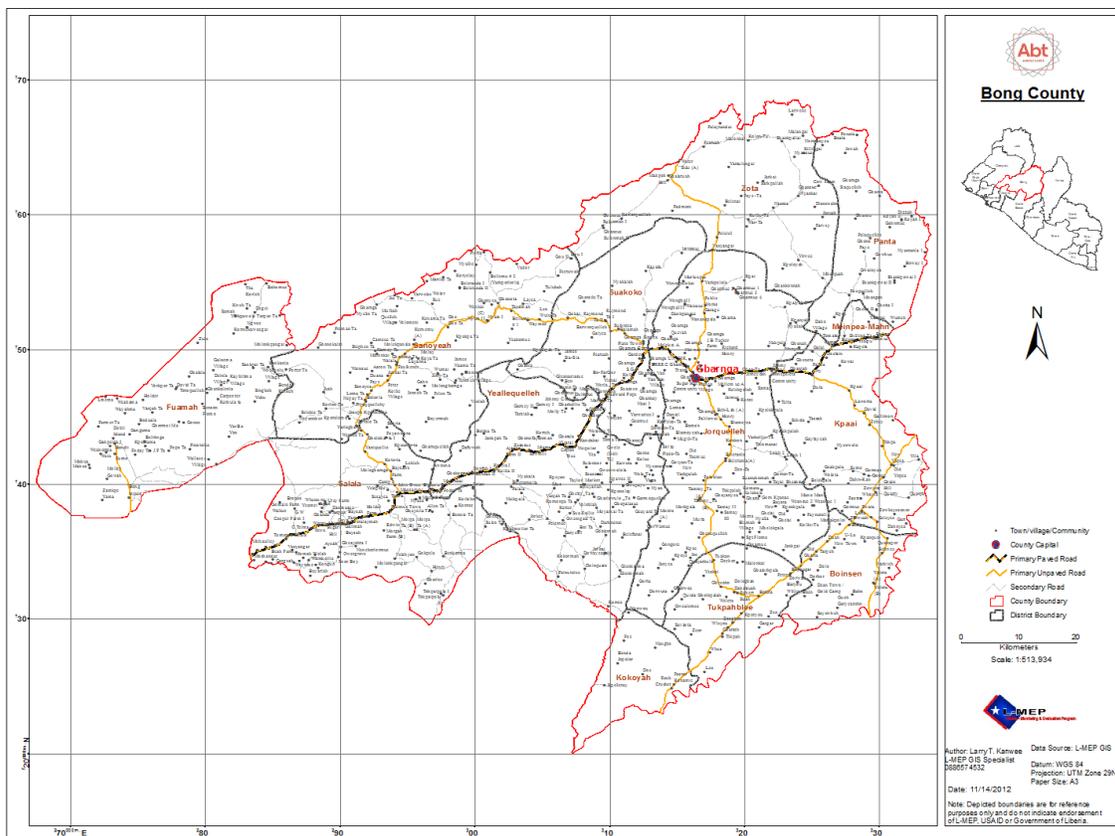
National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
North Lorma	Wenegri Forest	Foya	<i>None</i>	Wenegizi Mountains
South Lorma	Wologizi Mountains			Wologizi Mountains

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
				Lofa-Mano

## Bong County

Bong is a county in the north-central portion of the West African nation of Liberia on the main paved road that runs from Monrovia to Sanniquellie in Nimba County. Bong County has the third largest county population in Liberia and is the third largest County in terms of area. Gbarnga serves as the capital with the area of the county measuring 8,772 square kilometers (3,387 sq mi). As of the 2008 Census, it had a population of 333,481, making it the third most populous county in Liberia.

Figure 18: Bong County map



(map provided of L-MEP)

Named after Mount Bong in the southern portion of the county, it is bordered by Lofa and Gbarpolu counties to the north, Margibi and Montserrado counties to the west, Grand Bassa County to the south, and Nimba County to the east. The St. Paul River is on the southwest of Bong County and forms a boundary between the county and Bomi & Gbarpolu counties. Bong County has an international border with the Republic of Guinea in the north.

Before the war, Bong County enjoyed a vibrant socio-economic life, attracting the most investment in the country. Bong County is still one of the richest in Liberia, boasting natural resources such as gold, diamonds, iron ore and timber.

### **Districts**

Bong County has twelve districts (2008 population):

- Boinsen District (8,210)
- Fuamah District (28,823)
- Jorquelleh District (79,129)
- Kokoyah District (3,702)
- Kpaai District (25,949)
- Panta District (16,473)
- Salala District (43,617)
- Sanoyeah District (30,330)
- Suakoko District (29,180)
- Tukpahblee (11,731)
- Yeallequellah (36,097)
- Zota District (20,240)

### **Demographics**

Traditionally, at certain times in the year, especially during the rains, people have moved in search of alternative sources of income, especially to the rubber plantations. The population is now thought to be decreasingly transient in nature.

Males are estimated at 40 percent, females 51 percent, about 46 percent of females are the children bearing age (15-49 years), fertilities rate of 6.7, children under five years is 15 percent. The County's dependency ratio is 1.41 according to the Information Management Office of Bong County (IMO), making it higher than Liberia as a whole, which has a ratio 1.37. Families or households in the County are generally headed by males at a rate slightly higher than the national average; the sex of household head is estimated at 84% male and 16% female, while the national figures are 87% and 13%. The percentage of elder-headed households in the County is the same as the national percentage, at 8%.

Ethnic groups found in Bong County include all of Liberia's 16 tribes. The Kpelle people represent the largest tribal block in the County, and members of many tribes speak the Kpelle language as a result. All of the tribes have over the years been interlinked mostly through marriage.

### **Climate**

The climate of Bong County is tropical, hot and humid. The temperature generally ranges from 65F to 85F. Based on the prevailing precipitation, two seasons are differentiated: rainy and dry. The rainy season lasts from mid-April to mid-October. The dry season begins in November and ends in April. However, with the planet experiencing climate change, a slight fluctuation in the timing of the seasons has been noticed.

Generally the wind blows from the Northeast during the dry season and from the Southwest during the rainy season. Wind mileage is normally greatest in the rainy season, sometimes bringing violent storms capable of destroying houses and crops.

Bong County has a conventional type of rainfall of around 70 to 80 inches. Toward the interior, the rainfall decreases because the air loses moisture except for high areas where the air forces rise causing some relief rain.

### **Topography**

The County is said to be well watered by six principal rivers and a number of small streams. The St. John River runs through Bong County and rises in Guinea where it is known as Mano River, north-west of the Nimba Mountains. The Mano River receives much water from Naye River, the Zoi and Yja Creeks.

### **Geology**

The soils of Bong County are mostly latosols, which occur on undulating and rolling land and occupies about 18% of the total land area in Liberia. This soil is heavily leached and silica nutrients and humus are readily washed out.

### **Vegetation**

Bong County is part of the high forest belt, which can be divided into an evergreen rain forest zone and the moist semi-deciduous forest zone. The evergreen forest receives an annual rainfall of 80 inches and consists of species that do not have a marked period of leaf fall. The tallest trees reach 200 feet.

The semi-deciduous forest is a transition to the deciduous forest type found in the Ivory Coast. The long dry season (4.5 – 5.5 months) forces many species to drop their leaves during part of this period to minimize evaporation. The occurrence of this vegetation in Bong County is based on soil conditions.

### **Administrative Structure**

The Superintendent of Bong County is the administrative head of the county and represents the Office of the President of Liberia in the county. The superintendent is assisted by an Assistant Superintendent for Development, who is responsible for coordination of development activities in the county including the formulation of the five-year county development agenda. There is a Superintendent Council, headed by the Superintendent that serves as an advisory council.

### **Institutional Structure**

The County Superintendent heads the County Administrative Unit, while the District Commissioners head the districts. At the community level, the Paramount Chiefs head the chiefdoms, Clan Chiefs head the clans, and Town Chiefs head the towns.

Community members elect the clan, town and paramount chiefs. The political subdivisions are created by the acts of the National Legislature. Currently representing the county administrative leadership are the positions of Superintendent, Assistant Superintendent for Development, County Administrative Assistant, Special Assistant to the Superintendent, County Inspector, Agriculture Commissioner, Project Planner and City Mayor. These officials are supported by representatives of various national Ministries and Agencies deployed in the county.

The County is divided into several political sub-divisions: one statutory district, twelve districts, thirteen chiefdoms, forty-two clans and twenty-seven cities.

### **Natural Resources**

Bong County has significant deposits of iron ore, diamonds, and gold, large stands of commercially

valuable timber and ideal conditions for rubber tree cultivation.

### *Tree Crops*

In pre-war times, farmers in Bong County always depended on cash crops for their livelihoods, to an even greater extent than food crops. The most commonly grown cash crops in the county are tree crops such as rubber, cocoa, coffee and palm oil. Like all other agricultural activities, the production of these crops ground nearly to a halt during the national crisis, and while the potential for growth is great, many farms are in dire need of rehabilitation.

There is one national forest in Bong County, the Lorma National Forest consisting of 43,405 hectares, where logging is allowed.

### *Mining*

Bong County has three alluvial diamond and gold mining areas with sizeable deposits: Wainsue, Jorpulu Clan, Jorquelleh District (gold), Totota, Salala District (diamonds and gold), and Kokoyah, Kokoyah Statutory District (gold). While the extraction of iron ore ceased with the departure of the Bong Mining Company during the war, there are still thought to be huge deposits of iron ore along the Bong Mines Belt in Fuamah District.

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### **Fisheries**

Many rivers, streams and fish ponds existing in the County serve as a main source of fish for domestic consumption. The local fish production is supplemented by fish from the ocean and sold on the local markets. There is no sign of large scale or industrial fishery. Aquaculture was formally introduced in the early 1950s in Bong County with the training of fish farmers. The Central Agriculture Research Institute (CARI) in Suakoko District has been in the vanguard of aquaculture development, constructing demonstration ponds and breeding and supplying local indigenous fingerlings such as tilapia and claria to local fish farmers. The industry is just being resuscitated following its complete destruction during the civil crisis.

### **Agriculture**

Bong County is situated in the Mountain and Plateau zones, where citizens traditionally grow rice, cassava, maize, oil palm, cocoa, coffee, rubber and sugar cane. Citrus and cereal crops are also cultivated in the County. Other sources of food are plantain, banana and fruits, which more or less grow in the wild.

In the area of livestock production, Bong County has large and small ruminants, pigs, rabbits, guinea pigs, chickens, ducks and guinea fowl, mostly raised on the domestic scale. The production of livestock has never been properly prioritized as compared to crops.

There are two agricultural systems in Bong County: communal farming and Kuus. Communal farming is like a cooperative system in which communities are engaged in large farm production in the town or village, and after harvest the proceeds are used for development upon agreement from the community either to build clinic, pit latrines or wells. Kuu is the system where farmers organize themselves into

groups of from seven up to twenty-two members, whereby each member of the group will be given a special time to go and work on his or her farm as a rotational procedure of the group. In this system, farmers find it very rewarding to carry on their work fast and on time. In this light, the government encourages farmers to be certified so as to protect and guarantee their kuus against any form of embarrassment. This practice is carried on across the length and breadth of the county.

### **Health Indicators**

As in the education sector, much has improved in health care delivery since the end of the war, but enormous gaps remain in both access and quality of care. No formal system of health administration has been established in Bong County. Health services are mainly provided in Gbarnga at Phebe Hospital with funding from the Lutheran Church and the Government of Liberia. Bong Mines Hospital in Fuamah District is run by the County Health Team. Thirty-three clinics are spread over the county, out of which 26 are supported by international NGOs. Phebe Hospital, being the major referral hospital in the County, provides VCT services and blood bank facilities. The only functioning x-ray machine resides at the UN BANBATT Level II Hospital. Many international NGOs collaborate with CBOs and the Government to carry out health related promotions and provide limited services, including GBV prevention and response, sexual and reproductive health education and referrals, and life skills education including hygiene and water safety, and awareness around HIV and AIDS and lassa fever.

### **Urban Water and Sanitation**

According to a recent UNICEF survey, water for domestic use comes mainly from unprotected sources (65%), yet only 35% of households purify their water before consuming it. Although 45% of households indicated that they use toilets, only 15% use ventilated improved pit (VIP) latrines or flush toilets. The rest use traditional toilets: open field or bush. Gbarnga City does not have a pipe-borne water supply system. Hand pumps exist, though not in great enough numbers to serve the city and the districts, and many are non-functional. In general, proper water and sanitation measures are not taken by locals.

### **Road and Bridges**

Bong County has a complex network of about 25 roads that connect the districts, towns and cities. The deplorable condition of these roads impedes the free movement of persons, goods and services, and this problem is seen by the majority of Bong County residents as the major impediment to development. Some roads are undergoing rehabilitation financed by donors such as EU, while others are maintained by the communities themselves through WFP/FFW projects. Engineers from the Bangladeshi UN peacekeeping battalion (BANBATT) have graciously undertaken the periodic rehabilitation of the unpaved main highways connecting Bong with Lofa, Nimba and Margibi Counties, but the roads quickly deteriorate in the six-month annual rainy season.

### **Water and Sanitation**

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### **Education**

Most of the school buildings in the County were damaged or destroyed in the war, and while there has

been significant progress made in recent years, the education students. A total of 800 teachers are deployed to these schools. There are also a number of private schools operating in the County, which provide employment for some 1,220 citizens. Cuttington University and Phebe School of Professional Nursing provide the only tertiary education in the County. In order to adequately respond to the ever growing educational needs, the CDA process calls for the construction or rehabilitation of 83 elementary schools, 6 high schools and 2 teacher training institutes.

**Environmental Issues**

The people of Bong County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people’s access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

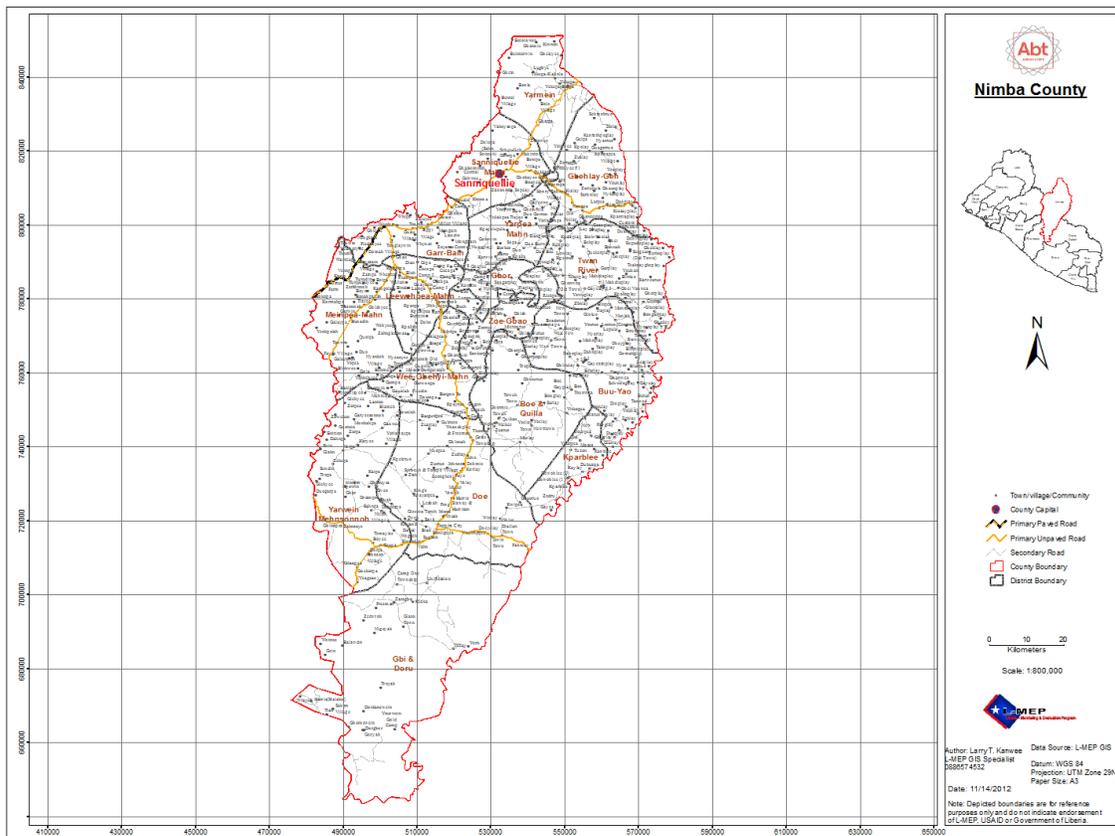
**Sensitive Sites**

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
<i>None</i>	<i>None</i>	Bong Mountain	Kpatawee Wetlands	<i>None</i>

**Nimba County**

Nimba is a county in the north-central portion of the West African nation of Liberia. Sanniquellie serves as the capital with the area of the county measuring 11,551 square kilometres (4,460 sq mi), the largest in the nation. As of the 2008 Census, it had a population of 462,026, making it the second most populous county in Liberia.

Figure 19: Nimba County map



(map provided of L-MEP)

Named after Neimbaa Tohn Mountain, the tallest mountain in the county, Nimba is bordered by Bong and Grand Bassa counties to the west, Rivercess County to the southwest, and Grand Gedeh County to the southeast. The northern and northeastern parts of Nimba borders the nation of Guinea, while the northeast lies along the border of Côte d'Ivoire. Nimba has been one of Liberia's most significant historical regions and is the second most important County in terms of population and politics. The County was deeply negatively affected by the civil war. Most of its people were forced to flee, thereby disrupting their livelihood. Its basic infrastructure including roads, schools, and health facilities remain in poor condition despite the efforts of local communities, the Government of Liberia, UN agencies, EU, NGOs and private investors to revive the economy and restore basic services.

### Districts

The districts of Nimba County include (population):

- Boe & Quilla District (18,262)
- Buu-Yao District (40,007)
- Doe District (35,918)
- Garr Bain District (61,225)
- Gbehlageh (Gbehlageh-Geh) District (32,176)
- Gbi & Doru District (8,131)
- Gbor District (10,875)
- Kparblee District (11,424)

- Leewehpea-Mahn District (24,747)
- Meinpea-Mahn District (24,157)
- Sanniquellie-Mahn District (25,370)
- Twan River District (37,479)
- Wee-Gbehy-Mahn District (32,934)
- Yarmein District (22,718)
- Yarpea Mahn District (21,647)
- Yarwein Mehnsosnoh District (25,584)
- Zoe-Gbao District (29,372)
- Saclepea District
- Tappita District
- Zoegeh District

### **Demographics**

The population is mostly young. According to the 2005 voter statistics as provided in the County Information Pack, 121,844 or 64% of a total of 190,264 registered voters were between the ages of 18-39. Gender distribution is fairly close: 46.37% female and 53.72% male. More than half of the females are within the child bearing ages of 14 to 49 years, giving rise to high fertility rates in the County.

All of Liberia's sixteen (16) ethnic groups are found in Nimba, but five of the ethnic groups are represented in higher numbers: the Gio, Mano, Krahn, Gbi and Mandingo. Of the five, the Gio and Mano are the predominant ethnic groups and are members of the Mende Fu language group, one of four language groups in Liberia. Over the years, the tribal groups of the County have been interlinked through marriage.

### **Climate**

Nimba has a tropical climate. There are two seasons: wet and dry. According to the New Geography of Liberia, average rainfall in Nimba is recorded between 12.5 – 25mm in January; between 100-150mm in the West and 150-200mm in the North, East and South of the County in April; and in October average rainfall is recorded between 200-250mm in the south-eastern portion and 250-300mm in the northwestern portion. Prevailing wind is generally south-easterly or monsoonal.

### **Topography**

There are three principal topographic areas: the northern part of the County is dominated by mountains, hills and deep valleys. Prominent among the mountains is Mount Nimba. The highlands of Nimba form part of the Bleetro-Nimba Block in the Central Region of Liberia, one of three large mountain blocks of Liberia, the other two being the Kpo-Wologisi Block in the western region and the Tienpo-Putu Block in the Eastern region. The Northern Highlands of Liberia are primarily found in Nimba and Lofa counties and form part of the Guinea Highlands also known as the Futa Jallon Mountains. Two relief features are characteristics of this region: long ranges and domed-shaped hills. The Nimba Range rises north of Sanniquellie and after twenty miles extends into the Republic of Guinea, where it reaches an altitude of 6,083 feet.

The so-called 'Guest House Hill' in the Yekepa area is the highest point of the Nimba Range on the Liberian side, and at the same time the highest elevation in Liberia, with an altitude of 4,540 feet above sea level. The south of the County is dominated by plains.

Nimba has four major rivers. St. John is the largest, forming the natural boundary between Liberia and Guinea in its upper stretch. It also internally separates Nimba and Bong counties. The Yah River also has

its source from Mount Nimba and flows centrally through the County from north to south-west in a stretch of 200km. The Cestos River (also known as the Nooh River) has its source, too, in the Eastern part of Mount Nimba. The Cestos River constitutes the natural boundary between Liberia and Cote d'Ivoire in the East. It has a stretch of over 300km and also borders Nimba with Grand Geddeh County. Other rivers in the County are the Twah River, Bee River and Weh River. Nimba County contains one artificial lake, Lake Teeleh in Sanniquellie City, which is 200m long and 120m wide.

### **Geology**

All three kinds of soil produced by different conditions of climate and vegetation in Liberia are found in Nimba: lateritic soil or latosols or upland soil, clay or swamp soil, and sandy soil. Generally, lateritic soils cover about 75% of Liberia according to W E. Reed. They are the most typical soils of the humid tropics, where there are alternating wet and dry seasons. This soil type is predominant in Nimba. According to soil scientists, latosols have only 0.24% nitrogen (plant food) and are very acidic. Their continuous farming requires the constant use of fertilizers, an input that nearly all farming households are too poor to afford, and this may explain the situation of annual bush fallowing by subsistence farmers in the County. Nevertheless, latosols are more productive than the other soil types and they provide valuable material for road building due to their hardness.

### **Vegetation**

Nimba's natural vegetation is composed of tropical rainforest, specifically high forest, broken forest and low bush. As in the other northern counties of Liberia the most prominent forest type is moist semi-deciduous. Trees of this forest type are the nesogordonia papaverifera, limba (*terminalia superba*), and obechi (*triplochiton scleroxylon*). Low bush establishes itself in the areas of land rotation where trees are cut and burnt as a result of the shifting or bush fallowing method of farming. Typical trees of this vegetation type are the umbrella or corkwood tree (*mussanga cecropioides*) and the oil palm. Swamps are common in the County, and there is a small portion of the vegetation covered with scattered trees and dense elephant grass (*pennisetum purpureum*). There are, however no natural grass fields except those created by human activities through farming, habitation or the development of football fields. The original vegetation of the County would have consisted of tropical rainforest, which was cut down primarily for farming purposes and the cultivation of other cash crops such as cocoa, coffee, oil palm and rubber. The land abandoned after farming is occupied by elephant grass that slows the regeneration of forest trees.

### **Institutional Structure**

Sanniquellie is the seat of the County administration. The County has sixteen administrative districts, one county district, five statutory districts and seven electoral districts, each with newly-elected representatives to the Nation Legislature. At the level of the Liberia Senate, the County has a senior and junior senator. The County administration is headed by a Superintendent and has representatives from key line ministries. Districts are headed by District Commissioners. Traditional authority is vested the chiefs and a council of elders, representing various tribal identities in the County.

The County leadership consists of two lines of authority. One consists of the office of the Superintendent and staff including the Assistant Superintendent for Development, County Inspector, Administrative Assistant, Land Commissioner, Agricultural Coordinator, Development Engineer, Project Planner, Political and Liaison Officer, Protocol and Information officers. The County Superintendent, the Assistance Superintendent for Development, the Statutory District Superintendents, County District, District and Township Commissioners are appointed by the President of Liberia. Districts are headed by commissioners, also appointed by the President.

Township commissioners are also appointed by the President. The municipal corporations are led by city mayors who are popularly elected. The next line of authority consists of customary traditional leaders headed by paramount chiefs followed by line of general and clan chiefs. These are elected by their people.

## **Natural Resources**

### *Mining*

While the exploitation of mineral resources was an important source of revenue and jobs in the past, it is today limited to illicit and unorganized artisanal mining of gold and diamonds. However, ArcelorMittal has contracted exploitation of the iron ore mine located at Yekepa in the northern tip of Nimba, along the boundary with Guinea and Cote d'Ivoire. The 270km railroad connecting the mining area with the Port of Buchanan is currently functioning. Diamonds are mined in the area between Sanniquellie and Yekepa, some part of Gbehlay-Geh, along the bank of Yar River ranging from Zor Gowee to Yarsonnoh, and in Zoe-Geh District. Gold is found in the Tappita area and other areas.

### *Timber*

Nimba County hosts many tree species that produce precious timber, formerly one the important sources of employment and income to the people. Timber exploitation was halted with the sanctions imposed by the UN Security Council, and the Government of Liberia cancelled all concession agreements for timber. Nimba County's tropical forest is threatened with indiscriminate exploitation of forest products either for export or for domestic use, extinction of rare species of trees, shifting or nomadic cultivation that leads to the destruction of the forest.

## **Agriculture**

Subsistence farming is currently the main source of income of the people of Nimba. Apart from small agricultural projects undertaken by some youth and women's associations, NGOs such as LCIP and ARS, there is not yet any large-scale farming in the County. The typical farming pattern is slash-and-burn and annual bush fallowing. The main food products are rice, cassava, plantain, banana, yam, and sweet potatoes. Some 75% of farm produce is used for family consumption.

Cash crop production of rubber trees, cocoa, sugar cane and coffee is the other main source of income in the County. The cultivation of 13,500 hectares of tree crops will eventually lead to economic growth through sale of products, value addition and job creation.

## **Healthcare**

Access to quality healthcare in Nimba is lacking for many residents. There are currently 41 functioning clinics, which is the same as in pre-war times. There are 526 MoH-assigned health workers serving at these facilities. Nurse aids constitute 21.2% of all health workers in the County, followed by registered nurses (17%), and trained traditional midwives (13%). Doctors make up only 0.9% of health workers in the County.

The hospital at Yekepa, built by LAMCO, is now being run by Arcelor-Mittal. In Sanniquellie, the Ministry of Health and MSF Holland are cooperating to run a hospital and a set of health posts which provide access to basic care. At Ganta, the Methodist Church runs a private hospital. At Saclepea, MSF Switzerland runs a temporary comprehensive health center and is building a permanent one to move into during 2007. MSF Switzerland also operates three health posts at Lepula, Diallah, and Zekepa (all in

southern Nimba). There are other small clinics and health posts operated by NGOs like MERCI and Africare. Presently, Equip-Liberia is running two health centres in Kparblee District one is in Zodru while the other is in Yourpea New Town. Also a private clinic is being run by one Thomas Saulgaie in Kparblee Town. This clinic has about eighteen bed rooms.

Much of the population has access to traditional healers and to unregulated, privately operated pharmacies. The healers are using herbs of unknown efficacy, and the pharmacies are selling chloroquine, a drug which is known to be ineffective against the majority of malaria cases seen in Nimba.

**Water and Sanitation**

Access to acceptable level of sanitation and safe drinking water sources is poor. A more efficient water system is needed in the six of the major cities: Sanniquellie, Ganta, Saclepea, Tappita, Karnplay and Bahn.

**Roads and Bridges**

Access to market and basic social services is challenged by the deplorable conditions of roads throughout the County. All internal roads are laterite roads. With less than 25km of paved road, investment in road construction and maintenance remains urgent. All seventeen districts ranked road construction or rehabilitation as their top priority. Fifty-one roads and bridges throughout the districts have been prioritized by citizens for construction or rehabilitation. The railroad from Yekepa to Buchanan was rehabilitated by ArcelorMittal under the new mining agreement between GoL and the company.

**Education**

There are 554 schools for a student population of 145,272 (53% male and 47% female). There are 34 upper secondary schools and no formal multilateral/vocational/ college/university level institutions in the County. There are 4,114 school teachers of which only 1,311 have been reactivated.

**Environmental Issues**

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people’s access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets.

**Sensitive Sites**

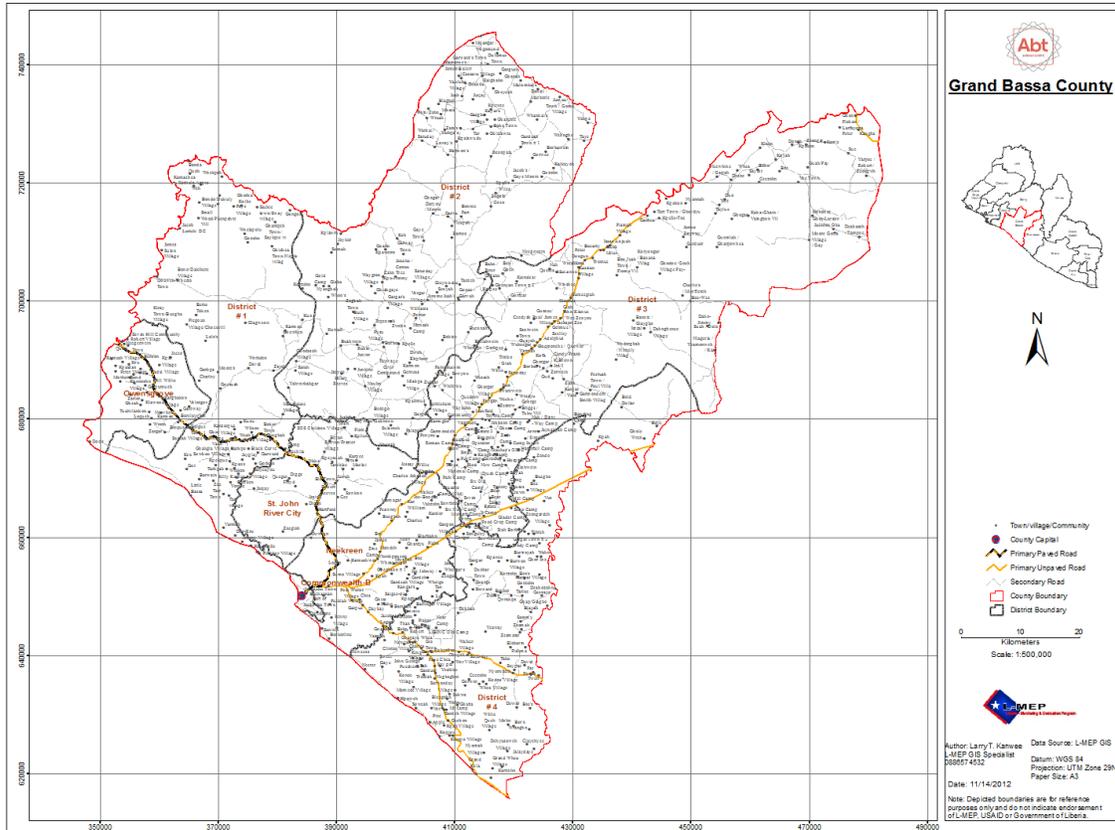
National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
Gbi	West Nimba		Gbedin Wetlands	Nimba Mountains
Gio	East Nimba Nature Preserve			
East Nimba				
West Nimba				
Krahn-Bass				

## South Central Region

### Grand Bassa County

Grand Bassa County is located on the Southwest of the country and is bordered by the Atlantic Ocean to the west and four counties: Margibi on the Northwest, Bong on the North, Nimba on the East, and River Cess on the Southeast. The total land area the County is approximately 3,382 square miles (8,759 square kilometers).

Figure 20: Grand Bassa County map



(map provided of L-MEP)

Grand Bassa County is one of the three original counties, along with Montserrado and Sinoe, that first formed the Republic of Liberia. It was established in 1833 and its capital is Buchanan City, named for Thomas Buchanan, an American who served as the first Governor of the Commonwealth of Liberia. As of the 2008 Census, it had a population of 221,693, making it the fifth most populous county in Liberia.

Among the county's notable residents were Joseph James Cheeseman and Anthony Gardiner, presidents of Liberia during the 19th century. The port of Buchanan was constructed by LAMCO to serve the export of iron ore carried through the railway from Nimba. The civil war destroyed the port, railway and the township. In 2005, LAMCO's facilities were taken over by Arcelor-Mittal (AM), which has begun a gradual reconstruction. The once bustling port is now a ghost town.

Before the war, the County enjoyed a vibrant economy. International companies such as the Liberian

American Mining Company (LAMCO)/Liberian Mining Company (LIMINCO), the rubber plantation of the Liberian Agricultural Company (LAC), the palm oil plantation Liberian Incorporated (LIBINC), the logging concerns Oriental Timber Company (OTC) and National Milling Company all had operations in the County, and the harbor of Buchanan, Liberia's second largest port, was very active. The civil conflict had disastrous consequences on all these activities, which virtually came to a halt.

### **Districts**

The districts of Gran Bassa County include (population):

- Commonwealth (34,893)
- District #1 (24,612)
- District #2 (25,722)
- District #3 (49,525)
- District #4 (30,454)
- Neekreen (32,563)
- Owensgove (13,914)
- St. John River City (10,010)

### **Demographics**

The average household size has been measured at 4.8 persons, quite small comparing with other counties in southeastern Liberia. The County has a dependency ratio of 1.33, lower than the national dependency ratio of 1.37. As in the rest of Liberia, households are overwhelmingly male-dominated, at 87%.

Bassa-speaking people are in the majority, making up 94% of the County's population. Other ethnic groups in the County include the Kpelle (5%), and the Kissi (1%), and small numbers of other groups. The Kru, often originating from neighboring Sinoe County, and Fanti fishermen and traders are also a part of the population. Traditional culture remains strong, with the Poro and Sande societies playing a major role in the education and initiation of boys and girls.

### **Climate**

The climate is tropical, hot and humid; Bassa is among the wettest counties of Liberia with an annual average rainfall of about 400 mm per year. Based on the prevailing precipitation, two seasons are differentiated – rainy and dry. The rainy season lasts from late April to October. The dry season begins in November and ends in April.

### **Topography**

Grand Bassa has a flat coastline. A narrow coastal plain extends inland from the seashore, and the land gradually rises to the hilly hinterland of the County. High elevation regions have forest of evergreen and deciduous trees, including ironwood and mahogany. The County has several major rivers. These are St. John, Farmingtohn, Merchin, New Cess, Ilor, Timbo, and Benson River. Consequently, the shore is broken by estuaries, tidal creeks, and rocky capes. The coastal region does not rise more than 60 to 70 meters, excepting occasional small hills. This situation makes several settlements near the sea—including Buchanan City—vulnerable to inundation and erosion. Moreover, Benson River and Merclin River overflow the banks in some areas during the rainy season. As a result, many villages remain inaccessible during certain periods of the year due to the deteriorated roads.

### **Geology**

The County's soils can be categorized as laterite (55%), which is leached out, alluvial (19%) and sandy

and loamy (26%). Alluvial soil is prevalent in the leeward districts. Two onshore sediment-filled basins are located along the coastline: Roberts Basin, which is filled with sediments of the Farmington River formation and Paynesville sandstone; and the Bassa Basin, which is filled with material from the St. John River formation.

### **Vegetation**

The County is generally covered by green forest, but there is also savanna. The territory not covered by the forest is used for farming using traditional methods. Rubber trees and palms are also planted in the concession areas and on small private farms

### **Institutional Structure**

The office of the County Superintendent, nine District Commissioners and a battery of line ministry officials were appointed by the new Government in 2006 and are deployed in their duty stations. The five Statutory District Superintendents and the staff of their offices that were appointed by the National Transitional Government of Liberia (NTGL) have still to be confirmed in their posts pending the comprehensive reform of local governance.

The County went through a series of political and territorial metamorphoses over the years until, on 18 April 1985, during the administration of Samuel Doe, the part of the County known as River Cess was promoted to status as a County, thus splitting the region away from Grand Bassa. In October 2003, a few days before the end of the mandate of the 51st national Legislature, the County's previous four districts (District #1, #2, #3, and #4) were divided into its current five statutory districts, nine administrative districts, eleven townships, three cities (Buchanan, Edina, and St. John River City) and forty-five clans. This most recent restructuring has resulted in confusion for many citizens, who still tend to use the names of the previous denominations.

### **Natural Resources**

Grand Bassa County is endowed with ample exploitable natural resources including gold, timber, diamonds, crude oil, uranium, sand and rock. Timber and gold are explored but on a small scale, while crude oil and uranium are unexplored. There are no mining and logging companies active in County at present. This is partly due to the ban on timber that was lifted not so long time ago, but also to lack of infrastructure and basic services, limited supplies, scarcity of qualified manpower, and security fears.

The beginning of the operations of large corporations and the rehabilitation of the basic infrastructure (Buchanan port, Monrovia-Buchanan highway, and the railway Buchanan-Yekepa) will facilitate the arrival of other companies in the County.

#### *Timber*

The County still retains a good portion of its forest area. This forest was exploited for years by big logging companies, but with limited benefit to the population. Concerns about Liberia's forest and mineral resources been used to fund aggressions in the West African sub-region led to the imposition of sanctions on the industry by the United Nations. As a part of the forestry reform program, the Government of Liberia (GoL) cancelled all concession agreements across Liberia. Consequently, there exists no formal forestry activity in the County. Now that the United Nations Security Council has partially lifted the ban on the forestry sector, hopes are high for the return of logging companies. The new agreements will focus on responsible logging, which considers the environment and the needs of local communities.

### *Mining*

There is no comprehensive survey on mining activities taking place in the County, but 1% of households sampled in the CFSNS were involved in mining activities in 2005. It is expected that ArcelorMittal will export the iron ore mined in Nimba County through the port of Buchanan.

### *Rubber*

The production of rubber provided income for some 4% of households sampled by the CFSNS in 2005. This activity is mostly connected with the Liberian Agricultural Company (LAC) rubber plantation, which is the second largest in the country. The restarting of LAC activities has been at the center of several controversies with communities living within and near the plantation. The company's plan to extend its operations beyond the current area is one reason for tension, while rubber theft against LAC is another. With the presence LAC, and with the replacement of old rubber trees being conducted by BRE, there is potential for processing of rubber into finished goods for export.

### **Fisheries**

In the city of Buchanan the major economic activity is fishing, but it is only carried out on a small scale. There is a great potential for fishing industry in Buchanan, so far unexploited due in part to the lack of refrigeration facilities.

### **Agriculture**

Palm oil and food crops production are the most important livelihood activities in the County. Currently the palm oil is mostly produced by former employees and squatters of the concession area of Liberian Incorporated (LIBINC), also known as Palm Bay plantation. In the absence of any formal management control, residents of the concession area are harvesting in an unsustainable manner and the health of the trees is deteriorating. Negotiation has begun between the government and LIBINC, and hopefully the management will return to invest once again in the plantation. LIBINC was once the largest palm oil plantation in the country.

Access to agricultural land for cultivation was estimated at 81% in the 2006 Comprehensive Food Security and Nutrition Survey (CFSNS). Of that percentage, some 83% of farmers did cultivate crops. The main crops cultivated were cassava (87% of farmers), rice (60%) and plantain/banana (7%). The main crops produced for household consumption included rice, cassava (used to make the traditional dumboy, gari and fufu dishes, which in Grand Bassa County is more popular than rice), plantain/banana, sweet potatoes and corn. Some 36% of households produced cash crops including cacao, plantain/banana, coffee, palm nuts/oil and coconut. Three percent of households' survey in the County owned goats, another 51% owned chicken and 8% owned ducks.

### **Healthcare**

The 75-bed Government-owned hospital is fair condition and continues to play an important role in the health sector. The second hospital is presently managed by ArcelorMittal. The governmental hospital as well as all other clinics in the County is supported by international non-governmental organizations, with the government playing a leading role through the Ministry of Health and Social Welfare (MoHSW). There are 31 functional health facilities in the County according to the County Health Team. The County is divided into seven health districts (Owensgrove, District #1, #2, #3, #4, Buchanan, and Camp wood), districts that do not match either with the current administrative boundaries or with the old administrative boundaries that still are used by Norwegian Refugee Council for its statistics. This complicates the comparison of data of different sources.

### Water and Sanitation

Prior to the war Buchanan had a water and sewage system that was limited to the city. Due to long years of neglect, the entire system has broken down, leaving the population in great need of improved water and sanitation facilities. The Comprehensive Food Security and Nutritional Survey in 2006 estimated access to improved water at 10% and improved sanitation at 7%. Below is a presentation of water and sanitation facilities reported by MoHSW in March 2007. An analysis of the population and household ratio by LISGIS is also presented in tables below.

### Roads and Bridges

Roads remain the key challenge for Grand Bassa. The major highway linking Buchanan to Monrovia is in deplorable conditions, with many nearly-impassible spots. Roads to outlying areas are also badly damaged and in some areas completely impassible or non-existent. Before the war the County was connected to Nimba and Bong Counties via a railroad, but during the conflict the system was badly damaged.

### Education

The County educational system was once fairly functional. Today, there is a shortage of educational facilities. The available schools often face problem of over-a crowdedness. Availability of trained and qualified teachers is also a serious problem. Due to poor incentives, many teachers left the classrooms in search of greener pastures. Currently there are 257 functioning educational facilities in the County, but many are operated by volunteers in makeshift facilities such as churches and private accommodations, and do not have desks or chairs.

### Environmental Issues

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people's access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

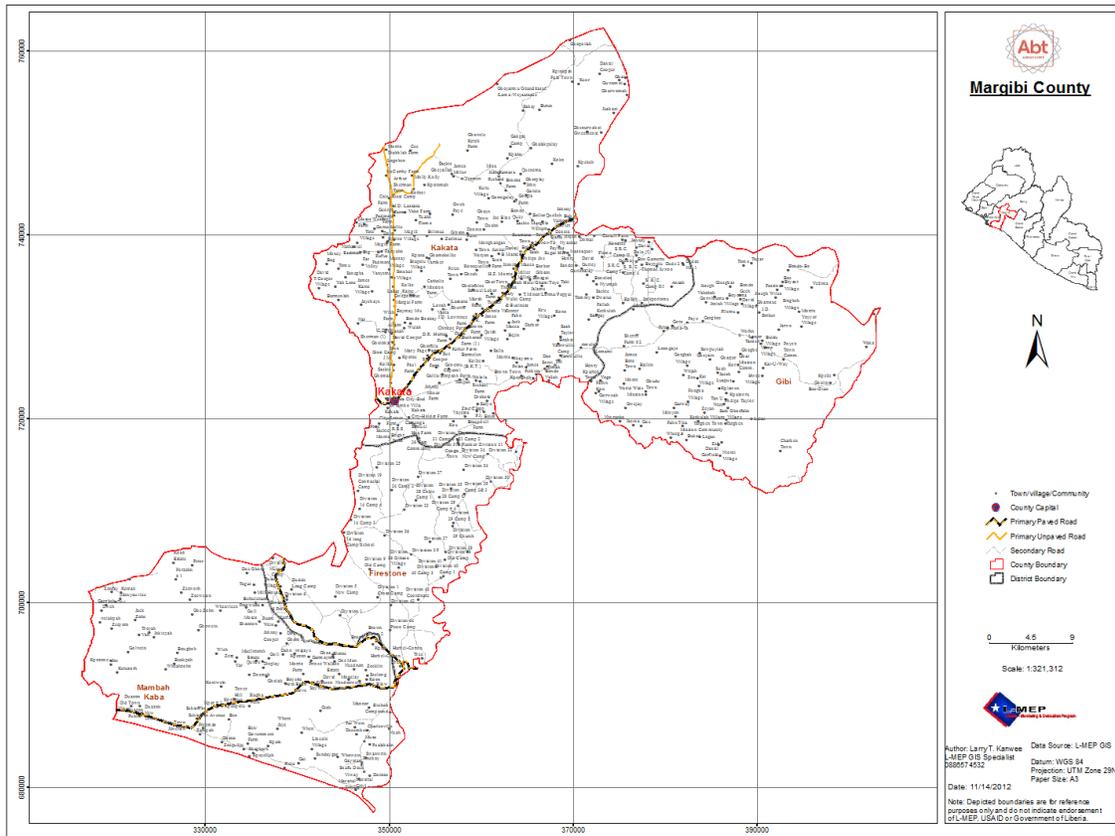
### Sensitive Sites

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
<i>None</i>	<i>None</i>	Margibi Mangrove (coastal)	<i>None</i>	<i>None</i>

### Margibi County

The Margibi County is located in central Liberia just about 45 minutes' drive from Monrovia and is situated along the Atlantic Ocean to the South, and neighbors Montserrado County on the East, Bong County on the North and Northeast, and Grand Bassa County on the West. The total land area of the County is approximately 2866.67 square miles, with an estimated 118,000 acres of this total being utilized by rubber plantations, namely Firestone and Salala. As of the 2008 Census, it had a population of 209,923, making it the sixth most populous county in Liberia.

Figure 21: Margibi County map



(map provided of L-MEP)

During the Second World War, the US Government built the Roberts International Airport (RIA) for US military use, and it remains the only Liberian international airport and main gateway to the country.

It is one of the newest counties, created just prior to the civil war. It was founded in 1984 as the 13th county, when two territories, Marshall and Gibi, were removed from Montserrado County and merged to form Margibi. The name derives from “Mar” for Marshall Territory and “Gibi” from Gibi District."

**Districts**

The districts of Margibi County include (population):

- Firestone (61,988)
- Gibi (14,250)
- Kakata (88,704)
- Mambah Kaba (44,981)

**Demographics**

The Bassa is the dominant ethnic group, though all or nearly all of Liberia's tribes are represented in the County.

**Climate**

The climate of Margibi is hot and humid, with an average annual temperature of 80°F(27°C). There are

two major seasons in Liberia, dry and rainy. The dry season lasts from December to March in the coastal areas, and for a longer period in the inland areas." Annual rainfall along the coast averages 200 inches (510cm). Inland areas receive about 85 inches (220cm) of rain per year."

### **Topography**

A narrow coastal plain extends inland from the coastline, and the land gradually rises to the high Bong Range in the Northwest, and Gibi Mountain in the North, bordering Grand Bassa County. Margibi County's most important rivers are the Farmington, which forms the border with Grand Bassa County, and the Du River, which forms the border with Montserrado County. Both rivers have the potential for hydroelectric power generation."

### **Geology**

The soil is excellent for agricultural production and many cash crops. The soil in the Lower part is mostly sandy clay loam, with an abundance of nutrients, and that of Upper Margibi is characteristic of highland soils."

### **Vegetation**

High-elevation regions have forests of evergreen and deciduous trees, including ironwood and mahogany. Mangrove swamps are found mainly in the coastal areas".

### **Institutional Structure**

The County is comprised of two main administrative districts, Gibi in the upper part and Mambah-Kaba in the Lower part, both of them headed by District Commissioners. The other subdivisions are the six townships (Cinta, Borlola and Larkeyta in Upper Margibi, and Charleville, Schefflin and Lloydville in Lower Margibi), also headed by Commissioners, and two cities (Kakata and Marshall) administered by city mayors. "Each mayor and district and township commissioner reports directly to the county superintendent, who heads the hierarchy of administrative officers.

### **Natural Resources**

Margibi County is endowed with diamonds, water, timber, and iron ore, among other important natural resources. These resources are not currently a major part of the economy because they are extracted only on a small scale, especially in the case of pit-sawing and diamond activities. There are no logging, mining, or diamond companies operating in the County as yet. Diamonds are also being mined on a very small scale as a result of the restrictions on the mining of solid minerals." Forestry and timber processing are not a major part of the economy of Margibi County, as the only extraction ongoing is small-scale illicit pit sawing.

### **Agriculture**

The agricultural productive capacity in the County is below average for Liberia. About 80 percent of farming is subsistence farming. " Food crops production is not as widespread in this County as other counties in Liberia. Only about every second household has access to agricultural land, according to the CFSNS. In 2005, rice was only produced by 33% of farming households. The main crops cultivated in 2005 included cassava (79%), rice (33%) and corn (12%). This is in part explained by the local preference for the traditional dumboy dish, which is more commonly consumed than rice.

Commercial or cash crops produced in the county included rubber, produced by 52% of households; cacao, produced by 10% of households; coconuts, produced by 14% of households; sugarcane and pineapple, each produced by 14%; plantain/ banana, produced by 34%; palm nuts, produced by 14%; and cola nuts, produced by 3%."One percent of households surveyed owned goats, another 6% owned

pigs, 6% owned ducks and 39% owned chickens. "

### *Rubber*

Rubber tapping has the potential to again be the most important income-generating activity in the County. Liberia's largest rubber plantation, Firestone, along with the Salala Rubber Corporation, are very active. Rubber tapping provided income for some 30% of households sampled by the CFSNS in 2005. Theoretically, with two of the major Rubber Plantations in the County, local government should have access to a portion of the tax income-collected from plantations. Unfortunately, little from these taxes trickles down to the County and the plantations refuse to pay any dues, arguing that they are already paying the Central Government.

### **Fisheries**

Exports of fish from Liberia can theoretically take two forms. Either fish can be landed and then exported, or foreign vessels paying a license fee and an export tariff can catch it, and either land it overseas or transship it at sea. "There are currently no exports of frozen or fresh product from Liberia, and virtually no exports of smoked products to regional markets although it is anecdotally reported that some women fish processors do occasionally export small quantities."

### **Healthcare**

Besides the Firestone medical facilities, which receive approximately 9,000 patients visits a month and at times buttresses other facilities by helping to provide storage and some medical equipment, there are two main functional Government hospitals serving the County: C.H Rennie Hospital, a referral site in Kakata; and Mike M. Baydoun Health Center in Marshall City. Apart from the two hospitals, the Government owns 19 clinics among the 36 functioning health facilities in the County. The most prominent among them may be the Dolo Town Community Clinic that was built by the US Embassy. All the Government medical employees are on the government payroll and treatment is provided free of charge with drugs provided by Government and INGOs. Firestone Liberia actively participates to vaccination campaigns for the eradication of childhood diseases.

### **Water and Sanitation**

Water and electricity are still a wish for many communities. As typical rural Liberian county, Margibi does not have access to public power. All individuals and organizations in need of electricity, including the local authorities, have to operate their own generators. A survey has just been conducted for connection of Kakata and Marshall to the Emergency Power Program already operational in Monrovia. Prior to the war, most parts of Margibi County had a water and sewage system that has since broken down, leaving the population even in the cities without improved water and sanitation facilities. With 146 hand pumps in use in the County, an average of 1650 people are making use of each pump. Some 1685 people share each available latrine, as there are only 143 latrines in use in the County".

### **Roads and Bridges**

Communities living in 305 villages located in remote areas such as Worhn in Gibi District and Marshall City, Larkayta and Llyodsville Townships are completely inaccessible by road during rainy season. Thus, fishing boats remain the only alternative used to cross many rivers into some parts of Lower Margibi

Despite the two paved highways linking Margibi to Monrovia, the county still has a very bad road network, rendering it difficult to liaise with the remotest and historical fishing base of Marshall or even the beautiful hills in Worhn in Gibi Districts, both localities being only 20 km away from the main paved highways."

## Education

Margibi County is well known for its concentration of outstanding educational institutions. The most prominent among them is the Booker Washington Institute (BWI), which awards diplomas and is known for its vocational/technical training courses. The County also boasts the Harbel Multilateral High school, where the University of Liberia is operating up to 2nd year of studies; the extension of the Gbarnga-based Cuttington University College; the Kakata Rural Teacher Training Institute, in charge of training and reactivation of teachers; and the Konola Academy, a co-educational institution and prestigious upper secondary school; among others".

The Firestone school system, owned and operated by the Firestone Rubber Company, caters to over 15,000 children within the concession area. This school system is well organized and effective, as not only do they have appropriate facilities and educative materials, but also boast a science laboratory at the Firestone Senior High School.

50 educational facilities are fully functional. The Government through the Ministry of Education runs several of them at primary and junior schools level, while faith-based communities and private organizations run the others.

Despite the many well-known schools, many children in remote areas of Margibi County still lack access to education because of bad road conditions, damaged facilities, and a lack of qualified teachers. Like many LNP and other Civil Servants, teachers are often reluctant to settle in far-flung areas because of the hardship and low salary. Some informal education targeting over-aged students and adults is also organized by women's groups as a means of skills improvement and reducing illiteracy."

## Environmental Issues

One of the most pressing environmental problems is the dumping of rubber company waste into the rivers. This situation is creating a major hazard for the marine life in the Wea River (Weala and Salala) and the Farmington River (Firestone). Firestone has submitted to the Government an Environmental Management Plan that addresses a wide range of environmental management issues.

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people's access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

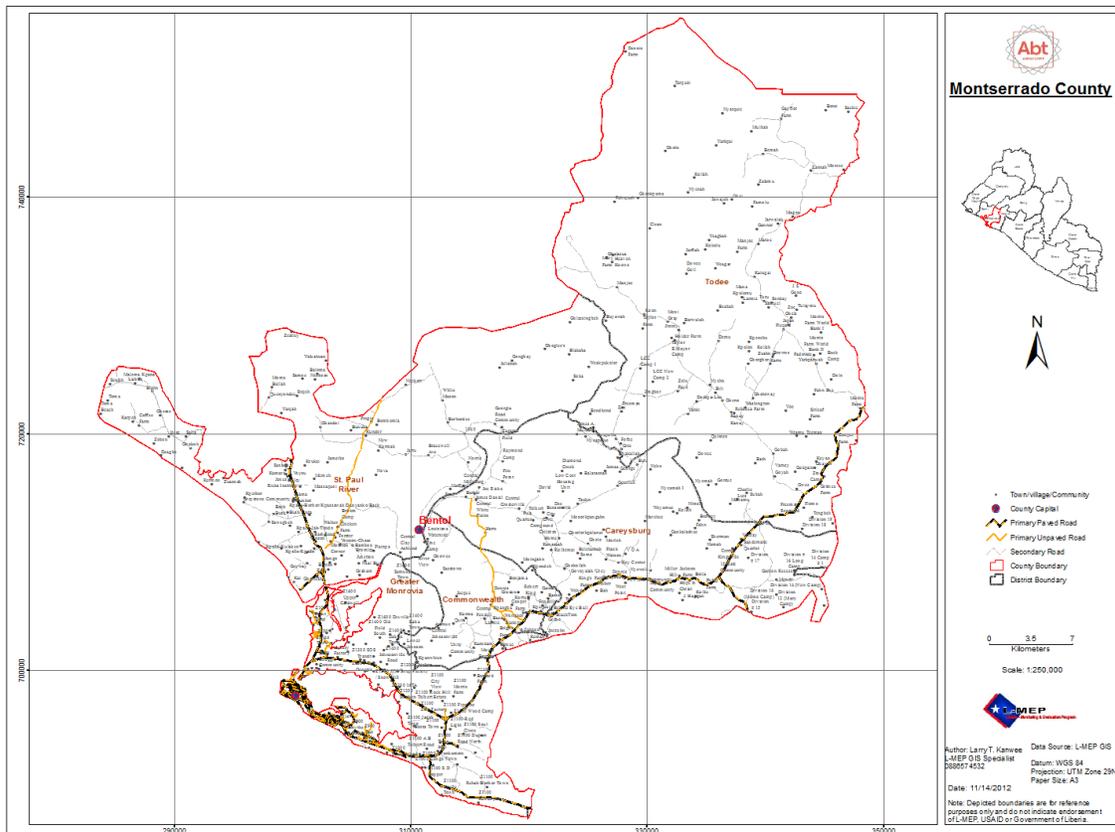
## Sensitive Sites

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
<i>None</i>	<i>None</i>	Margibi Mangrove (coastal)	Marshall Wetlands	<i>None</i>

## Montserrado County

Located on the coast in the northwestern third of Liberia, Montserrado County is bordered by three counties. The Atlantic Ocean makes up the county's southern border, while Bomi County lies on the western border, Bong County is to the north and Margibi County to the east. Bensonville serves as the capital with the area of the county measuring 1,909 square kilometres (737 sq mi), the smallest in the country. As of the 2008 Census, it had a population of 1,118,241, making it the most populous county in Liberia.

Figure 22: Montserrado County map



(map provided of L-MEP)

Montserrado County was one of the first three counties to sign the Declaration of Independence in Liberia on 26 July, 1847, and is thus almost as old as the Republic itself. Hosting the capital, Monrovia, it is the most populous County with all ethnic groups and dialects in the country represented.

On December 11, 1821, officials from the United States arrived aboard the vessel *Alligator* under the command of Captain Robert F. Stockton at Mesurado Bay. Stockton and Dr. Eli Ayers negotiated to acquire the land in and around the bay from the native chiefs for a settlement by former slaves before sailing to Sierra Leone to pick up these colonists. On January 7, 1822, the former slaves arrived and settled Providence Island on the Mesurado River under the auspices of the American Colonization Society, and by April they had moved to the mainland. Many of the communities in the county are

named for the pioneers who settled the area and their former homes in America. Natives inhabiting the land that made up the county were from the Deygbo, Gola, and Kpelle tribes.

The County includes developed areas such as townships and cities surrounding the capital, as well as more underdeveloped remote areas such as Todee District and St.Paul, where many villages are not reachable by road and people have to walk for hours and days to access basic service such as health and education. Mountains and river valleys provide fertile grounds in the interior, while savannah fields and mangrove woodland cover the Atlantic coastline.

Due to the country's capital being located in the County, Montserrado was particularly affected by the conflict. To this day, most of Montserrado's basic infrastructure remains damaged and basic social provisions are to a great extent grossly inadequate, particularly in the rural areas. After the war, the County has been the host of about 60% of IDP and returnee camps and a center for ex-combatants and deactivated security forces seeking new ways to make a living.

### **Districts**

The districts of Montserrado County include (population):

- Careysburg (29,712)
- Commonwealth (11,876)
- Greater Monrovia (970,824)
- St. Paul River (71,831)
- Todee (33,998)

### **Demographics**

Montserrado is a politically influential county, being home to the country's capital, but also because of its disproportionately high population; it is estimated that almost half of all Liberians live within Greater Monrovia. Montserrado County's average household size was 6.4 persons, higher than the national household size of 5.6. This scenario likely a symptom of the rural-to-urban migration that is so evident in the County nowadays. The County has a dependency ratio of 1.39, which is also higher than the national figure of 1.37. Eighty-three percent of households are headed by males.

At the time of its founding, Montserrado County was composed of three main tribes: the Deygbo or Dey on the coast, and Kpelle and Gola in the North. These groups were joined by the formerly enslaved people from America in 1821. Eventually all of Liberia's 16 major tribes came to populate the County, so that today Montserrado, and particularly Greater Monrovia, is considered highly diverse and representative of the population of Liberia as a whole.

Montserrado is the smallest county by size at 1,909 square kilometres (737 sq mi), but largest by population, approximately 33% of Liberia's total population. The population density is 599.7 inhabitants per square kilometre (1,553 /sq mi), the highest in Liberia. The average household size was 4.7 people, a decrease from 5.4 at the 1984 Census. The county capital of Bensonville has a population of 4,089.

Males outnumber females in the county. All of Liberia's 16 main tribal groups are represented in the ethnic make up of the county. Kpelle speaking groups represent 52% of the population while Bassa speakers comprise 21%, followed by Lorma with 6%, Kru with 4%, and all others with 3% or less each.

### **Climate**

Like the rest of the country, Montserrado has a tropical climate with two seasons, rainy and dry. The

rainy season covers May to November, while the dry season is between December and April. Between December and February, the hot and dry wind “Harmattan” blows from the Sahara and causes marked fluctuations of temperature between day and night with a minimum of 10 degrees Celsius. The average temperature falls between 21 and 36 degrees Celsius. Annual average rainfall is about 75 inches.

### **Topography**

The County’s topography consists of hills and valleys in the interior and lowlands along the Coast. Apart from direct access to the sea, the County has many rivers and creeks. Rivers include the St. Paul, Mesurado, Du, and Po.

### **Geology**

Montserrado soil consists mostly of alluvial soils, primarily clay, washed seaward from the streams and rivers of the interior valleys.

### **Vegetation**

The lowlands along the Coast are full of savanna grass fields, mangrove woodlands and palm trees. Moving inward into the County, one can observe hills and swamp valleys, which the inhabitants use for upland and lowland farming. Montserrado has abundant tropical forest crisscrossed by many rivers including the St. Paul, Po, Du and Mesurado. Creeks include the Stockthon, Mambay and Bear.

### **Institutional Structure**

Each county in Liberia is headed by a superintendent appointed by the Liberian President. Other executive offices include commissioners for districts and townships, line ministries, and an assistant superintendent that focuses on development. The county is divided into two districts, seven cities, one borough, twenty-one townships, seven clans, and two chiefdoms. A district superintendent heads each of the two statutory districts.

### **Natural Resources**

Montserrado County is endowed with abundant natural resources. Amongst them are; diamonds, gold, timber and water. The exploration of gold and diamonds in the County, just like in any other County, has been done on a low-scale, partly due to United Nations sanctions, which were recently lifted. As a result, the sector’s job creation potential has not been fully realized. Timber processing (pit-sawing) is also done on a small scale in the County, largely in rural areas.

The County is blessed with many fresh-flowing water sources, among the St. Paul River, which flows from the Guinea highland. Communities around the river find their livelihoods in fishing, though the sector has not been developed to potential. The non- functioning hydropower plant on the St. Paul River will likely generate many jobs for citizens once it is made operational.

### **Agriculture**

Commercial or cash crops produced in the County include rubber, (produced by 41% of households), cocoa (produced by 5% of households), coconuts (produced by 19% of households), sugar and pineapple (11% and 16% respectively), kola nuts (16% of households) and palm oil (49%). Two percent of households kept pigs, 7% kept ducks and another 44% kept chickens. Yet these agricultural activities are overwhelmingly subsistence-level, and the County still has great potential to increase production once farmers have access to capital for tools, pesticides, seeds, and other inputs.

Agriculture is small part of economy, with the main crops consisting of cassava (90% of all crops), rice

(16%), other vegetables (18%), corn (16%), sweet potatoes or eddoes (8%), plantain or bananas (8%), and pulses (1%). Livestock is mainly pigs, chickens, and ducks. Commercial crops grown include cocoa, coconuts, sugarcane, pineapple, kola nuts, palm oil, and rubber.

#### *Palm Oil*

Some palm oil is produced on government owned farms in Mt. Coffee and Fendell. The County has great potential for expansion in oil palm production, with two state- owned oil palm plantations in Fendell (283 hectares) and Mt. Coffee (141 hectares), and ample acreage for further such development.

#### *Rubber*

Rubber plantations are located in the Todee and Careysburg districts. These include the Morris American Rubber Company in Todee that employs 600 and the Liberia Resources Corporation in Careysburg with 300 employees. Overall rubber production accounts for eight percent of household income in Montserrado County.

#### *Mining*

Small-scale mineral extraction occurs for gold and diamonds. Other resource extraction activities include logging and fishing.

Due to a lack of formal employment, many engage in informal businesses and trading. As of October 2006, employment in the county is primarily self-employment with only 17% of households having members that were salaried employees. The largest income generation activity was through petty trade or small business, with 46% of households engaged in these activities. This was followed by 25% for making charcoal, 19% for temporary employment, and 18% for palm oil/nut production and sales. The national government is the counties single largest employer.

#### **Healthcare**

Montserrado does have a good number of health facilities, but most are in need of rehabilitation and the deployment of qualified medical personnel. The Ministry of Health and Social Welfare in March of 2007 reported the presence of 6 functioning hospitals, 44 functioning clinics and 10 health centers, for a total of 60. The Ministry of Health and Social Welfare in March of 2007 reported the presence of 96 pharmacies and 228 drug stores in Montserrado County.

#### **Water and Sanitation**

The Liberia Water and Sewer Corporation (LWSC) was efficiently functioning within Montserrado County before the 1990s. Pipe-borne water from the Mount Coffee Hydro Electric dam ensured a constant supply of water to the County. With this supply there was a marginally efficient sewage management system in place. With the coming of the civil crisis, the dam was put out of use and locals now have to rely on wells and hand pumps. The LWSC is working hard to restore water to some parts of the County, and has restored service in a few areas. Still, the majority of residents are without water or sanitary facilities, and this situation has often led to out-break of water borne diseases. There are approximately 13,000 wells in the county and 518 hand pumps.

#### **Roads and Bridges**

The road and bridge network has crumbled due to decades of neglect.

#### **Education**

The county had a total of 947 students enrolled in school in 1910. In 1948, the missionaries from the Pentecostal faith opened a school in Mein Clan in Todee District. Additional primary schools were built

in the 1970s, while in 1976 the University of Liberia opened the Fendall branch campus in Louisiana. Bentol City added a high school in 1978. The University of Liberia’s main campus is located in Monrovia, and includes the country’s only law school in the Louis Arthur Grimes School of Law.

Enrollment in primary schools in the county totaled 314,409 students, which was 35% of the total number for the nation as a whole. Students attended a total of 1,096 schools in the county. Thirty three percent of county residents had no formal education, while 27% had attended some elementary school. Seven percent completed elementary school, 19% had some high school education, and 11% completed high school. One percent each of residents completed college, attended college, or have received a vocational education. Enrollment for school age children is 70%, with 76% for males and 65% for females

**Environmental Issues**

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people’s access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

**Sensitive Sites**

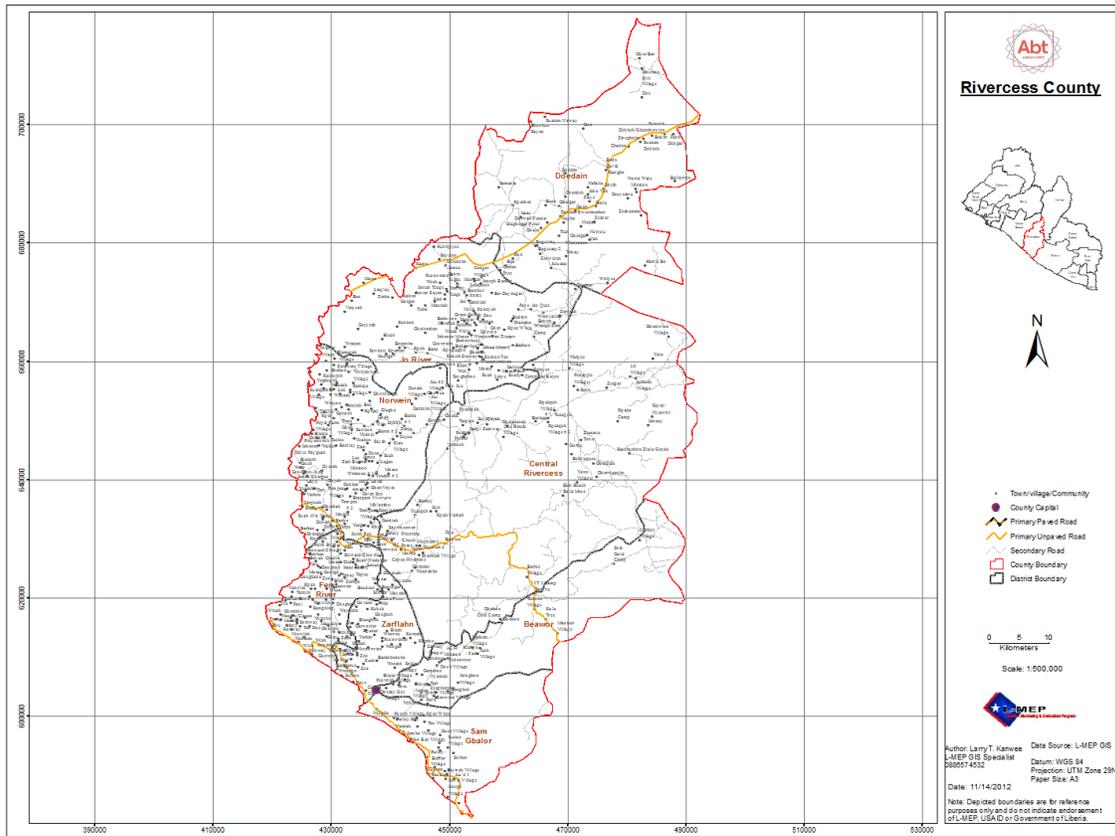
National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
<i>None</i>	<i>None</i>	<i>None</i>	Mesurado Wetlands	<i>None</i>

**South Eastern A**

**River Cess County**

Rivercess County in the south-central portion of the West African nation of Liberia. Cestos City serves as the capital with the area of the county measuring 5,594 square kilometers (2,160 sq mi). As of the 2008 Census, it had a population of 71,509, making it the third least most populous county in Liberia. Eighth largest in size, it is bordered by Grand Bassa County to the west, Nimba County on the northeast, and Sinoe County to the southeast. The southern part of Rivercess lies on the Atlantic Ocean and has a coastline of 62 kilometers. Prominent geographical features demarcating the County are River Timbo in the West, River Blonne in the East, and the Whomehand Gienee Rivers in the North. Cestos City is situated on the coast, alongside the Cestos River.

Figure 23: River Cess County map



(map provided of L-MEP)

River Cess was the twelfth county established in Liberia. The County derives its name from the Cestos (meaning “crawfish basket”) River.

In the past tensions arose on account of logging activities. The local populace felt that timber was being exploited from their community without any benefit to them. In 2005 there was a serious problem regarding acceptance of the authority of the Liberia National Police in River Cess.

**Districts**

The districts of River Cess County include (population):

- Beawor (3,854)
- Central RiverCess (8,303)
- Doedain (13,041)
- Fen River (12,630)
- Jo River (8,921)
- Norwein (13,900)
- Sam Gbalor (3,714)
- Zatlahn (7,146)

## **Demographics**

Average household size for River Cess County is 5.5. The County has a dependency ratio of 1.43; higher than the national dependency ratio of 1.37. Households are mostly male dominated, with only 12% of households headed by females. About 1 percent of all households surveyed reported having orphans.

Indigenous tribes make 99% of the population, dominated by Bassa (78%) and Kru (18%) tribes. Kru population is founding the districts of Yarnee and Timbo, mostly involved in fishing activities. The Mandingo tribe is also represented by a small minority population near Cestos. Many Mandingos have adopted the Bassa culture, yet continue to speak their own language. Representations of Kissi, Gio and Krahn are also visible in the area but in a small minority. There are many people whose parents belong to more than one tribe on account of marriage, especially Kru and Bassa, but these people mostly identify themselves with the Bassa culture, since it is dominant in the area.

## **Climate**

The region experiences heavy rainfall, ranging from 160cms to 170cms annually, with the heaviest rains in August to September. Temperatures generally range from 25 to 32 degrees Celsius. The coastal areas experience high humidity during the months of November to January. Wetlands and swampy areas are common in the County on account of the heavy rainfall. The climate during the months from December to May is most conducive to farming of rice, cassava, rubber, cocoa and palm trees. Dust-laden harmattan winds blow down from the Sahara from December to March, and since it does not usually rain this season, the dust tends to remain noticeable in the air for two months.

## **Topography**

River Cess County is generally considered lowland and partly thick green forest. The major mountain ranges in River Cess are found in Morweh District. The Cestos River runs through the lowlands into the Atlantic Ocean.

## **Geology**

Soil types vary with location. In the Timbo district area, the soil is sandy. In Yarnee District, one sees mangrove swamps and water-logged soils. In the Central River District, the soil has a reddish color. In Morweh, the soil is both reddish and of the Mangrove type.

## **Vegetation**

The vegetation of River Cess is both savannah and green forest, mostly the latter.

## **Institutional Structure**

River Cess County has eight administrative districts: Dodain, Joe River, Fehn, Zarflahn, Nyunwein, Central River Cess, Bear-Wor, and Sangbalor. These are further divided into statutory districts. The County is headed by a Superintendent appointed by the President. Each statutory district is headed by a District Superintendent who reports to the County Superintendent. The administrative districts are headed by District Commissioners appointed by the President, who report to the District Superintendent. The administrative districts are further sub-divided into chiefdoms that are headed by elected Paramount Chiefs. These chiefdoms are further divided into clans that are headed by Clan Chiefs. The clans are further sub-divided into zones headed by General Town Chiefs, who are elected. The Zone Chiefs control Town Chiefs who are selected by the residents of the town.

## **Natural Resources**

### *Timber*

River Cess County has three major logging concession areas in Morweh, Central River Cess and Yarnee Statutory Districts respectively, exceeding 160,000 hectares of prime forest in total. There is also a special soft-grade timber stand of 50,000 hectares planted by GoL near Neezuin in Central River Cess. The area has a variety of species of trees with commercial potential, including Niangon (heritera utilities), tetra, abjura (mitragyna ciliate), ekki (lophira alata), lovoa, sipo, bozze and sapale. Of these, niangon and tetra are dominant, and are principally used for construction of houses and furniture making.

The Forestry Development Authority (FDA) has declared the area of tropical rain forest in Cestos-Sahnkwehn as "Proposed Protected Forest". The Krahn-Bassa Forest in the Southwest of the County has also been declared as a National Forest.

Three large timber companies including the Oriental Timber Company (OTC), STC and the River Cess Logging Company were active in the County until the end of the war, which testifies to the economic potential of timber logging. County residents see high potential for the establishment of a local timber processing plant to manufacture such products as paper, tissue, and plywood, and provide employment. One proposed site for such a facility is Neezuin in Central River Cess Statutory District on the Buchanan-Greenville Highway.

### *Rubber*

While potential exists for expanded production of rubber, currently rubber tapping is not a major feature in the County's economic life.

### *Mining*

Like many counties in Liberia, River Cess County has ample potential mineral resources that are yet to be tapped. Gold and diamonds are currently mined illegally, and only at the artisanal level. The 2005 CFSNS found 2% of households involved in mining activities.

## **Fisheries**

River Cess County has four principal rivers (Timbo, Cestos, Po and Sahnkuen) along with many smaller rivers that flow into the Atlantic Ocean, which provide breeding grounds for the wide range of fish resources including large pelagic, small pelagic and demersal fish, shrimp and lobster. These varieties can be exploited for domestic, regional, and international trade.

Fishing is the second-largest economic activity in the County after farming. Five fishing teams work out of Cestos City using motorboats for ocean fishing, and a number of unaffiliated fishermen use canoes on the ocean and in rivers. The industry remains in its infancy, and provision of inputs to fisher folk will have major benefits to the economy of Cestos City.

## **Agriculture**

The agriculture sector is in need of revitalization after the long war. Before the war, there existed many farm cooperatives in River Cess County, and about 90% of the population was engaged in farming activities. Subsistence farming is still the predominant economic activity.

Access to agricultural land for cultivation was estimated at 76% in the 2006 Comprehensive Food Security and Nutritional Survey. The main crops cultivated during this time and their corresponding

percentages are as follows: Rice (84%), Cassava (77%), and assorted vegetables (6%). The main crops produced for household consumption included rice, cassava, plantain/banana, vegetables, sweet potatoes and corn. Cash crops included rubber (31%), coffee (4%), cacao (19%), coconuts (16%), sugarcane (7%), pineapple (13%), plantain/banana (50%), palm nuts/ oil (12%) and cola nuts (2%). One out of every four to five households in 2005 had a small section of land (0.5 - 1.0 acres) upon which cocoa or coffee trees were grown to provide cash income. Rice is grown mostly under rain-fed conditions. Shifting cultivation and bush fallowing are widely practiced across the County due to the generally low fertility of soils and the nutrient needs of the rice plant to produce a reasonable harvest.

One percent of household survey in the County owned goats, another 1% owned pigs, 41 percent owned chicken and 6% owned ducks.

### **Healthcare**

The entire County is served by only ten health care facilities (NRC Needs Assessment Survey, January 2007). Five of these facilities are located in Morweh District (Blowhen Sayon, Gbeh Wodobli, Ziadue, Zammie and Zeegar Town), and the remaining five can be found in Timbo Statutory District (Bargbeh Town, Cestos City, Guewein, Neezuin and Sawkon). The County does not have an assigned doctor, and most health workers are untrained or poorly trained volunteers. Health facilities need to be renovated and refurbished with hospital equipment and regular supplies of drugs. Malaria is reported to be the major cause of mortality in the County and there are regular incidences of cholera, measles, and respiratory infections. Antenatal natal care is almost totally unavailable, with a record 80% of births taking place in private homes (UNMIL Civil Affairs Profile, 2005). The closest hospital is the Government facility in Buchanan, and the bad roads and lack of transportation often result in the death of patients.

### **Water and Sanitation**

There is no public facility for the provision of safe drinking water anywhere in the County. The majority of the population takes its water from forest creeks and rivers for drinking and other household use. Hand pumps and wells used by the populace before the war have been mostly damaged or are in a state of disrepair. Humanitarian agencies including the International Committee of the Red Cross (ICRC) and Action Contre la Faime have renovated old wells and installing hand pumps in some areas, but the work stopped in 2005.

### **Roads and Bridges**

The roads around the County are in a sorry state, resulting in hundreds of villages inaccessible by car, resulting in generalized deprivation and economic stagnation.

### **Education**

*(no information was available)*

### **Environmental Issues**

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people's access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement

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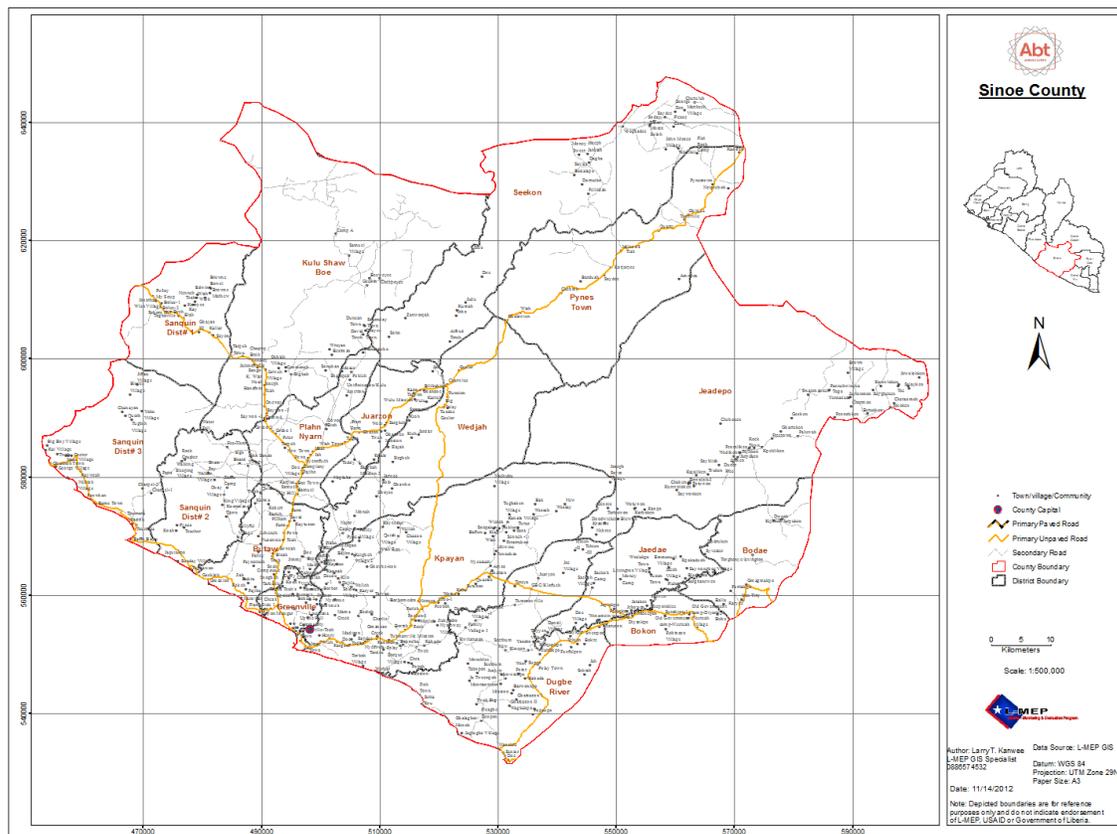
**Sensitive Sites**

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
Krahn-Bassa	None	Senkwehn (coastal)	None	Cestos Swenkwehn

**Sinoe County**

Sinoe County is found in the Southeastern region of the Republic of Liberia, which is on the West Coast of Africa. Sinoe is bordered by Grand Gedeh County on the North, by River Cess County on the West, by Grand Kru and River Gee Counties on the East, and by the Atlantic Ocean on the South. Sinoe covers a land area of about 3,861 Square miles (10,000 square kilometers) and has a total coastline of 86 km. Greenville is the county's capital. As of the 2008 Census, it had a population of 102,391, making it one of the least populous counties in Liberia.

Figure 24: Sinoe County map



(map provided of L-MEP)

Sinoe is the third original County in the Republic and one of the signatories to its Declaration of Independence on July 26, 1847. After having been inhabited by various African peoples over the millenia, Sinoe was discovered by the Portuguese in the 15th Century as part of what they called the Grain Coast. Prior to the Declaration of Independence, the County was established by the Mississippi Colonization Society in 1822 and later became part of the Republic in 1838.

## **Districts**

The districts of Sinoe County include (population):

- Bodai (3,539)
- Bokon (4,373)
- Butlaw(3,432)
- Dugbe River (9,239)
- Greenville (15,715)
- Jaedae (3,539)
- Jeadepo (7,895)
- Juarzon (6,088)
- Kpayan (10,661)
- Kulu Shaw Boe (8,555)
- Plahn Nyarn (6,677)
- Sanquin District #1 (2,118)
- Sanquin District #2 (3,256)
- Sanquin District #3 (3,152)
- Seekon (7,024)
- Wedjah (4,061)

## **Demographics**

Sinoe County has an average household size of 5.5 persons and a dependency ratio of 1.37. Like the rest of Liberia, the society is largely patriarchal, thus accounting for an 89% rate of male household heads. The Kru vernacular, followed by the Sapo are the most commonly spoken dialects in the County with percentage distributions of 52% and 39% percent respectively. Of households surveyed during the 2006 Comprehensive Food Security and Nutrition Survey (CFSNS), 2% reported having members who were chronically ill or disabled, while 43% were headed by chronically ill or disabled persons. The County also reported 1% of households with orphans.

## **Climate**

The climatic condition in Sinoe County is typical of the equatorial tropics, with a high temperature and high humidity. The County has two seasons, rainy and dry, which show distinction in the temperature according to the seasons. The average annual temperature during the dry season (the hot period) is December to March and exceeds 79 degrees Fahrenheit (26 degrees Celsius). At its peak in February, the temperature rises above 80 degrees Fahrenheit. The County experiences westerly wind and heavy storms during the rainy season, and moist winds during the dry season. Annual rainfall is over 80 inches in the County.

## **Topography**

The physical features of Sinoe County are about sixty percent lowland with somewhat increasing elevation from the coast. It has some high hills and few mountains and valleys, mainly in Jaedae, Jedepo and Dugbe River Districts on the left bank of the Sinoe River. The County has six major rivers including the Sinoe River, Dugbe River, Sanquin River, Tarsue River, Baffu River, and Plason River. Sinoe has a number of natural falls that may be suitable for the construction of hydroelectric plants. Some of these natural falls are: Sinoe River Fall in Wehjah District, Dugbe River Fall in the Dugbe River District, Sanquin River Fall in the Troh Chiefdom/Sanquin Statutory District and the Hamgbe River Fall, situated in the upper region of BOPC and Tumata.

## **Geology**

Sinoe soils are typical for the country, comprising sedimentary rocks, loamy clay, sandy clay loam, and marshland/swampy soil.

## **Vegetation**

Sinoe has an evergreen rain forest, which receives an annual rainfall of 80–85 inches. The Sinoe National Park is composed of virgin forest reserved for eco-tourist activities and biomedical research as well as wildlife preservation. The height of the tallest trees is approximately 200ft. Due to shifting cultivation, most of the evergreen forests have been converted into farmland or secondary forest. The coastal area is noted for savanna and mangrove with some grassland.

## **Institutional Structure**

The Sinoe County institutional structure includes 5 Statutory Districts, 16 Administrative Districts, 69 Chiefdoms, 101 Clans, 574 Towns and 43 cities.

## **Natural Resources**

### *Timber*

Sinoe is endowed with vast natural primary rain forest including the Sapo National Park. Due to restrictions placed on logging activities in the country, there has been no commercial logging undertaken for a long period of time. Pit sawing is being done on an illicit and meager level, thus insignificantly impacting the economic life of the locals.

A significant portion of Liberia's forests is located in Sinoe County. Eight of the 56 registered companies during logging's peak production in the 1980s operated out of Sinoe, making the County one of the premier producers of timber in the country. It had the largest plywood factory in West Africa prior to 1980. Developed by the Vancouver Plywood Corporation of Canada, the sprawling industrial site lay dormant outside Greenville, Sinoe. The plant was an early pioneer in biofuel generation using wood chip and biomass to produce electricity.

The Port of Greenville provided facilities for export of plywood directly to markets around the world. The port has also made Greenville the traditional transit point for commerce throughout the Southeast Region and beyond into the border Towns of Guinea, and La Cote d'Ivoire through Grand Gedeh, Rivercess and River Gee Counties.

### *Mining*

Gold and diamond deposits were discovered in Sinoe in the 1990s thereby attracting great number of people from far and near. However, it is dismaying to note that the locals have not adequately benefited from the exploitation of these minerals. The Kimberly regulation gives hope to the people and their County as they stand to benefit this time around from exploitation of the gems from the County.

### *Palm and Coconut Oil*

Reports indicate that palm oil has excellent medium-term prospects on the international market, and Liberia has a very good agro-climatic comparative advantage for its production, probably the best in West Africa. A strong demand for vegetable oils, particularly with the emerging bio-fuel market, is expected to support high prices for palm oil.

Three large State-owned plantations have been established in the Southeastern counties of Grand Gedeh, Maryland and Sinoe with hybrid Tenera oil palm obtained from Cote d'Ivoire. The Butaw Oil

Palm Plantation gave Sinoe the second largest plantation in the country. It has total planted acreage of about 8,000 but can be extended to 20,000. The development of private small and medium-scale plantations was promoted in the 1980s under the various Agricultural Development Projects. These efforts resulted in the establishment of about 150,000 acres (about 70,000 hectares) of oil palm plantations throughout the country.

### *Rubber*

Commercial rubber tapping was once one of the most important economic activities of the County. Today, the only ongoing rubber tapping is illicit and benefits only 6% of the County's households. The rubber from the once-proud Sinoe Rubber Plantation is currently being exploited in an unsustainable fashion; the rubber trees in the near future may not produce latex due to the "slaughter tapping" by illegal tappers. Participants in the CDA consultations have called for investments and incentives to reactivate production at the Sinoe Rubber Plantation, steps which will bring much-needed jobs to the County.

### **Fisheries**

Liberia has a wide range of fish resources including pelagics, demersal fish, and shrimp/lobster, which can be exploited for domestic, regional and international trade. If carefully managed, this trade has the potential to make significant contributions to both poverty alleviation and food security. Sinoe has a tradition of hardy artisanal fishermen dating back hundreds of years. Fanti fishermen who migrated to the County from Ghana several decades ago have reinforced this tradition. Together these fishermen haul in large quantities of fish daily and lose much needed income due to lack of cold storage and proper processing facilities. It is estimated that using largely dugout canoes without motorization these fishermen catch about 40 tons of fish monthly but lose over half for want of facilities.

### **Agriculture**

Prior to the civil conflict that engulfed the country, Sinoe County was noted as one of the country's agricultural strongholds. There existed several agricultural industries such as the Sinoe Rubber Plantation (SRP) located in Wedjah District – the second largest rubber plantation in the country next to Firestone; the Butaw Oil Palm Company (BOPC) in Butaw District; two coconut Plantations producing coconut oil – located in Kpanyan and Sanquin Districts respectively. The BOPC produced on the minimum level about 350 drums of oil daily and comprised a workforce of 2,800. These industries provided jobs for County inhabitants as well as those migrating in search of better life.

Before the war, farmers produced red palm oil, plantains, eddoes, cassavas, bananas, sweet potatoes and other crops. Vegetables such collard greens, potatoes greens, cabbage, pepper, corn, bitter balls, and eggplants were produced as well for sale in the local markets. Subsistence rice farming enabled the people to be self-sufficient in food production, thereby availing adequate food supplies in the County and giving the opportunity to transport food to other parts of the country, particularly to Monrovia for sale. Today the people continue to practice agriculture, but well below potential.

Food crops cultivated in 2005 according to the CFSNS included cassava cultivated by (72%), sweet potatoes/eddoes (14%), and plantain/banana (10%) vegetables (1%). In addition to these food crops farmers in the County also cultivated cash crops. These included rubber (9%), coffee (8%).

### **Healthcare**

One of the major problems in Sinoe County is health care. Prior to the civil war in 1990, 33 clinics were operated throughout the County, as well as one government hospital, F.J. Grante Memorial, which was

well staffed and well equipped. Between 1993 and 1994 there were five clinics operated by the INGO Merlin, along with the OPD section of the F.J. Grante Memorial Hospital. Merlin also provided ambulance services, transporting critical patients from Sinoe to Buchanan. Presently, the F.J. Grante Hospital is only meagerly functional, lacking adequate drug supplies, equipment and trained doctors, while the five static clinics previously operated by Merlin remain unreliably open, but totally without medical supplies or staff salaries. There are also two private clinics: the Catholic clinic and ENI clinic are expected to be open soon

### **Water and Sanitation**

The water and sanitation situation in the County is quite poor. In most of these areas drinking water is taken from creeks or open wells while the bushes are used as toilets. According to a survey carried out by NEWERA in 2004, most of the County, especially the rural areas, have no access to working hand pumps or wells. Out of a total of 109 hand pumps that were constructed in Sinoe County, only 51 are functional. Most have not been chlorinated and treated for months. In May 2005 six hand pumps were rehabilitated in a few

County districts through the National Foundation Against Poverty and Disease (NAFAPD) funded by UNMIL QIP. The NEWERA report indicates that out of a total of 236 toilets, there are only 159 poorly operational in the entire County. NEWERA through a project funded by QIP constructed six pit latrines in Sinoe County in May 2005.

### **Roads and Bridges**

Sinoe roads have always been in generally terrible shape, especially during the rainy season. The fourteen years of civil conflict compounded the problem because during that period, road maintenance was never undertaken, damaged/broken bridges at present cause impassibility for vehicles in most parts of the County. The main transport routes to Sinoe are the Monrovia—Buchanan—Greenville highway and the Monrovia—Zwedru—Greenville highway, which are all barely accessible. Several minor roads exist in the County which was constructed by logging companies for their convenience, but are all been taken over by bushes, making them quite impassable.

### **Education**

Recent statistics from the office of the County Education Officer puts the number of public schools at 175, with an enrollment population 17,715 categorized as follows: 149 primary schools with 14,118 students, and 26 secondary schools with 3,597 students. The total number of teachers and support staff in the Sinoe school system is 597 (Source: County education Officer, June 2007). Most schools do not have adequate numbers of teachers to meet student enrolment needs. All of the operating schools operate below minimum standards and are either run from private homes or church buildings or mosques. Prior to the war, most schools were in fairly good condition, but the vast majority were damaged or destroyed. Other major hindrances to education in the County are the lack of educational supplies, furniture and equipment, mobility, and adequately trained and salaried teachers.

### **Environmental Issues**

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people's access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their

environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

**Sensitive Sites**

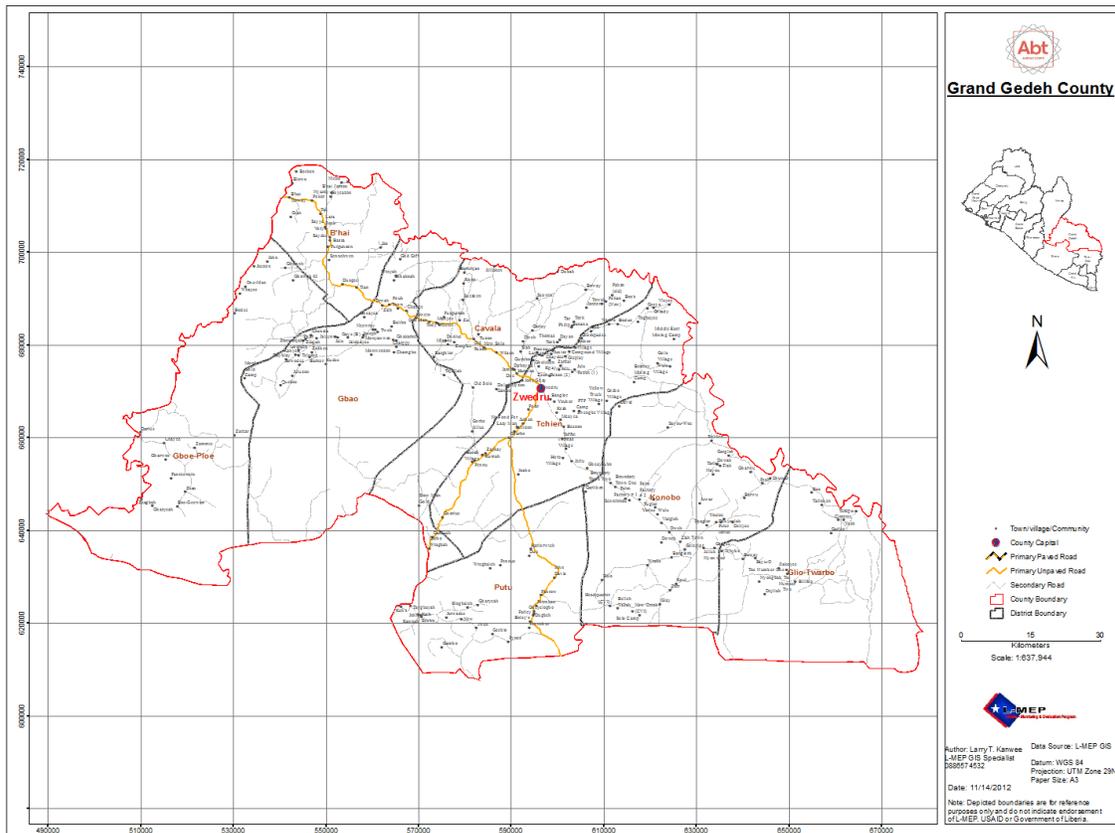
Three community forests, each one square mile large, were established in Kabada, Geeloh Town and Nimopoh Clan, all in Sinoe County.

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
Krahn-Bassa	Sapo National Park	Senkwehn (coastal)	None	Cestos Senkwehn
		Grand Kru River		Sapo National Park

**Grand Gedeh County**

**Grand Gedeh County** is in the southeastern portion of the West African nation of Liberia. Zwedru serves as the capital with the area of the county measuring 10,484 square kilometres (4,048 sq mi). As of the 2008 Census, it had a population of 125,258, making it the ninth most populous county in Liberia. The county is bordered by Nimba County to the west, Sinoe County to the southwest, and River Gee County to the southeast. The northern part of Grand Gedeh borders the nation of Côte d'Ivoire.

Figure 25: Grand Gedeh County map



(map provided of L-MEP)

Grand Gedeh is one of the few leeward counties created in the 1960s. It was established in 1964. Grand Gedeh was formerly known as the Eastern Province under the 1847 Constitution of Liberia. Its original capital was Tchien, now known as Zwedru.

### **Districts**

The districts of Gran Geheh County include (population):

- B'hai (10,367)
- Cavala (14,159)
- Gbao (12,324)
- Gboe-Ploe (6,271)
- Gilio-Twarbo (6,271)
- Konobo (24,705)
- Putu (16,426)
- Tchien (31,976)

### **Demographics**

Grand Gedeh County's average household size is 6.1 persons. The County has a dependency ratio of 1.21. The local society like the rest of Liberia is male-dominated with 93% male-headed households. The Kranh-speaking people are in the vast majority, making up 96% of the County's population. Other groups in the County include the Sapo (1%), the Bassa (1%) and the Kpelle (2%), though it is thought that all of Liberia's 16 tribes are represented at least in small numbers.

### **Climate**

The climate of Grand Gedeh County, like many parts of Liberia, is determined by the Country's geographic position near the equator and Atlantic Ocean. Temperatures are warm throughout the year with extremely high humidity. The climate is characterized by little seasonal change of temperature and humidity, but by changes between day and night. There are basically two seasons, rainy and dry, which are marked by variation in precipitation. These seasonal patterns result from the movement of high and low pressure belts caused by the changing angle of the sun. The rainy season runs from April to October, while the dry season runs from October to April. The average annual rainfall of Grand Gedeh County ranges from 76 inches in the upper or northern part to 107 inches in the lower or southern part. Average temperature is 77.5° F (25.5°C).

### **Topography**

Grand Gedeh is categorized under the highlands of Liberia, which is generally characterized by plateau and mountain ranges up to 1,000 ft (300 M). Important mountain ranges are the Puto and Tiempo. The hilly terrain is an impediment to road construction; gradients are steep and irregular, and the river valleys are V-shaped and narrow in their upper reaches.

### **Geology**

The soils are not unlike those of the rest of the country, generally amenable to a variety of agricultural uses. The rock of the County forms part of the West African croton, recognized by its stability and general absence of tectonic activity during the last 2,500 million years.

### **Vegetation**

The vegetation of Grand Gedeh County is typical of the tropical rain forest, characterized by evergreen and semi-deciduous forest.

## **Institutional Structure**

The following government institutions are in place in the County: Ministries of Internal Affairs; Education; Health and Social Welfare; Commerce and Industry; Finance; Rural Development; Agriculture; Lands, Mines and Energy; Gender and Development; Youth and Sports; National Defense; and Justice, as well as the Forestry Development Authority, and Liberia Domestic Airport Agency.

## **Natural Resources**

### *Timber*

Grand Gedeh County is mostly characterized by primary rain forest, which contains many species of trees attractive to foreign and local investors. Prior to the civil crisis, several logging companies operated in Grand Gedeh, including LLWPC, PTP, and ULC, whose activities created valuable jobs. Concerns that Liberia's forest and mineral resources had been used to fund aggressions in the West African sub-region led to the imposition of sanctions on the industry by the United Nations. As a part of the forestry reform program, the Government of Liberia (GoL) cancelled all concession agreements across Liberia. Consequently, there exists no large-scale or formal forestry activity in the County.

### *Mining*

Prior to the civil crisis there were two companies involved in gold mining in Tchien and Konabo Districts, namely CVI and Bentley International. Since 1990 mining has only been carried out illicitly and in an unorganized fashion. Grand Gedeh is known to have gold, diamond and iron ore deposits, the development of which will contribute to the overall development of the County and improve living standards.

## **Agriculture**

In 2005, the farming community in Grand Gedeh County cultivated the following food crops: rice (93% of farmers), cassava (35%), sweet potatoes/eddoes (3%), plantain/ banana (12%), corn (5%) and other vegetables (3%).

Some 26% of farmers were growing cash crops in 2005. The most important cash crop grown in the County in 2005 was cocoa (72% of cash crop producers). This was followed by plantain/banana (38%), coffee (13%) rubber (4%), palm nuts/oil (4%), coconuts (2%) and pineapple (2%).

## **Healthcare**

Out of a total of 17 Basic Health Units in the County, only 11 are functional in the three districts. One hospital is operational, located in the Zwedru. MSF, Merlin and Caritas are the three NGOs running these health facilities. Three ambulances donated by UNHCR are used by Merlin. The Ministry of Health and Social welfare in March of 2007 reported the total absence of pharmacy and drug/medicine stores in Grand Gedeh.

## **Water and Sanitation**

Only about 42% of the Liberian population has access to improved drinking water and only about 39% of the population has adequate means of human waste collection.

## **Roads and Bridges**

The Chinese UNMIL contingent has repaired most of the roads between Zwedru and the other Counties: Zwedru–Greenville (Sinoe), Zwedru-Tappita (Nimba) and Zwedru- Harper through Fishtown (River Gee). But with the heavy rainy season and lack of maintenance, most of these roads will likely deteriorate again. Many bridges are impassable due to the war, lack of maintenance or structural weaknesses and

need to be fixed.

As the roads improve, private individuals are providing transportation for persons and goods from Monrovia or neighboring countries to Zwedru and through Grand Gedeh to River Gee, Maryland and Sinoe Counties. No government owned or contracted transportation company is operating in Grand Gedeh County. Private motorbike taxis are commonly used for trips within Zwedru and to nearby towns.

### Education

The educational sector in Grand Gedeh is in need of assistance in many different forms. Schools are in need of renovation, furniture, WATSAN facilities, teachers' quarters, and learning materials. Teachers are in need of training and better incentives.

### Environmental Issues

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people's access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

### Sensitive Sites

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
Krahn-Bassa	Grebo	Zwedku*	<i>None</i>	Zqedru*
Grebo	Gbi			

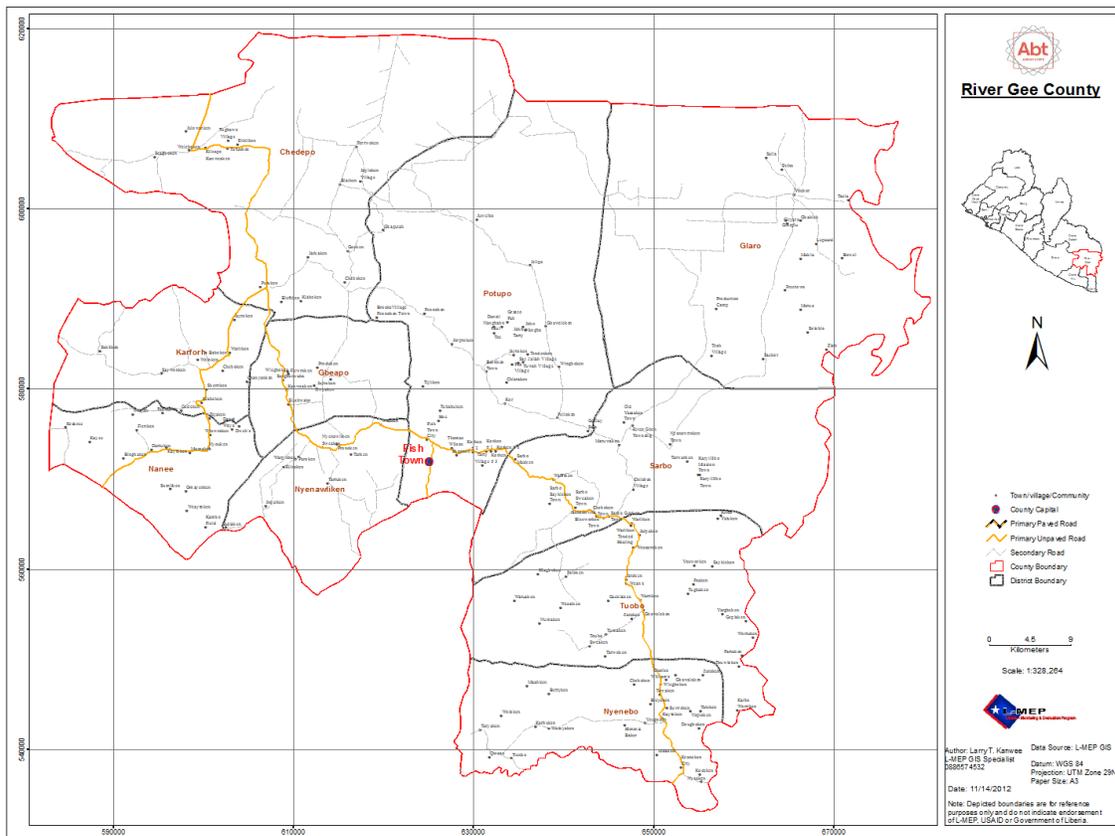
\* *Probably different spellings of same site*

## **South Eastern B**

### River Gee County

River Gee County is in the southern portion of the West African nation of Liberia. Fish Town serves as the capital with the area of the county measuring 5,113 square kilometres (1,974 sq mi). Tenth largest in size, it is bordered by Sinoe County to the west, Grand Gedeh County to the north, and Grand Kru and Maryland counties to the south. The eastern part of River Gee borders the nation of Ivory Coast along the Cavalla River. As of the 2008 Census, it had a population of 66,789, making it the third least populous county in Liberia.

Figure 26: River Gee County map



(map provided of L-MEP)

River Gee is one of the newest counties in Liberia. It was carved out of Grand Gedeh County, which was formerly part of the Eastern Province prior to 1964. The County was established in 2000 and has its political seat in Fish Town. Establishment of the County was predicated upon growing tensions between the Grebo and Krahn ethnic groups over the years, particularly during the 1980s and 1990s, characterized by military and phantom democratic regime of Samuel Doe, and the early war years of Charles Taylor. The quest for a separate political identity was eminent, owing to the rancor between the two groups. River Gee has three large settlements: Fish Town, which is famous for its catfish water, Kanweaken, which is a commercial Town, and Webbo, noted for missionary activities.

### Districts

The districts of River Gee County include (population):

- Chedepo (10,518)
- Gbeapo (10,934)
- Glaro (4,992)
- Karforh (5,956)
- Nanee (6,002)
- Nyenawliken (5,159)
- Nyenebo (5,703)
- Potupo (7,337)
- Sarbo (5,320)

- Tuobo (4,868)

### **Demographics**

River Gee County has an average household size of 5.9 persons and a dependency ratio of 1.35. Local society, like the rest of Liberia, is patriarchal, thus accounting for the sex of household head for male and female being 91% and 9% respectively. 10% of households sampled in the County were headed by elderly persons. The Grebo and Krahn vernaculars are the two most often spoken in the County. Grebo is the largest ethnic group, accounting for some 92% of the total population. Of households surveyed during the 2006 Comprehensive Food Security and Nutrition Survey (CFSNS), 13% reported having members who were chronically ill or disabled, while 29% were headed by chronically ill or disabled persons. The percentage of orphans in the County amongst household surveyed is 1%.

River Gee has one of Liberia's lowest population densities per square kilometer. Some areas have very small communities, sometimes with no more than 10 families, spread throughout the forest.

### **Climate**

River Gee's climatic condition is typical of the upper southern part of Liberia, characterized by warm temperatures and extremely high humidity. Seasonal changes of temperature and humidity are minor, although there are variations between day and night. There are basically two seasons, the rainy and the dry. The rainy season runs from April to November, while the dry runs from November to April. Average annual rainfall of River Gee is 107 inches, and the average temperature is 77.5°F.

### **Topography**

The topography of River Gee is typical of the highlands of Liberia. It is generally hilly and gradients are steep and irregular. Important highlands are the Tienpo Mountain and the Killepo Range. River valleys are v-shaped and narrow in their upper reaches.

Drainage systems include the Cavalla, Dugbe, Gee, Nun and Gbeh Rivers, as well as numerous creeks and tributaries, resulting in a dendritic (tree-like) drainage pattern. Waterfalls, rapids and crags are typical characteristics of the rivers and streams.

### **Geology**

The geology of River Gee has similar features to most other parts of Liberia. The formation of rocks forms part of the West African Croton, noted for the absence of tectonic activities over the last 250 million years.

### **Vegetation**

Vegetation of River Gee County is typical of the tropical rain forest, which is characterized by evergreen and semi deciduous forest. Logging and farming activities over the years have contributed to about 2.6% loss of the forest in the County. Nonetheless, the County still boasts of ample forest and timber for harvest.

### **Institutional Structure**

The constitutionally mandated structure of local government in Liberia includes: a Superintendent who leads the County Administration with the support of the Assistant Superintendent for Development and District and Township Commissioners who are also appointed by the President. In addition, Line Ministries are deployed to the County and within districts; these are civil servants who receive their appointments from central government line ministries. City Mayors, Clan Chiefs,

Paramount Chiefs and General Town Chiefs are elected during municipal elections, but due to the civil conflict and the installation of the transitional administration they have remained in power without going through the normal procedure of selection.

## **Natural Resources**

### *Timber*

River Gee County has large, rich forest that contains numerous species of trees that are sought after by foreign and local investors. Before the civil crisis in Liberia, many logging companies operated in the area, including MWPI, TTCO and MLC (in Sarbo and Glorra Districts), and ULC (in Chedepo, Tienpo and Gbeapo Districts). These organizations created employment opportunities, maintained feeder roads, trained people as skill laborers in the wood processing industry and provided health care, all of which helped to improve the living standards of the people in the region.

### *Mining*

Before and after the civil crisis, only illicit mining by private individuals has been going on in the County. The GoL commissioned comprehensive food and nutrition survey report published in 2006 puts illicit mining activities in River Gee at 4% among households.

According to Land and Mines Ministry, there are ample deposits of high-grade gold and diamonds in Joquiken, Gmayenken, and the Killepo Belt. Investments in mechanized mining will provide economic empowerment, reduce unemployment, increase development initiatives and contribute to the goals in the PRS.

### *Rubber*

The proportion of households in the County engaged in rubber tapping as means of generating income is put at 8%, but the potential is much greater. Investments in the rehabilitation of River Gee's rubber industry will have important effects on the economy.

## **Agriculture**

Subsistence agriculture is the only mode of agricultural productivity. Cooperative forms of work (locally known as *koo'* in other parts of rural Liberia) are also a normal pattern in farming activities. The local economy in River Gee is largely horticultural and subsistence based. The agriculture activities in the County are limited to shifting cultivation, which does not produce enough food for consumption and sale.

## **Healthcare**

There are three Health Centers and 11 public clinics in the County. These facilities have not received routine assistance from INGOs or UN agencies. Recently, Medical Emergency Relief Corporative International (MERCi) targeted six of them. The County has no referral hospital. Two small private clinics are also operating in Jarkaken, Chedepo District, supported by Catholic Health Service (CHS); and in Japroken, Potupo District, supported by the Lutheran Church. The American NGO Christian Humanitarian Assistance Programme (CHAP) plans also to offer some support to the clinic in Tiempo Statutory District. There is no secondary health care. There is not a single doctor in the County and there is an evident need of trained and qualified health personnel, since the majority of the health workers are volunteers. Moreover, despite their dedication, the salaries of contracted health workers are not paid regularly. All health clinics are reported to be lacking hospital equipment and medicines. Additionally, people who live outside the main Towns have to walk for hours in order to reach a clinic or

Health Center.

### Water and Sanitation

The war affected every sector of Liberian infrastructure, including water and sanitation. Access to safe drinking water remains the same as in the war years, although with minor improvement through the help of UNDP and German Agro Action (GAA), an international NGO. Most of the hand pumps and wells used by the local population prior to the war were destroyed during the conflict. The large majority of citizens use water drawn from creeks and rivers for personal consumption.

### Roads and Bridges

Road transport is very challenging in River Gee. The County has one major ‘highway’ that runs North to South: the Zwedru-Fish Town-Harper highway. UNMIL Chinese Engineering and Rehabilitation, Recovery and Reintegration (RRR), working on road rehabilitation and side brushing, has made the Zwedru-Fish Town-Harper highway passable deep into the rainy season, while last year in late May and early June there were two major impassable spots on both East and West from Fish Town. Presently, there are a couple of bad spots which can easily develop into critical spots if no action is taken to prevent this deterioration. There are 22 secondary roads leading to district Towns and villages. Many of them are in poor shape.

### Education

The education sector in the County, like in other parts of Liberia, faces numerous difficulties, from inadequate facilities to inadequate personnel and material in terms of quantity and quality. The result is that there is a general lack of modern school buildings, furniture, and materials, making for an inadequate learning atmosphere. Additionally, a large number of untrained teachers, most of whom are volunteers, continue to pose major challenges to the quality and standard of the school system. The County hosts the only training institute for primary school teachers in the entire southeastern region, the Webbo Rural Teacher Training Institute (WRTTI). Located in Konowroken, Webbo Statutory District, the premises remain in good condition although damaged during the war. Plans to rehabilitate WRTTI are currently under consideration.

### Environmental Issues

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people’s access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

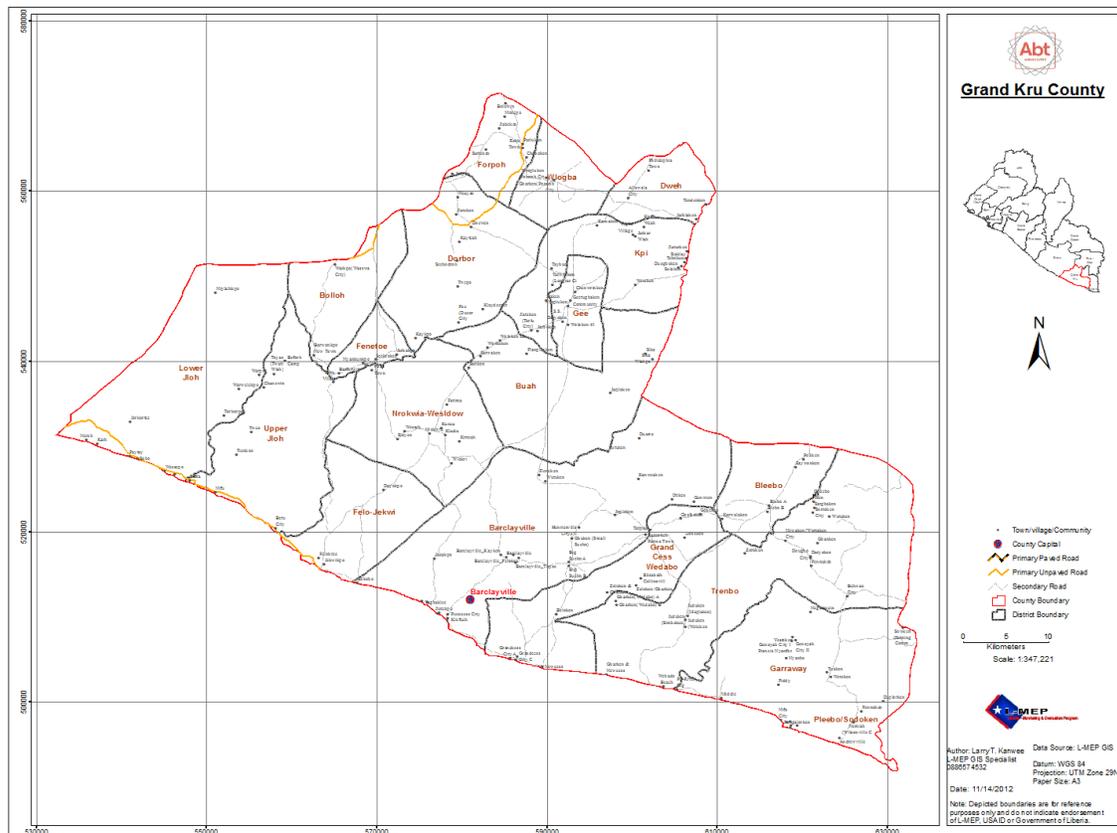
### Sensitive Sites

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
Grebo	Sapo National Park	Grand Kru River	<i>None</i>	Cavalla River
	Grebo			

## Grand Kru County

Grand Kru County is in the southeastern portion of the West African nation of Liberia. Created in 1984, Barclayville serves as the capital with the area of the county measuring 3,895 square kilometres (1,504 sq mi). The county is bordered by River Gee County to the northeast, Sinoe County to the northwest, and Maryland County to the southeast. The southern part of Grand Kru borders the Atlantic Ocean. As of the 2008 Census, it had a population of 57,913, making it the least populous county in Liberia.

Figure 27: Grand Kru County map



(map provided of L-MEP)

Grand Kru was created in 1984/1985 by the merger of Sasstown Territory and Kru Coast Territory. Kru coast territory which had previously been part of Maryland County, and Sasstown territory which had previously been part of Sinoe county.

The socio-economic situation of Grand Kru County is fragile for the fact that the County is isolated from nearly all basic services and residents largely depend on subsistence farming for survival. A few government and NGO jobs are the only sources of wage employment.

### Districts

The districts of Gran Kru County include (population):

- Barclayville (11,573)
- Bleebo (1,710)

- Bolloh (1,917)
- Buah (643)
- Dorbor (2,364)
- Dweh (928)
- Felo-Jekwi (2,011)
- Fenetoe (1,696)
- Forpoh (1,545)
- Garraway (9,525)
- Gee (2,543)
- Grand Cess Wedabo (10,809)
- Kpi (1,597)
- Lower Jloh (1,285)
- Nrokwia-Wesidow (1,876)
- Trenbo (3,631)
- Upper Jloh (1,573)
- Wlogba (687)

### **Demographics**

Households in Grand Kru County were recently reported to have an average membership of 5.8 persons, while nationally the rate is slightly lower at 5.6 persons. The County's dependency ratio is 1.61. Families or households in the County are headed mostly by males (90%), while Liberia is 87% and 13% for males and females respectively. Elderly-headed households in the County represent 7% of the total, higher than the national percentage. Some 4% of households in Grand Kru include chronically ill or disabled people, compared to the average of 9% across Liberia.

Three major dialects are spoken in the County. These include Bassa (spoken by 1%), Grebo (spoken by the majority (65%), and Kru (spoken by 33%).

### **Climate**

The geographic position of Grand Kru County near the equator and proximity to the Atlantic Ocean determine the County's climatic condition. Average annual rainfall ranges between 107 inches in the Northern part of the County to 160 inches in the Southern part. The climate is characterized by little seasonal change in temperature and humidity, but by daily changes between day and night. The seasons (dry and rainy) are marked by variation in precipitation. The rainy season runs from April to September while the dry season spans between October and March. Generally the wind blows from the Northeast during the dry season and from the Southwest during the rainy season. Due to the equatorial location of Grand Kru County, the sun is overhead almost all the year. Average annual temperature is 25.5°C (77.5°F).

### **Topography**

The topography of Grand Kru is generally characterized by two major landforms: coastal plains and rolling hills. There are several hills, plains and valleys and one recognized mountain called Sawleh, in Dorboh Statutory District. There are many rivers, including Dorboh, Norh, Misnoh, Snoh, Neh, Chen, Barffor, Gen, and Gbatu, all with waterfalls. There is a lake in Sasstown called Trengbe.

### **Geology**

The geological structure of Grand Kru County is typical of South-eastern Liberia, which is generally

classified as having rock of the Eburnean age, generally biotite rich. The major tectonic feature is the Dube Shear Zone, which has potential for mineral exploration.

Soil types found in the County are reddish-brown soil and gray to black soil. These soil types support the growth of variety of tree crops such as rubber, oil palm, coffee and other crops such as corn and rice. The southern part of the County is characterized by sandy soil.

### **Vegetation**

Forest resources in the County are vast and unexploited. Grassland includes a huge savannah spread over the coastal areas of the County suitable for animal husbandry. Prior to the civil war the region's extensive rainforests contained a wide variety of wildlife including wild pigs, bongo, dik-dik, pangolin, civet, pygmy hippo, African buffalo and colobus monkey all of which are hunted for food and hides. Also found are snakes, and very small populations of forest elephants and leopards.

### **Institutional Structure**

*(No information was available)*

### **Natural Resources**

#### *Timber*

A good portion of Liberia's forest reserve is located in the southeastern region, of which Grand Kru is a part. The total forest cover for Maryland, Grand Kru and River Gee counties is 119,344 hectares. About 75% (89,508 hectares) of this forest cover is located in Grand Kru County. According to the Forestry Development Authority (FDA) the forest of Grand Kru can support logging activities for up to 25 years, and as logging commences, plans will be laid for the implementation of a reforestation program to renew the resource. Many non-timber forest products are also found in abundance in Grand Kru County including bamboo, reed, rattan bush, meat, nuts berries, and materials for traditional medicines and local construction.

#### *Mining*

Exploration carried out in the County suggests huge deposits of gold and diamond. For example, reports from an exploration conducted by Liberty Gold Company reveal that Dugbo and surrounding areas including Clay-deeper are endowed with huge deposits of gold and diamond. Currently, there are only illicit mining activities ongoing.

Grand Kru County has three mining agencies: Buah Mining Agency, Barforwin Mining Agency and Barclayville Mining Agency. There are eight mining claims, five survey clearances and three prospecting licenses in the three agencies. Liberty Gold is a private firm that has applied to the Government of Liberia and is now prospecting in Grand Kru County. Against the backdrop of the new Mineral Development Agreement (MDA), Grand Kru County has selected industrial gold mining as one of its major investment priorities in the Poverty Reduction Strategy (PRS) process.

### **Fishing**

Grand Kru County has a long coastline that has potential for mechanized ocean fishing, especially from the communities of Garraway, Po-River, Grandcess, Picniccess, Sasstown and Jloh. Traditionally, the Kru people on the coast are a fishing people, but today fish only on the artesanal level. Also inland fishing and aquaculture have huge potential in Grand Kru due to its many rivers, creeks and swamps.

## **Agriculture**

The two main staple crops cultivated are rice and cassava. Subsistence farming is usually conducted in community farms using a process of shifting cultivation. Like most other counties in Liberia, in 2005 farmers in Grand Kru were cultivating the following food crops (by percentage of farmers): rice 82%, cassava 82%, sweet potatoes/eddoes 10%, plantain/banana 22%, and vegetables 11%. During this same period the following cash crops were cultivated: rubber 19%, coffee 1%, cacao 20%, sugar cane 27%, pineapple 12%, coconut 12%, plantain/banana 65%, palm nut/oil 5% and cola nut 3%.

## *Livestock*

Grand Kru County has great potential for livestock breeding and poultry, as there are large savanna grasslands in the County. The County was historically known for the breeding of the livestock, especially cows, goats and sheep. Currently people are restocking on an individual basis in almost all of the major communities the County. Poultry, cattle, sheep and goats are found in and around most villages. Most animals are of pygmy variety as larger varieties die quickly due to the heat and humidity.

## **Healthcare**

Health services are severely limited, especially in the largely inaccessible districts of Buah, Forpoh, Jloh, Dorbor and Sasstown. This in combination with the food security problem means that the health of the people suffers. According to the Comprehensive Food Security and Nutrition Survey, more than 70 percent of households are considered to be food insecure or highly vulnerable to food insecurity. Grand Kru also has the highest chronic child malnutrition rates (47.3%). Access to health services such as immunization, Vitamin A supplementation and de-worming is extremely low, and infant and child feeding practices are poor due to poverty and lack of information.

## **Water and Sanitation**

Only an estimated 7% of the (58,125) population has access to safe drinking water, while 85% of the population has no access to proper toilet facilities. In 2004 the NGO Emergency Rehabilitation Services implemented a water and sanitation project with funding from the Emergency Response Fund. No agency implemented activities in the sector in 2005. In 2006, the Lutheran World Federation is digging 13 wells and UNHCR about 17 - 12 new and 5 rehabilitated by their implementing partner CARITAS. In 2006 the UNMIL QIP unit financed a US\$24,500 project through LADI (Liberian Agency for Development Initiatives) for six wells and three latrines in the communities of Behwan, Farina Town and Big Suehn, but did not complete the project.

## **Roads and Bridges**

Roads are the top-most priority issue among the people in Grand Kru. The County has long been referred to as the "Walking County", as more than two-thirds of the County is inaccessible by car. The situation has changed with the landmark construction and inauguration of the George W. Bush Bridge, but the lack of roads and bridges continues to hamper development as well as humanitarian assistance. Even though from 1990 to 2003, the County experienced the kind of logging exploitation that is often accompanied by improvements in road infrastructure, the County still makes due with crude log bridges, even over its largest rivers. Moreover, eight out of twelve months the County is completely isolated from the rest of the country due to bad roads precipitated by heavy rain.

In June 2005 the UN Integrated Regional Information Network reported that the roads in Grand Kru had decayed and become overgrown by dense bush, rendering them impassable, except on foot, and that the bridge across the Nu River at Barclaville had been destroyed.

### Education

The County education supervisory team is now staffed with a County Educational Officer (CEO) and eight District Education Officers (DEOs). But throughout the County, most schools lack proper structures, chairs and tables, and remain in dire need of educational resources for both teachers and students. There are still only five schools equipped with desks and chairs. The lack of trained and qualified teachers especially for the senior high schools is an issue of high priority.

### Environmental Issues

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people's access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty- environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

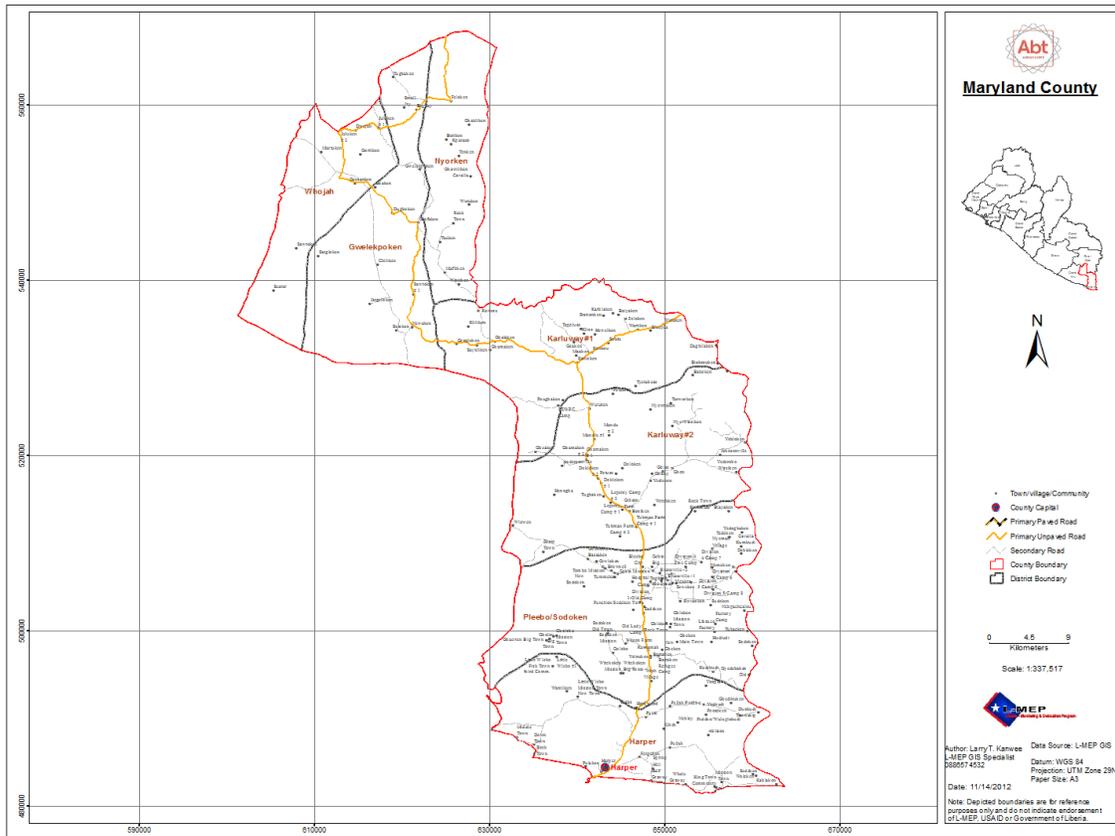
### Sensitive Sites

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
<i>None</i>	<i>None</i>	Grand Kru River	<i>None</i>	<i>None</i>

### Maryland County

Maryland County is in the southeastern portion of the West African nation of Liberia. Harper (also known as Cape Palmas) serves as the capital with the area of the county measuring 2,297 square kilometres (887 sq mi). The County borders the Atlantic ocean to the South; the Cavalla River representing the international border with the Republic of Ivory Coast to the East; Grand Kru County on the West; and River Gee County to the Northwest. As of the 2008 Census, it had a population of 135,938, making it the seventh most populous county in Liberia.

Figure 28: Maryland County map



(map provided of L-MEP)

Named after the State of Maryland in the United States, it was an independent country as the Republic of Maryland from 1854 until it joined Liberia in 1857.

### Districts

The districts of Maryland County include (population):

- Gwelekpoken (10,060)
- Harper (38,024)
- Karluway #1 (8,494)
- Karluway #2 (17,159)
- Nyorken (10,057)
- Pleebo/Sodoken (43,223)
- Whojah (8,921)

### Demographics

The main ethnic group in the County is Grebo, also found in River Gee County, eastern Grand Kru County, and southeastern Sinoe County. It is roughly estimated that about 98% of the County's population is Christian, 1% Muslim and another 1% Animist.

### Climate

Maryland County is situated in the 100 to 120 inches rainfall zone. The annual average rainfall is 101.5 inches. Relative humidity is high and the sunshine hours are favorable for the growth of a variety of crops. Two seasons—rainy and dry—exist in the area. Rainy season begins in April and ends in October, while the dry season commences in November and ends in March. The highest temperature recorded for this area was 28 degrees Celsius. The coldest months are August and September.

### **Topography**

The Topography of Maryland County is gently rolling with wide and shallow valleys. There are a few hills, valleys and swamps toward the far North and Central part of the County. Maryland County has large rivers: the Cavalla, located in the East, the Gee River, in the Northwest, River Nun in the West and Ni Dellor in the West. The Gee River has several waterfalls, which flow and drain from the swamps and tributaries into the Ocean.

Elevation ranges from sea level along the Atlantic Ocean to 826 ft. (248 m) at Wuluke village.

### **Geology**

Soil types found in the County are reddish-brown soil and also range from gray to black soil. These soil types support the growth of a variety of tree crops such as rubber, oil palm, coffee, as well as corn and rice. In the southern part of the county, the soil type is sandy.

### **Vegetation**

Because of Liberia's geographical location, Maryland County falls within the tropical rain forest region. The vegetation found covering the County consists of primary and secondary forests and savannas. The primary forest is found towards the Northern part of the county. Some of the primary forest resources have been exploited by logging companies, reducing it to secondary forest. Shifting cultivation practices are also destroying the forest in the area.

### **Institutional Structure**

Maryland County is divided into seven main administrative Districts. A district commissioner heads each district. The County has two Statutory Districts – Barrobo and Karluway, each headed by a statutory district superintendent. There are forty-seven townships, each headed by a township commissioner. Maryland County has four cities, including Harper Pleebo, Karloken and Glofaken, each headed by a city mayor. The County has four electoral districts, 15 chiefdoms and 26 clans.

The constitutionally mandated structure of local government in Liberia includes a Superintendent, who leads the County Administration with the support of the Assistant Superintendent for Development, and District and Township Commissioners, who are also appointed by the President. In addition, Line Ministries are deployed to the County and within districts – these are civil servants who receive their appointments from the central government. City Mayors, Clan Chiefs, Paramount Chiefs and General Town Chiefs are elected during municipal elections, but due to the civil conflict and the installation of the transitional administration, they have remained in power without going through the normal procedure of selection.

### **Natural Resources**

Maryland County is also endowed with rich soil, minerals, ocean, rivers, lakes and forest. All of these natural resources have high potential for investment.

### *Forestry*

Prior to the war, Maryland had a viable trade in timber, and new investments in the sector could yield significant dividends for the people of the County, both in terms of employment and revenue generation. Currently, there exists no large-scale formal forestry activity in the County. The forest provides many resources for citizens, such as logs, raffia, medicinal herbs, charcoal and firewood. Despite the economic importance of the forest, farmers through their shifting cultivation practices continuously deplete it.

### *Mining*

The County is known to contain sizeable deposits of gold, manganese and bauxite, suggesting major prospects for the mining industry. Gold mining in the County is being carried out only on a small scale.

### *Rubber*

Rubber production is the County's largest industry. Rubber from the County is produced by the Cavalla Rubber Plantation and 115 of small-size individual rubber farms. The Cavalla Rubber Plantation is the largest producer of rubber in Maryland County. The raw rubber produced by the Plantation is transported to Monrovia by sea.

### **Fisheries**

Fishing is a common livelihood activity along the coast, employing an estimated 2,000 people. The majority of the fishermen are found in Harper District, most of them Fantis, a people originally from Ghana. The local fisher folk also include the Grebo and Kru. Presently, there are no facilities for the preservation of fish in Harper, Cavalla, Rocktown, Middletown, and Fish Town. Presently, fishing is carried out only on the subsistence level, and fisher folk do not have the required implements to fish at a profitable scale. Inland or river fishing is on a relatively small scale.

### **Agriculture**

Presently, the agricultural sector is the major employer in the County. The primary staple foods in Maryland are rice and cassava, supplemented with plantains, yams and eddoes. Current agricultural productivity is low, due to primitive farming methods, lack of modern technology, inadequate tools, and a lack of access to capital/credit. Farmers usually apply a system of shifting cultivation, and every year they clear up to 5 acres of wild forest or low bush with crude hand tools.

### **Healthcare**

The status of health services in the County has been gradually improving, but much still needs to be done to ensure access to quality health care for all the people of Maryland. According to the County Health Team (CHT), there were 23 health facilities before the war, but presently there are only 17 supported including one referral hospital (JJ Dossen Hospital, supported by Merlin) and 16 clinics (7 supported by UNHCR through MERCI, 2 by Catholic Health Services, 1 by a private company, 4 by UNICEF through WVL and 2 by Merlin). The remaining ones are yet to be reactivated. Support provided to the health facilities include rehabilitation, provision of drugs, medical supplies and equipment, and a stipend for the health workers

### **Water and Sanitation**

Presently most people drink unsafe water from creeks, rivers and open wells as most of the hand pumps have been destroyed. SOLIDARITE and CARITAS with funding from UNHCR, ECHO and DFID are involved in construction and rehabilitation of wells and installation of hand pumps and sanitation, while ERS with support from UNICEF are providing water and sanitation facilities to schools in Harper District. DRC has

got funding from ECHO to implement water and sanitation activities as well. Proper waste disposal is lacking and people in the County defecate in the bush and on the beach. The County has had high incidences of acute watery diarrhea outbreaks especially during the rainy season.

From data consolidated by the Water and Sanitation Sector Working Group, there are about 265 wells, creating access to clean drinking water to about 66,250 people. However, whether all of them are currently functioning, is not known. There are about 1,056 family latrines and 37 institutional latrines completed, but it is difficult to tell whether all of them are being appropriately used. The sector is currently looking for ways to verify the functionality and usage of the completed water and sanitation facilities in the county.

### **Roads and Bridges**

Harper is a port city and is connected to the rest of the country by road, air, and sea. The main road proceeds north from Harper passing through Pleebo, Karloken, Fish town and Zwedru. The road connection to Barclayville (the Administrative Capital of Grand Kru County) branches off at Pleebo. A short distance from Harper towards Pleebo, another road to the East leads to the Cavalla River to the border with Côte d’Ivoire at Pedebo. The most difficult part of the road is the Welegboken swampy area, which is some 80 km from Harper towards Fish Town. The road is particularly impassable during the rainy season, implying complete inaccessibility by road to the whole Southeast region. In the northern part of the County lies the District of Barrobo, whose development has been hampered by the lack of roads. Smaller roads and footpaths are the only connections between many towns and villages. Presently, Harper City has one airfield operated by UNMIL, which also serves for ICRC and WFP aircraft. There are no railroads in the entire county.

### **Education**

The education sector is in a very poor state, with most schools dilapidated from years of neglect. According to report from the County Education Office, there are 151 schools in total with 42 in Harper, 40 in Pleebo, 34 in Karluway and 35 in Barrobo. There are 31 ALP schools in the County supported by Ibis and UNICEF through CAP. DRC, UNICEF, WFP, UNHCR, WVL and Ibis are involved in the Education sector support with assistance ranging from school rehabilitation, construction, provision of teaching and learning materials, water and sanitation facilities, Accelerated Learning Programmes (ALP) and Emergency School Feeding.

### **Environmental Issues**

The people of the County, and especially the poor, are critically dependent on fertile soil, clean water and healthy ecosystems for their livelihoods and wellbeing. This reliance creates complex, dynamic interactions between environmental conditions, people’s access to and control over environmental resources, and poverty. In addition to being vulnerable to environmental hazards, the poor are usually confronted by economic, technological and policy-related barriers in deriving full benefits from their environmental assets. Taking strategic actions based on knowledge of the poverty-environment relationship is a prerequisite for enduring success in the effort to reduce poverty. Investments in the productivity of environmental assets will generate large benefits for the poor and for the enhancement of overall growth.

### **Sensitive Sites**

National Forests	Protected Areas/ National Parks	Areas considered for PA status	Important Wetlands	IBA
<i>None</i>	<i>None</i>	<i>None</i>	<i>None</i>	<i>None</i>

## PESTICIDE PROCEDURES

Regulation 22 DFR 216.3(b) mandates the consideration of twelve factors when a project includes “assistance for the procurement or use, of both of pesticides”. This section addresses each of those twelve factors for the Malaria Control Program in Liberia.

### a. The United States Environmental Protection Agency’s Registration Status of the Requested Pesticide

Pesticides registered for IRS in Liberia and the United States, and recommended by WHO, will be preferred in this IRS project. However, some of the pesticides on the WHO list are not registered with the USEPA, for economic reasons rather than technical ones. Because this is an economic issue rather than a technical one, and because there is widespread use of these chemicals around the world, with a good database attesting to the safety of the chemicals, USAID and USEPA has chosen to allow the use of all WHO-recommended pesticides under the Africa IRS program. **Annex 5** presents toxicity data for these chemicals.

According to the US regulation 22 CFR 216.3 (b), when dealing with a project that uses pesticides, it is also a fundamental requirement that the pesticides be registered by the host governments. The pesticide regulating body in Liberia is the National Quarantine and Environmental Services of the Ministry of Agriculture, who monitor the import and use of pesticides in country. A permit must be obtained from the MOA in order to import the chemical. The following are the malaria control pesticides for IRS that are registered in Liberia. All WHOPES-approved pesticides for IRS are included in this SEA, except DDT.

The WHOPES pesticides considered for IRS that are also currently registered for use in Liberia include the following:

Table 8: WHOPES Pesticides Registered for Use in Liberia

Trade Name	Active ingredient	Uses	EPA status
<i>(None)</i>	Malathion		
Fenitrothion 50EC	Fenitrothion	General use	permitted
Sumi-Feni	Fenitrothion	General use	permitted
Sumithion 50 EC	Fenitrothion	General use	permitted
Actellic 25EC	Pirimiphos-methyl	General use/storage	permitted
Actellic Super EC	Pirimiphos-methyl	Storage	permitted
Cocostar 210 EC	Pirimiphos-methyl+bifenthrin*	Cocoa insect pests	provisional
Ficam Plus 10%	Bendiocarb	General use	permitted
Uden 20EC	Propoxur	Restricted use on cocoa	restricted
Festac 10% EC	Alpha-cypermethrin	General use	permitted
<i>(Cocostar 210 EC*)</i>	Bifenthrin		
Baythroid 168P	Cyfluthrin	Cotton insect pests	restricted
Decis 12.5 EC	Deltamethrin	General use	permitted
K-Otab	Deltamethrin	General use	permitted
K-Othrin SC25	Deltamethrin	General use	permitted
Deltaphlan 125 EC	Deltamethrin	General use	permitted

Trade Name	Active ingredient	Uses	EPA status
Trebon	Etofenprox	General use	permitted
Karate 2.5EC	Lambda-cyhalothrin	General use	permitted
Zap	Lambda-cyhalothrin	General use	-
Coopex	Permethrin	General use	permitted
Permethrin 50EC	Permethrin	provisional	provisional

EC=emulsifiable concentrate

Insecticides that are currently registered for Public Health use in Liberia include the following:

**Table 9: Insecticides Registered for Public Health Use in Liberia**

Trade Name	Active ingredient	Uses	EPA status
K-Othrine	Deltamethrin	Indoor pest control	permitted
Responsar	Cyfluthrin	Indoor pest control	permitted
Solfac	Cyfluthrin	Treatment of bed nets/indoor pest control	permitted

Banned chemicals include persistent organic pollutants (POPs), though DDT is listed under restricted use.

A request for approval must be made to the MOA for any pesticides that are selected by the Malaria Control Task Force that are not registered for use in Liberia, before procurement is initiated.

#### **b. The Basis for Selection of the Requested Pesticides**

Insecticide selection for any PMI supported program is subject to international procurement requirements of the US Federal laws. Requests to purchase public health insecticides used in IRS must be initiated at class level, rather than for a particular insecticide (compound). The insecticide class to be used in IRS is selected for each campaign based on a number of considerations.

#### **Primary Criteria for choosing pesticides:**

- a) **Approval by the World Health Organization Pesticide Evaluation Scheme:** Only insecticides approved by WHO can be used in IRS. Organophosphates, carbamates, and pyrethroids are WHOPES approved classes of pesticides for use in IRS and thus any can be used based on entomological data and host country registration status.
- b) **Registration for use in the country:** According to the National Quarantine and Environmental Services of the Ministry of Agriculture, Malathion is the only WHO malaria control pesticide that is not registered for use in Liberia. Bifenthrin is registered combined with pirimiphos-methyl in one of the listed products.
- c) **Residual effect for a period longer than, or at least equal to, the average duration of the malaria transmission season in the area:** According to WHO, all pyrethroids, carbamates, and organophosphates are expected to have duration of 3 to 6 months in terms of effectiveness; however, the duration of effectiveness varies under different climatic conditions. Three pyrethroids, known as longer-lasting pyrethroids, can last up to eleven months based on various field trials. For this reason, pyrethroids make the best choice during insecticide selection due to the longer residual

effect. Technical information on duration of effectiveness on the primary wall surface types will continue to be considered when selecting insecticide class(es).

- d) **Pesticide must be appropriate for use on the wall surfaces of the selected location:** Structures in the targeted regions can be made from one of four different materials: concrete brick, mud stucco over mud and twigs, thatch and zinc (corrugated metal). Near major towns and commercial centers, cement and brick walled houses predominant. The pesticides are more effective on the brick surfaces, and are less so with decreasing effectiveness on mud and thatch respectively. Structures made of corrugated metal are not sprayed as the pesticides to not adhere sufficiently to the surface to be effective.
- e) **Local vector susceptibility to the insecticide;** One of the major concerns when implementing IRS campaign is to prevent resistance to insecticide among vectors. Resistance to insecticide develops when a hereditary feature is selected in an insect population that reduces the population's sensitiveness to a given insecticide. The implementing partner is working closely with the Vector Control Unit (VCU) of the NMCP and the Liberia Institute for Biomedical Research (LIBR) to provide entomological monitoring of insecticide resistance and quality of spraying. The most experienced among the VCU technicians are engaged in some of the monitoring activities. Sentinel sites representing intervention and control site were selected to monitor mosquito densities, behavior, and insecticide resistance status. The implementing partner has developed data collection tools that enabled the collection of PMI entomology indicators. At the time of the writing of this report, most of the IRS target regions are showing resistant to deltamethrin (pyrethroid). An annual entomology study will provide support for insecticide selection for each IRS campaign.
- f) **Ecological impact:** The PEA for IVM assessed the toxicity of IRS insecticides to non-target organisms, including mammals, birds, fish, bees, and 'other aquatic' organisms. In summary, pyrethroids and carbamates are similar in toxicity to non-target organisms. Apart from propoxur, which has a low toxicity for fish and other aquatic organisms, the rest of the insecticides are all highly toxic to the same. Similarly all the insecticides from the approved classes are highly toxic to bees, apart from pirimiphos methyl. In mammals, all the insecticides approved by WHO for IRS carry low-to medium toxicity, with the exception of lambda cyhalothrin and propoxur, that are categorized as highly toxic to mammals. In avi-fauna, only propoxur is categorized as highly toxic with the rest categorized as low/medium in toxicity. It is important to note that in Liberia, wildlife thrives throughout the country due to the favorable ecological conditions. It is extremely important to maintain this biodiversity.

Table 10: Pesticide Toxicity

IRS Insecticide	Mammal	Bird	Fish	Other Aquatic	Bee	Persistence	Bioaccumulate
Alpha-cypermethrin (P)	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Persistent	Highly Bioaccumulative
Bendiocarb (C)	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Persistent	Highly Bioaccumulative
Bifenthrin (P)	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Persistent	Highly Bioaccumulative
Cyfluthrin (P)	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Persistent	Highly Bioaccumulative
DDT (OC)	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Persistent	Highly Bioaccumulative
Deltamethrin (P)	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Toxic	Highly Persistent	Highly Bioaccumulative

IRS Insecticide	Mammal	Bird	Fish	Other Aquatic	Bee	Persistence	Bioaccumulate
Etofenprox (P)	Low Toxicity	Low Toxicity	High Toxicity	High Toxicity	High Toxicity	Low Toxicity	Low Toxicity
Fenitrothion (OP)	Low Toxicity	High Toxicity	Low Toxicity	High Toxicity	High Toxicity	Low Toxicity	Medium to High Toxicity
Lambda-cyhalothrin (P)	High Toxicity	Low Toxicity	High Toxicity	High Toxicity	High Toxicity	Medium to High Toxicity	High Toxicity
Malathion (OP)	Medium to High Toxicity	Medium to High Toxicity	Low Toxicity	Low Toxicity	High Toxicity	Low Toxicity	Low Toxicity
Pirimiphos-methyl (OP)	Medium to High Toxicity	Low Toxicity	High Toxicity	High Toxicity	Medium to High Toxicity	High Toxicity	Low Toxicity
Propoxur (C)	High Toxicity	High Toxicity	Low Toxicity	High Toxicity	High Toxicity	Medium to High Toxicity	Medium to High Toxicity

Source: IVM PEA

Key	
High Toxicity	High Toxicity
Medium to High Toxicity	Medium to High Toxicity
Medium Toxicity	Medium Toxicity
Low to Medium Toxicity	Low to Medium Toxicity
Low Toxicity	Low Toxicity
Data Not Found	Data Not Found

g) **Human health impact:** The PEA for IVM also assessed cancer and non-cancer risks associated with all WHOPEs-approved insecticides by process (e.g., mixing insecticide, spraying, residing in sprayed house, etc.) and pathway (e.g. inhalation, dermal, ingestion, etc.), and cancer risks by process and pathway where available (mainly for DDT and select pyrethroids). In general, pyrethroids and carbamates pose less non-cancer risks than organophosphates when risks are assessed via any pathway. If organophosphates are used, then decisions on insecticide type should be informed in part by the human health toxicity and risk associated with each compound and formulation. For most organophosphates, it will be necessary to monitor the level of acetyl cholinesterase in any worker who may have been exposed to contamination. Occupational exposures to OP insecticides are measurable using blood cholinesterases and urinary excretion of chemical biomarkers. PMI will evaluate various approaches for monitoring sprayer exposure to Organophosphates (OP), and will develop protocols based on these evaluations. PMI will use these protocols to guide the implementation of the OP monitoring program. An investigation will need to be conducted to determine if Liberia has the capability to conduct biomonitoring and what level of capacity building would be required.

**Secondary Selection Criteria:**

Once the Malaria Task Force approves the analysis of these factors, then the criteria is updated to include international procurement language in which the criteria is clearly stipulated and then tendered out in accordance with international open competitive procurement rules. Once there are responses to the call for bids, the resulting proposals are subjected to secondary criteria including:

- Appropriate packaging for safety and standard delivery tools
- Unit cost of insecticide
- Timely delivery of the insecticide to the preferred point of delivery

- Local representation of supplier in host country
- Technical assistance with training and troubleshooting by supplier

Once a winning bid is selected, it is then submitted to PMI for approval and the local selection committee (including the NMCP), is informed of the now-named insecticide that has been selected and the reasons for its selection for the current IRS round. Once PMI/USAID, grants its approval, then procurement of the insecticide starts.

### c. The Extent to Which the Proposed Pesticide Use Is Part of an Integrated Pest Management (IPM) Program

IPM is defined<sup>6</sup> as:

“Integrated pest management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials [pesticides] are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms, and the environment.”

In Liberia, pyrethroids are being used in agricultural contexts, and may be responsible for the increased resistance that has been shown for some of these compounds. Also pyrethroids are used on LLINs, which have been widely distributed throughout Liberia, and may be contributing to the resistance issue.

Use of IPM for the control of the vector population responsible for malaria is limited to some common sense safeguards, such as limiting standing water around homes and communities, which can serve as a breeding ground for mosquitoes. However, because of the life-cycle requirements and the adaptability shown by these vectors, and the environmental conditions of Liberia, integrated practices have not demonstrated effectiveness.

IPM is often used in an agricultural context, but similar in nature is the concept of Integrated Vector Management (IVM). The major characteristics of IVM include:

- *Methods based on knowledge of factors influencing local vector biology, disease transmission, and morbidity;*
- *Use of a range of interventions, often in combination and synergistically;*
- *Collaboration within the health sector and with other public and private sectors that impact vectors;*
- *A public health regulatory and legislative framework.*

USAID strategy has been that IRS will be implemented as a component of IVM for malaria control, along with LLINs, larviciding and environmental management. These interventions are described in a preceding section on *Proposed Action and Alternatives*.

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<sup>6</sup> (<http://www.ipm.ucdavis.edu/IPMPROJECT/about.html>)

#### d. The Proposed Method or Methods of Application, Including Availability of Appropriate Application and Safety Equipment

IRS involves spraying a liquid insecticide with long lasting residual activity on the indoor wall surfaces where mosquitoes usually rest. The pesticide then dries up and leaves a crystalline deposit on the sprayed surface. A lethal dose of the insecticide is absorbed when the mosquito rests on the surface, which kills the mosquito.

Pesticide will only be applied using pressurized spray equipment approved for the pesticide in use, by trained spray operators wearing full PPE (face mask, gloves, overalls, hard hats with face shields, boots, neck protection and goggles). Experienced program operators will train spray operators in the correct spray procedures. These procedures have been proven to be effective for providing long-lasting effectiveness toward controlling the malaria vector mosquito.

The following IRS equipment will be used:

- **Spray Nozzles**

The program in Liberia will procure 8002E nozzles for the spray pumps, which are the standard size recommended by World Health Organization for mud wall.

- **Spray pumps**

The spray operators who implement IRS use HUDSON X-PERT backpack compression sprayers to apply a measured amount of insecticide on the interior walls of houses and structures. A water-soluble insecticide is added to the sprayer containing a pre-measured amount of water, the sprayer is pressurized, and the material is then applied to the interior walls of targeted house (structure). After the day's spraying is complete, spray operators must clean the sprayer following the manufacturer's recommendations to ensure their proper operation and calibration.

#### e. Any Acute and Long-Term Toxicological Hazards, either Human or Environmental, Associated with the Proposed Use and Measures Available to Minimize Such Hazards

The two broad categories of hazard are exposure to humans and domestic animals, and release into the environment causing environmental damage. These may occur at any point, from the production or importation of the pesticide through transportation, storage, distribution, pesticide preparation, spray application, cleanup, and final disposal, as well as post-spray due to improper spray deposition on household articles, or improper behavior of beneficiaries regarding sprayed surfaces. Hazards are examined in detail in the Environmental Mitigation and Monitoring Plan (EMMP) is discussed in the Environmental Impact section and **Annex 1**. The EMMP also includes mitigation strategies for each of the risks. The consequences of release and exposure are found in the toxicological profiles and in Table 5. The acute and long-term toxicological hazards of pyrethroids, carbamate and organophosphate-based pesticides are detailed in **Annex 5: Pesticide Profiles**.

Major hazards include exposure during handling (transporting or spraying), environmental release through vehicular accidents during transportation, and in the event of a fire at the storage facility or in transport igniting the pesticides. These hazards are discussed in more detail in the Environmental Impact section of this report, and have been addressed in the Environmental Mitigation and Monitoring Plan (**Annex 1**). In addition, the *Pesticide Storage and Stock Control* by the Food and Agriculture Organization

of the United Nations (FAO) provides detailed guidance on proper storage management practices, as well as remedial measures in case of spillage and incidents brought on by natural disasters including flooding. These guidelines therefore provide a sound basis for minimizing the risk of human, animal, or environmental exposure.

Exposure treatment for carbamates, pyrethroids, and organophosphate-based pesticides are detailed in Table 2, 3, and 4 and **Annexes 2 and 3**. Training for supervisors, spray team leaders, spray operators, washpersons, storeroom managers, and health officials include recognition of the symptoms of poisoning, incident response elevation protocol, and, for the medical professionals, the treatment protocols for each pesticide.

Specific measures to mitigate transportation-related exposure will include:

1. Training drivers before they transport insecticides from the customs warehouse or central storage facility to the local storage facility.
2. Ensuring that drivers are thoroughly knowledgeable about the toxicity of insecticides, and that training includes opportunities for drivers to respond to scenarios related to the transport of specified insecticides:

Drivers must prevent pesticide contamination in vehicles rented for the project in order to avoid negative consequences when the vehicles are used for other purposes, such as food transport. To prevent pesticide runoff from vehicle washing, drivers are responsible for wiping the vehicle bed with a damp cloth before washing the exterior of the vehicle

Under existing legislation, it is a legal requirement for major incidents resulting in spillage to be reported. However, a general observation is that in most developing countries, a lack of clarity on what constitutes a reportable chemical incident results in under-reporting (e.g., reporting a traffic accident involving a spillage as a traditional road accident, omitting the spillage aspect).

Other than transporters, storage area personnel, and spray teams, the people at risk of exposure are primarily the beneficiary population in the targeted communities. Acceptability of the pesticide and IRS intervention among the targeted households is a primary external factor and critical for compliance. The IEC program is of critical importance toward gaining this acceptability. It is important that the targeted community and households are adequately educated on safety, including procedures for removing personal belongings prior to spraying, observing the required exclusion period, and avoiding contact with sprayed surfaces on an indefinite basis.

Information, Education, and Communication (IEC) programs, also referred to Behavior Change Communication (BCC), are currently being implemented in targeted communities under the ongoing IRS operation. The BCC program utilizes television and radio shows, as well as community gatherings, schools, and places of worship to provide information on the importance of malaria control activities. NMCP also trains government county health team (CHT) and peer-educators to disseminate malaria messages and stimulate behavior change within communities. In conjunction with the Ministry of Education, the BCC program also incorporates malaria prevention messages into the Liberian education system, by training educators to use and understand malaria messages and by integrating malaria prevention strategies into the school curriculum. Through all of its activities, the BCC program emphasizes the role of the community in malaria control and prevention.

The campaign also includes direct communication through the spray operators. Communities are mobilized by each local administration. Clear instructions are provided on what to do before and after the house is sprayed, including the removal of all foodstuffs and cooking utensils, barring of entry into the sprayed rooms for at least two hours, preventing the re-entry of children until the floors have been swept clean or washed, and targeted training of selected health care providers at the region, district, and community levels on the management of pesticide poisoning.

#### f. The Effectiveness of the Requested Pesticide for the Proposed Use

Pesticides are selected for IRS based on efficacy in the intended use, and other extrinsic variables. Selection criteria have been expounded in the Description of Alternative and Proposed actions section discussion on Pesticide selection, and in *Factor b* of this PERSUAP.

Once the program is established, it is necessary to monitor vector resistance prior to the initiation of spray activities, to ensure that acceptable kill levels will be achieved. A resistance monitoring program has been established and is operating, and the results from this ongoing program will be a primary determinant of the choice of pesticide and other supplementary actions.

Pesticide efficacy is also affected by vector behavior, insecticide quality, and the residual action of the pesticide. The probability of vector-pesticide contact depends on whether the targeted vector feeds indoors (endophagic) and rests indoors (endophilic), as this increases the likelihood of the vector resting on the sprayed wall. The efficacy of the pesticide to kill may be either compromised if the vector exits after feeding without resting on the wall, or absent if the vector feeds outdoors (exophagic) and rests outdoors (exophilic). *An. arabiensis* and *An. funestus*, the major malaria vectors in Liberia, are mainly endophagic and endophilic. This makes them suitable targets for IRS.

Knowledge of vector susceptibility is critical to planning and evaluating the effectiveness of the IRS program. It enables timely forward planning to (i) manage the development of the resistance and (ii) evaluate new or alternative insecticides for possible future introduction should a change of pesticide be required. Resistance testing is done to (i) establish a baseline susceptibility of the local vectors for future reference, (ii) monitor changes that occur as time progresses, (iii) identify the mechanisms of resistance and cross-resistance to inform the resistance management strategy that will be adopted, and (iv) evaluate the susceptibility of the local vectors to potential alternative insecticides, should there be a need to change pesticide.

Vector resistance may differ in origin, intensity, type, and significance for vector/disease control in a given population. The evaluation of the significance of resistance to vector control should therefore consider the biochemical and genetic characteristics of the resistance, as well as the eco-epidemiology of the disease and operational characteristics.<sup>7,8</sup> Resistance also tends to be highly focal (i.e., limited to a definite area). It is therefore important to ascertain the spatial distribution of the observed resistance to better inform the resistance management strategy to be employed and the geographical extent to which it will apply (e.g., what geographical area a possible change in pesticides for IRS will cover).

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<sup>7</sup> WHO (1986) **Resistance of vectors and reservoirs of disease to pesticides: tenth report of the WHO Expert Committee on Vector Biology and Control**. World Health Organization, Geneva.

<sup>8</sup>Brogdon, W.G. and McAllister, J.C. (1998). Insecticide Resistance and Vector Control *Emerging Infectious Diseases* 4(4): 605-613.

The operational criterion for vector resistance is having 20% or more survival rate in the number tested using standardized methods of the WHO.<sup>9</sup> Irrespective of the pesticides used for IRS, national capacity is being strengthened to enable systematic evaluation of the mechanisms for resistance development and the gene frequencies among the local malaria vector populations. There is also a need to evaluate other pesticides and non-chemical alternatives to facilitate the evolution of a full-fledged IVM for malaria.

The residual efficacy of the pesticide being used for IRS is crucial to evaluating the implication of vector resistance. Generally, a positive correlation between observed vector resistance and a decline in pesticide efficacy is an important criterion in determining the need for a change of the pesticide in a local area. It is important that wall bioassays be carried out at specified intervals after the IRS operation in order to determine the period and level of residual activity in a given locality and the sprayed surface.

The third major factor affecting the effectiveness of the pesticides is their quality (specification). If the active ingredient, for example, is not up to the recommended specification and concentration, it may lead to under-dosage of deposited pesticide, which then contributes to intervention failure. Storage of pesticide for too long a time, or in extremely hot warehouses can lead to breakdown of the active ingredient. Poor pesticide quality may present additional risks to the pesticide handlers and spray operators who may be exposed. For this reason, samples of the pesticide should be taken prior to use, and analyzed for the concentration of the active ingredient.

#### **g. Compatibility of the Proposed Pesticide with Target and Non-Target Ecosystems**

The WHOPES recommended pesticides are incompatible with the non-target ecosystems (humans, animals, and the environment), in that if they are released to the non-target environment in large quantities, they would have negative effects on land and water based flora and fauna. However, the IRS implementation process is designed to ensure that to the maximum extent possible, pesticides are deliberately and carefully applied to the walls of dwellings, and do not come in contact with humans, animals, or the environment. IRS implementation is also planned to minimize and responsibly manage the liquid wastes through the reuse of leftover pesticides, the triple rinsing of equipment, and the daily washing of PPE. In addition, contaminated solid wastes are incinerated in an approved incinerator that will destroy the pesticide and prevent environmental contamination. The Environmental Mitigation and Monitoring Plan is discussed in the Environmental Impact section and **Annex 1** details the measures that will be enacted to prevent contamination of ecosystems.

The pesticides are compatible with the target environment (walls) in that they dry on these surfaces, and are not released to any great extent. The dried pesticide remains on the sprayed surfaces, and performs as designed, killing vector mosquitos that rest on them.

#### **h. The Conditions under Which the Pesticide Is To Be Used, Including Climate, Flora, Fauna, Geography, Hydrology, and Soils**

In general, carbamates, pyrethroids and organophosphates have the potential to cause harm to bees, birds, fish, and other aquatic organisms. Affected Environment of this SEA discusses the environmental conditions that exist in Liberia relative to the implementation of IRS.

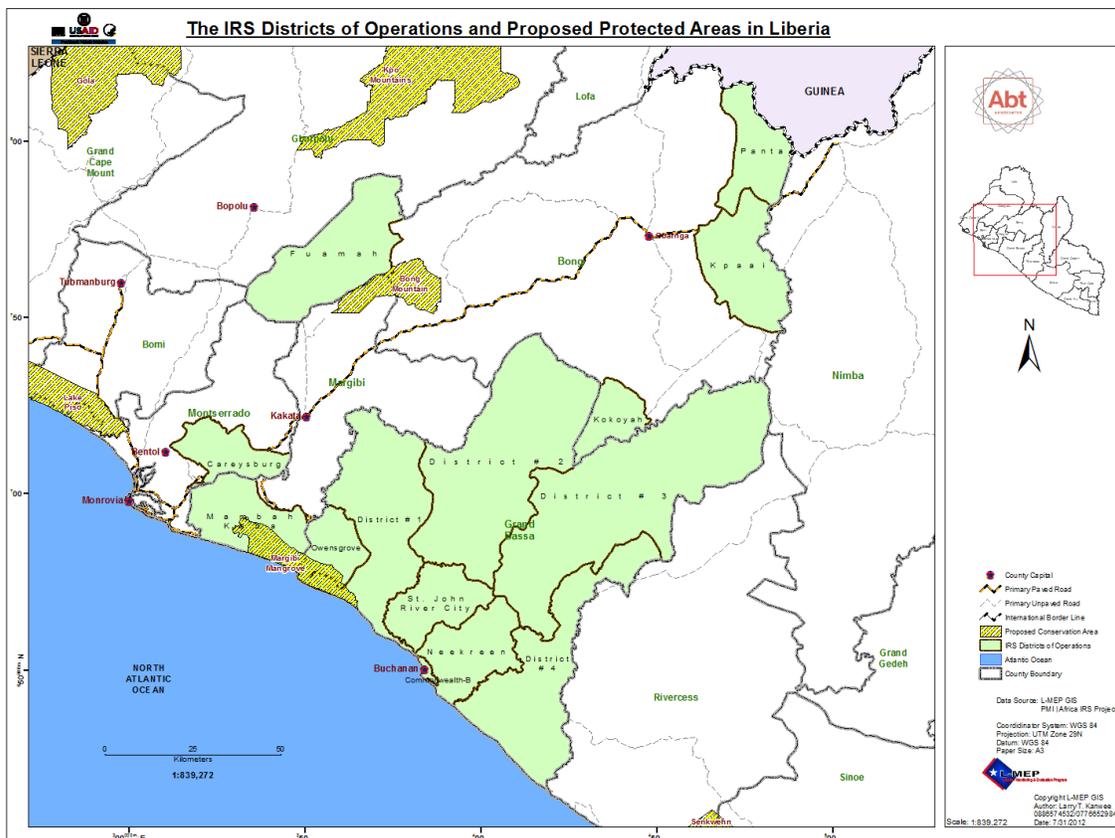
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<sup>9</sup> WHO (1998). *Test procedures for insecticide resistance monitoring in malaria vectors, bio-efficacy and persistence of insecticides on treated surfaces*. World Health Organization, Geneva, WHO/CDS/CPC/MAL/98.12

Particular attention will be paid to any areas where bee-keeping or natural bee habitats are established. In addition, bird-nesting habitat will be protected (especially IBAs), and all insecticides will be kept away from all water habitats and resources. IRS will be prohibited within protected areas or sensitive ecosystems. Prior to spraying, the implementing partner will identify households within sensitive areas, and train sprayers to identify houses that should not be sprayed. The implementing partner will consult with the EPA regarding the application of pesticides near ecologically sensitive areas, such as wetlands, lake shores, river edges, protected areas and National Parks and follow their policies and guidelines. In general, no IRS activities will take place within 30 meters of any sensitive sites.

Strict supervisory control will also be established to prevent contamination of agricultural products.

Figure 29 : Protected area and IRS sites map



(map provided by L-MEP)

**i. The Availability and Effectiveness of Other Pesticides or Non-Chemical Control Methods**

This IRS program is limited to using those pesticides that are on the WHO list of recommended pesticides. WHO currently recommends twelve insecticides from four chemical groups for IRS, each with

a specific dosage regime, duration of effectiveness, and safety rating.<sup>10</sup> (The organochlorine, DDT, will not be considered in this program). Each of these agents has been evaluated for effectiveness within the program, and continuing monitoring for resistance and susceptibility will be employed to allow up-to-date decisions prior to each spray campaign. The goal of this SEA is to broaden the options for pesticide use to combat periodic resistance development.

The approved insecticides are effective for differing periods (see Table 1), generally categorized as 2-3 months, 3-6 or 4-6 months. Within this range, the effective period depends on local circumstances, including dosage actually applied, wall type, climate (temperature and humidity), and resistance to that chemical in the mosquito population.

For IRS to be effective, the NMCP must either use a chemical that lasts longer than the average malaria transmission season or conduct multiple rounds of spraying to achieve continuous control with a shorter-lived chemical. Based on the WHOPEs table, all six pyrethroids, the carbamate prothion and the organophosphate fenitrothion are potentially effective with one application per year, but the remaining pesticides require two applications per year. Based on Liberia's tropical climate, these results may vary.

Other malaria control methods such as larviciding are generally not effective due to Liberia's high rainfall and abundant number of wetlands making it unfeasible to attempt to treat a sufficient number of sites to have any impact on larvae development. Also non-chemical means of malaria vector control are generally not effective for the same reasons. Alternative means of achieving the goals of IRS are discussed in discussion on malaria control alternatives.

#### **j. The Requesting Country's Ability to Regulate or Control the Distribution, Storage, Use, and Disposal of the Requested Pesticide**

The National Quarantine and Environmental Services bureau within the Ministry of Agriculture is responsible for regulating the importation and use of agricultural chemicals, including fertilizers and pesticides. It issues permits for the importation of agricultural chemicals and implements international conventions governing pesticides and chemicals. Unfortunately, it has no scientific testing facility and limited capacity to conduct field monitoring of agricultural chemical use.

Liberia has a number of government agencies, ministries, and bureaus, along with municipal and state industry entities, whose mandates encompass environmental issues in some fashion. These entities' environment-related mandates and activities overlap in certain respects and in some cases appear to conflict with one another.

The Environmental Protection Agency is the principal authority for the management of the environment. The Environmental Protection Agency is by law responsible to coordinate environmental management and works in collaboration with stakeholder institutions and government. The Forestry Development Authority is responsible for sustainable management of forest and its related resources. It manages protected area programs and administers wildlife and national parks. The Ministry of Health and Social Welfare coordinate and administers the general health services of the country. The National

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<sup>10</sup> Najera JA, Zaim M (2002). Malaria vector control – Decision-making criteria and procedures for judicious use of insecticides. WHO, Geneva, WHO/CDS/ WHOPEs/2002.5. (Document available at: [www.who.int/ctd/whopes/docs/JudiciousUseRev.pdf](http://www.who.int/ctd/whopes/docs/JudiciousUseRev.pdf))

Bureau of Fisheries is charged with conserving all fish resources and aquatic environments in Liberia.

Waste management has emerged as one of the greatest challenges facing local authorities throughout Liberia. The volume of waste being generated continues to increase at a faster rate than the ability of authorities to improve the financial and technical resources needed to parallel this growth. Waste management services have increasingly become inadequate, as evidenced by the rise in illegal dumping and proliferation of the now seemingly permanent piles of rubbish in some commercial, industrial, and residential areas of urban settings.

The Environmental Protection and Management Law (EPML), April 30, 2003, forms the legal framework for the sustainable development, management and protection of the environment by the Environmental Protection Agency in partnership with relevant ministries, autonomous agencies and organizations. The Law stresses intersectoral coordination and authorizes EPA, in consultation with the relevant Line Ministries, agencies and/or authorities, to promulgate several procedures, measures, guidelines, plans, registries, criteria, licenses/permits, standards and regulations to protect the environment. Part IV of the EPML concerns the establishment of environmental quality standards and includes Solid Waste Management Guidelines. Part V of the EPML covers pollution control and licensing. This part, in conjunction with many of the requirements in Part IV, provides for the development of programs to manage: Pesticides, Toxic and Hazardous Materials, Leaded Gasoline and Paint, Hazardous Waste, Wastewater Effluents, Solid Waste Management, and Air Pollution.

#### **k. The Provisions Made for Training of Users and Applicators**

The effectiveness of the IRS program depends on the availability of adequately trained spraying personnel, well-maintained equipment, and competent supervision, as well as end-user acceptability and compliance. USAID has developed guidelines for IRS operations (“*PMI IRS Best Management Practices*”), and WHO provides a training manual “*Manual for Indoor Residual Spraying*”<sup>11</sup>. Other resources include the *WHO-UNEP Manual on Sound Management of Pesticides and Diagnosis and Treatment of Pesticide Poisoning*,<sup>12</sup> the PEA-IVM of USAID, as well as this SEA, all of which provide precise precautions and recommendations on many aspects of IRS operations.

PMI will support the training of spray operators and supervisors, and provide overall guidance and logistical support to the IRS operations in Liberia. The implementing partner will continue to provide technical support for environmental compliance, with a medium-term goal of building national capacity to progressively transfer responsibilities. Preparations will include the following:

- A training of trainers program (TOT) in which potential supervisors<sup>13</sup> and team leaders are trained on all aspects of IRS operation in collaboration with the NMCP and the District Health Service. Areas of training shall include planning of IRS, household preparations, record keeping, community mobilization, rational/judicious use of insecticides including sprayer and PPE

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<sup>11</sup> World Health Organization (WHO). 2002. *Manual for Indoor Residual Spraying: Application of Residual Sprays for Vector Control* (WHO/CDS/WHOPES/GCDPP/2000.3).

<sup>12</sup> WHO (2007). *WHO-UNEP Manual on Sound Management of Pesticides and Diagnosis and Treatment of Pesticide Poisoning: A Resource Tool*. World Health Organization, Geneva. 332 Pages. (Document also accessible at: [www.who.int/ipcs/en/a](http://www.who.int/ipcs/en/a))

<sup>13</sup> These are usually health-related government staff within the targeted district (health assistants/educators/ inspectors, nursing assistants, and community development assistants).

cleaning, personnel management, environmental aspects of IRS – including geographical reconnaissance, and data recording and analysis.

- The identification of temporary workers recruited from local areas and trained as spray operators and wash persons. New operators will receive five to seven days of training prior to the spray operations. Priority areas of training will include:
  - How to properly mix the wettable powder and filling of the sprayer
  - Correct spraying (maintaining 35-55 psi pressure, spray nozzle at 45 cm from the sprayable surface, swath overlap, etc.)
  - The correct use of protective materials and related safety precautions
  - Support to households on safety issues
  - Personal safety relating to the different pesticides used for IRS (carbamate and organophosphate-based pesticides, as well as the pyrethroids which are currently in use)
  - Environmental safety in relation to pesticides, including management of the empty pesticide sachets
  - The use of daily spray cards and data entry

### **I. The Provisions Made for Monitoring the Use and Effectiveness of the Pesticide**

Two kinds of measurements are needed to provide a complete understanding of the effectiveness of pesticide that is being used for IRS. The immediate (output) level relates to the efficacy of the pesticide, that is, the degree to which the pesticide is able to kill the targeted mosquito vectors, and involves direct entomological evaluations on pesticide contact bioassays and related pesticide resistance methodologies as recommended by WHO.<sup>14</sup> The second broad level of measuring the effectiveness of the pesticides relates to the general goal of reducing the local disease burden. This will require specialized entomological and epidemiological skills and the assessment of the impact of vector control operations, and possibly the assignment of the contributory impact of the IRS operations. This latter measurement is usually done through a combination of methodologies such as measuring the changes in parasite inoculation rates, passive case detection at health centers, and periodic community fever and parasite surveys (active case detection).

Another key characteristic of pesticide effectiveness is the longevity of the treatment. This characteristic has important economic and health implications: the program must adjust its spray schedule to make sure that there is active pesticide on the walls of homes during critical breeding periods. Unfortunately, the guidance that is provided with regard to effective period for each pesticide is very broad (e.g. 3-6 months), and the effective period is probably subject to complex environmental factors such as heat, humidity, and substrate (wall) composition. This area is ripe for research, and any contributions that could be made towards increasing the knowledge of the relationship between these variables and the resultant effectiveness of the pesticide would be very valuable.

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<sup>14</sup> WHO (1998). Test procedures for insecticide resistance monitoring in malaria vectors, bio-efficacy and persistence of insecticides on treated surfaces WHO/HQ, Geneva, World Health Organization, WHO/CDS/CPC/MAL/98.12

## Environmental Impacts and Mitigation and Monitoring Plan

This section addresses the potential direct and indirect impacts of the IRS program in Liberia, and also discusses mitigation and monitoring measures. The Environmental Mitigation and Monitoring Plan (EMMP) presents the Best Management Practices (BMP) and mitigation measures identified for the project, responsibilities for the implementation of the Plan, and monitoring and reporting measures. This EMMP is the guiding document for IRS management team in Liberia, which will be used as the tool for ensuring environment compliance for the program.

The EMMP summary (**Annex 1**) presents a program by which the implementing partner, EPA and NMCP will assure initial and ongoing compliance with environmental requirements and guidelines. The plan also includes descriptions of activities proposed for mitigating environmental and social impacts.

### Potential Positive Effects of the IRS Program

#### ***Direct Positive Effects***

The direct positive impacts of the IRS program are generally the reduction in malaria morbidity and mortality that will result in a reduction in human suffering, and will lead economic growth. Other positive impacts include reduced incidence of adult morbidity, miscarriages, low birth-weight, and adverse effects on malaria-induced fetal neurodevelopment; and reduced incidence of malaria-related childhood anemia, complications, organ failure. There is also the benefit of elimination of household pests, including other bugs, as well as vermin in some cases.

#### ***Indirect Positive Effects***

The IRS program will also indirectly contribute in the enhancement of the local economy in the following indirect ways: spray operators, washers, mobilizers, supervisors will all receive a daily payment for their work. There will also be capacity building in the form of training of a large number of people associated with IRS operations. A reduction in household pests may result in a reduction in other diseases carried by the pests.

### Potential Adverse Impacts

Adverse impacts of IRS project are those unintended effects of the project that can compromise the well-being of the environment and human health.

#### ***Indirect Adverse Effects***

After completion of the IRS program, USAID will leave remaining IRS equipment in the hands of the county and district health offices; and will no longer supervise its use. IRS equipment left to Liberia government officials includes backpack compression sprayers, unexpired unused chemicals, and used, cleansed boots that are still in operable condition. The action of leaving behind IRS equipment may temporarily, and in a minor way increase the total pesticide load on the environment.

#### ***Direct Potential Adverse Effects***

##### **Contamination of surface water courses and underground water**

During IRS implementation, it will be possible to accidentally release insecticides into water bodies during the transportation and storage of pesticides, application of insecticides to walls, and clean-up of IRS

equipment and PPE. It is also possible to have a deliberate release through washing in areas other than the soak pit, or improper disposal of leftover pesticide.

A spill into surface water bodies is a key concern in IRS because it could not only lead to contamination of water routinely used for domestic purposes but could cause a fishkill, possibly causing loss of a food supply. Other aquatic organisms that are vital to a healthy ecosystem could also be wiped out.

Contamination of underground water resources is possible through improper disposal of left over pesticide on the ground, especially if there is a high water table. However, the impacts of this risk are likely to be insignificant because pyrethroids, organophosphates and carbamates degrade very quickly when exposed to sunlight and in the soil. If wash areas and soak pits are properly constructed and used, liquid pesticide waste will be captured in the charcoal layer of the soak pit and held until it breaks down by natural processes.

### **Impacts to Birds, Fishes, and other organisms from pesticides:**

The degree of toxicity of the four World Health Organization (WHO) approved pesticide classes to birdlife, aquatic life and insects especially bees including the degree of persistence and bio-accumulation is well-documented and very important to remember. See Table 5 for details.

### **Impacts on Bees**

Though beekeeping is not widely done in Liberia, the project should make conscientious effort to identify any locations where bee-keeping is kept. Spraying in areas near beehives can lead to the death of the bees, which are vulnerable mostly to pyrethroids, and should be mitigated at all times.

### **Summary of Toxicity of pesticides to Avifauna, Aquatic life, mammals and insects by Class**

#### **Pyrethroids:**

- All pyrethroids are highly toxic to bees and highly toxic to fish and other aquatic organisms except Deltamethrin, which has low toxicity to other aquatic organisms<sup>15</sup>.
- Birds, if exposed, are most affected by bifenthrin (low to medium toxicity). All other pyrethroids have very low toxicity to birds.
- In mammals, only lambda cyhalothrin is highly toxic to mammals. Alpha-cypermethrin and etofenprox have very low toxicity to mammals while bifenthrin, cyfluthrin and deltamethrin have low to medium toxicity.
- In terms of persistency in the environment, only cyfluthrin has more characteristics of persistency. The rest of the pyrethroids have low to medium toxicity.
- Bifenthrin does not accumulate in the environment. Potential for bio-accumulation in aquatic organisms for deltamethrin and cyfluthrin is relatively low while lambda-cyhalothrin is medium and alpha-cypermethrin is high.

#### **Carbamates: (Bendiocarb and Propoxur)**

- Carbamates are highly toxic to bees, and have the potential to cause cholinesterase depression in humans. Care must be taken to avoid skin contact with carbamates, especially

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<sup>15</sup> USAID's IVM PEA

by spray operators. All spray personnel should be trained to recognize the symptoms of cholinesterase depression, and know the protocol for obtaining medical assistance.

- In addition to other aquatic organisms Propoxur is also highly toxic to mammals and birds. Acute symptoms of propoxur poisoning in birds include eye tearing, salivation, muscle incoordination, diarrhea, and trembling. Depending on the type of bird, poisoning signs can appear within 5 minutes of exposure, with deaths occurring between 5 and 45 minutes, or overnight. On the other hand this insecticide has very low toxic properties on fish.
- Bendiocarb has low to medium toxicity on mammals and birds.
- In general both carbamates have low to medium indications for persistency in the environment and bioaccumulation in organisms

### **Organophosphates**

- Organophosphates have different characteristics and impacts on different organisms depending on the type of insecticide. However, all three WHO-approved organophosphates have the potential to cause cholinesterase depression in humans and other organisms, and *skin contact with these pesticides must be strictly avoided, especially by spray personnel*. All spray personnel should be trained to recognize the symptoms of cholinesterase depression, and know the protocol for obtaining medical assistance.
- Fenitrothion has low toxicity on mammals and fish and is not persistent in the environment. However it is highly toxic to bees, birds and other aquatic organisms, like crustaceans and aquatic insects and has a medium toxicity to aquatic worms. It has moderate to medium potential to bioaccumulate in organisms.
- Malathion is only highly toxic to bees. It has very low impacts on fish and other aquatic organisms, and has a very low potential to bioaccumulate in organisms or persist in the environment. Its toxicity on mammals and birds is low to medium.
- Pirimiphos-methyl is highly toxic to fish and other aquatic organisms and has a high potential to persist in the environment. It has low to medium toxic effects on mammals and bees. It does not bioaccumulate in organisms.

### **Human Exposure Risks/Impacts**

Exposure risks of all WHO approved pesticides in relation to cancer and non-cancer endpoints, and with respect to exposure dosage, Hazard Quotient and the Life Time Average Daily Dose (LADD) are presented in *USAID's IVM Programmatic Environmental Assessment 2007*. There is a draft update to this document under revision as of October 2012. The exposure risk for cancer and non-cancer endpoints is presented at different stages of the pesticide application including mixing, spraying, post spraying, dermal risk, etc.

#### **Inhalation exposure and risk during mixing**

- Of the proposed pesticides, only etofenprox (pyrethroid) and propoxur (carbamate) have carcinogenic properties once threshold levels are exceeded.

#### **Dermal exposure and risk during mixing**

- On the list of insecticides to be used in IRS only three (DDT, etofenprox (pyrethroid) and propoxur (carbamate)) have been determined to be carcinogenic at dermal exposure levels of 8E-07 mg/kg-day for etofenprox and 4E-06 mg/kg-day for propoxur.

### **Inhalation exposure and risk during spraying**

- Of the proposed pesticides, only etofenprox (pyrethroid) and propoxur (carbamate) have carcinogenic properties once threshold levels are exceeded.

### **Dermal exposure and risk during spraying**

- Of the proposed pesticides, fenitrothion and pirimiphos-methyl have non-cancer risks due to dermal exposure.

### **Resident dermal exposure and ingestion risk after spraying**

- The only concerns are to adults when using cyfluthrin and etofenprox (pyrethroids) and propoxur (carbamate). The risk is however very low.

### **Resident exposure and risk due to chronic ingestion after spraying**

- There are four insecticides with potential impact due to chronic ingestion by drinking insecticide contaminated water. These are Cyfluthrin, Permethrin and Etofenprox (pyrethroids) and propoxur (carbamate). Best management practices are recommended.

### **Resident dermal exposure and risk due to bathing using contaminated groundwater**

- Cyfluthrin and etofenprox (pyrethroids) have potential impact for dermal exposure using contaminated groundwater. When best management practices are applied in IRS, this risk is significantly reduced.

### **Resident exposure and risk due to reuse of pesticide containers**

- Only deltamethrin is registered to have potential for acute ingestion from using pesticide containers. However, residents will have no access to pesticide containers used in IRS. The pesticide containers are only available in IRS storage facilities which are securely double locked and must be disposed by incineration at high temperature.

### **Worker exposure and risk due to inhalation during spillage**

- According to information presented in the Programmatic Environmental Assessment, etofenprox and propoxur have potential to impact workers through inhalation during spillage. The workers are trained on how to handle spillage and must be equipped with appropriate PPE.

## **1. Worker and Resident Exposure Pathway**

During the IRS spraying process, spray personnel are at risk of un-intentional or deliberate exposure through accidents or poor and improper handling of the spray chemical. Worker exposure to the chemical could arise during the pre-spraying, spraying and post-spraying phase of the IRS operations. Beneficiaries can also be exposed during each of these phases, and additionally over the life of the pesticide on the wall.

### **a. Pre Spraying Exposure Pathway**

Preparing pesticide solutions during the IRS requires pouring the pesticide in the spray pump to ensure ample mix with the water. The process of mixing the pesticide can lead to exposures via inhalation, dermal contact, and incidental ingestion, mostly from releases of pesticide vapors, and solutions. Vapor releases can occur when liquid concentrated emulsions are diluted. Workers or residents can inhale the vapors or the particulates or be exposed through dermal contact. Spills could also pose significant risk, especially for children who ingest the resulting residues that are left on surfaces such as food, floors,

soil, as well as absorbing additional doses from eating plants and animals contaminated during the preparation for spraying.

**b. Exposure during Spraying**

Inhalation of aerosol vapors during spraying is the main process for worker exposure during IRS, however, dermal exposure through spills or absorption onto cotton overalls is also a significant risk. Especially in the case of organophosphates, the dermal hazard is significant, and can cause cholinesterase depression. Residents are mainly exposed through dermal contact with sprayed surfaces and incidental ingestion of insecticide after their houses have been sprayed, especially when food or drink are left in the house during spraying. Leaky equipment can also lead to insecticide exposure through dermal contact with the floors and incidental ingestion by children who may come in contact with the spills before they are cleaned up.

**c. Exposure during Disposal (including Progressive Rinsing)**

Disposal is a key issue with IRS intervention that utilizes pesticides especially during the decontamination process and disposal of the liquid effluent that will arise from washing and progressive rinse. Both burying and dumping can lead to dermal exposure to residents who come in contact with the soil or water in which the pesticide was disposed. Ingestion exposure can occur from drinking contaminated surface water. Once the excess formulation gets into the soil, the pesticide can reach the groundwater, which may be used as a water supply via household wells. Residents may then be exposed to this contaminated water by ingestion or by dermal contact when it is used for cleaning or drinking purposes.

**d. Occupant long-term exposure from residue**

Residents of sprayed structures, especially crawling babies and children, will have a finite exposure risk due to physical contact with sprayed surfaces, as well as small amounts released from substrate walls, ceilings, and eaves, due to physical surface breakdown.

## **Cumulative Impact**

The combined, incremental effects of human activity, referred to as cumulative impacts, pose a serious threat to the environment. Cumulative impacts develop over time, from one or more sources, and can result in the degradation of important resources.

The critical resources or ecosystems that can be affected by the IRS program over a period of time especially with regards to pesticide application include water supply, food supply, waste assimilation/disposal capacity, river, lake, and stream quality, agriculture, aquaculture, apiculture, human and animal health, biodiversity resources, environmental services, and others. Pesticide run off and accumulation in the rivers, streams and other water bodies, can lead to the progressive contamination of the water resources and reduction of aquatic biodiversity. However, using the IRS BMPs reduces the likelihood of releases, and the chances of a series of releases within the pesticides half-life is extremely unlikely, except in the case of willful malfeasance.

Continuous human exposure to pesticides over time can lead to health risks or complications, especially among spray operators and others in close contact with pesticides. This is particularly true in the case of organophosphates. However, the risk assessment performed in the PEA indicates minimal exposure with the use of proper technique and appropriate personal protective equipment (PPE), i.e. dust masks,

helmet, face shield, gloves, overalls and boots that minimize exposure by dermal absorption or inhalation, and a great reduction in the potential for harm.

The sprayed pesticides solidify on the walls, ceilings, and eaves of the structures, and become largely immobile and significantly less harmful. Exposure to the occupants will be further reduced by the procedures and safety measures described in this Environmental Mitigation and Monitoring Plan and **Annex 1**.

Pyrethroids, organophosphates and carbamates degrade very quickly when exposed to light and to the external environment, thus the cumulative and residual adverse impacts of their use will be insignificant. The soak pits used for waste disposal are designed to break down influent pesticides wastes within about three months, while the pesticides are held by the charcoal used in pit construction.

The long-term use of any pesticide could lead to insecticide resistance. To minimize this cumulative impact, insecticide resistance is actively monitored. The proposed action is designed with the concept of vector monitoring, insecticide rotation and mosaicking which will reduce the future incidence of vector resistance.

## **Mitigation Measures**

This section outlines the various mitigation measures proposed for any of the potential adverse impacts likely to occur as outlined above. The primary mitigation measures include delivery of a mix of Information Education and Communication (IEC) approaches targeting the residents and spray operators and all IRS personnel. The mitigation measures also include provision of Personal Protective Equipment (PPE), training of spray operators and strengthen supervision and monitoring.

### ***Residential Exposure***

Provincial and District authorities, implementing partners and IRS staff will work with relevant institutions at all levels to carry out an IEC campaign to sensitize residents to IRS activities, in accordance with WHO guidelines and also Liberia Malaria strategy 2008-2013. The IEC campaign (as well as IRS Project team leaders and supervisors who will also instruct residents on best practices prior to spraying) should focus on the following elements of residential safety during an IRS program:

- Clear homes of mats or rugs, furniture, cooking implements and foodstuffs prior to spraying; if furniture cannot be moved out of the home, then move it to the center of the room and covered with impermeable material
- Stay outside the home during spraying for two hours after spraying
- Move and keep all animals outside the home during spraying, and for two hours after spraying
- Sweep up any insects killed from the spraying and drop them in latrine pits
- Sweep floors free of any residual insecticide that may remain from the spraying
- Do not re-plaster or paint over the sprayed walls after spraying
- Keep using bed-nets for protection against malaria
- If skin itches after re-entrance into home, wash with soap and water; for eye irritation, flush eyes with water; for respiratory irritation, leave the home for fresh air; for ingestion, if soap and water are unavailable, or if symptoms persist, contact program staff or go to nearest health facility which has the appropriate medical intervention.
- If spraying during the rainy season, the teams should follow the following Contingency Plan which will minimize exposure of household effects

During the rainy season;

- Each spray operator must be given adequate covering material (3m by 3m minimum) which should be used to cover household effects not removed from the houses.
- Adopt a system of moving household effects to the center of the room and covering them with impermeable material before spraying
- Materials can also be moved into structures, which may not be sprayed e.g. an isolated kitchen or other domestic animal shelter.
- Move the household effects to one room, which should not be sprayed on that particular day but the next day.
- The spray teams should pay close attention to any signs of potential rains so that they prepare the communities accordingly.

When it rains in the mid of spraying;

- Stop the spraying activities. After the rains stop and the weather is considered good, spraying can continue.
- Cover the household effects with an impermeable material. These materials should have already been procured by the program and given to each operator.

### ***Pesticide Transport***

After the procurement of the insecticides for use during the current IRS campaign, insecticides are expected to move to the provincial warehouses by road. During transportation, there is a risk of vehicle accidents and consequently insecticide spillage. The transport must comply with environment management regulation, statutory instrument 12 of 2007 section 14, regarding hazardous substances, pesticides and other toxic substances and the guidelines of NEMA on transport of pesticides.

Prior to long-distance transport of the insecticide from the customs warehouse/central storage facility of the supplier, drivers will be informed about general issues surrounding the insecticide and how to handle emergency situations (e.g. road accidents). Training for long-distance transport will include the following information:

- Purpose of the insecticide
- Toxicity of the insecticide
- Security issues, including implications of the insecticide getting into the public
- Hazardous places along the routes to be taken, and mitigation measures
- Steps to take in case of an accident or emergency (according to FAO standards)
- Combustibility and combustion byproducts of insecticide

Drivers hired specifically for the spray campaign period will receive:

- Training provided to spray operators (with the exception of sprayer operation and spray practice)
- Handling an accident or emergency (according to FAO standards)
- Handling vehicle contamination

The vehicles to transport insecticides must be in good condition and preferably a lockable box truck. If the pesticides are to be left unattended for any period of time, including lunch breaks or overnight stops, a lockable box truck is essential.

Figure 30 : Emergency Response to Insecticide Spills

### **In case of Insecticide Spills**

1. Control, contain and clean up the spill
2. Protective clothing should be donned prior to attempting to clean the spills.
3. It is imperative to avoid fire as a result of the accident and a fire extinguisher should be deployed just in case. The engine should be shut off and smoking in the area strictly prohibited.
4. Onlookers and bystanders should be cautioned against approaching the accident site.
5. If the crew has come in contact with the pesticides, they should remove contaminated clothing immediately and wash the pesticide off their skin.
6. For major spills send for help immediately; drivers should have cell phones and an emergency number for use in such cases.
7. People should be kept away and the spill covered with earth, sand, etc.; no attempt should be made to wash away the spill with water or other substances.
8. Vehicles that are used for transporting large quantities of pesticides should be equipped with a bucket of sand, sawdust or soil, a shovel, and fire extinguisher.

Because vehicles used for insecticides transportation can be used for the transport of other goods including food, it is important to ensure that vehicles are decontaminated. The drivers will be responsible for cleaning and decontaminating the interior of the vehicle and exterior bed at the end of the spray campaign. Drivers will be provided with gloves and rubber boots to wear for cleaning the vehicle. All cloths used in wiping down the interior and bed of the vehicle will be washed with soap.

#### ***Accidental Warehouse Fires***

Human inhalation of toxic fumes in the event of a storehouse fire is also an unavoidable risk. The risk can be minimized, however, by following BMPs for storage, including prohibiting lighted materials in the warehouse and in the vicinity of pesticides, proper ventilation, etc.

Information on the combustion byproducts of pyrethroids can be found below (taken from USAID's *Integrated Vector Management Programs for Malaria Vector Control: Programmatic Environmental Assessment (IVM/PEA)*, as well as fire-fighting instructions from Material Safety Data Sheets.

Table 11: Insecticide, Combustion byproduct, and Extinguishing Instructions

Pesticide	Combustion Byproduct	Extinguishing Instructions
Alpha-cypermethrine	Open burning of lambda-cyhalothrin creates nitrogen oxides, hydrogen chloride, and hydrogen fluoride (WHO, 1997)	<p>Extinguishing media: For small fires use water spray, alcohol-resistant foam, dry chemical or carbon dioxide. For large fires, use Alcohol-resistant foam, Water spray.</p> <p>Extinguishing media, which must not be used for safety reasons: Do not use solid water stream as it may scatter and spread fire.</p> <p>Specific hazards during firefighting: As the product contains combustible organic components, fire will produce dense black smoke containing hazardous products of combustion. Exposure to decomposition products may be a hazard to health.</p> <p>Special protective equipment for firefighters: Wear full protective clothing and self-contained breathing apparatus.</p> <p>Further information: Do not allow run-off from fire-fighting to enter drains or watercourses. Cool closed containers exposed to fire with water spray.</p>
Bendiocarb	Fine dust may form explosive mixtures in air. The product is not flammable, but when heated above 125° C will evolve toxic fumes of methyl isocyanate. Water is the preferred extinguishing medium as it decomposes any methyl isocyanate.	<p>Water fog or fine spray, carbon dioxide, dry chemical, foam.</p> <p>Fire fighters should wear full protective gear, including self-contained breathing apparatus (AS/NZS 1715/1716). Keep unnecessary people away and move all other personnel to windward side of fire. Bund area with sand or earth to prevent contamination of drains or waterways. Dispose of fire control water or other extinguishing agent and spillage safely later.</p>
Delta-methrine	Combustion and/or pyrolysis of deltamethrin can lead potentially to the production of compounds such as formaldehyde, acrolein, hydrogen cyanide, and hydrogen bromide (UK PID, 2006)	<p>Suitable extinguishing media: Water spray jet, carbon dioxide (CO<sub>2</sub>), dry powder, foam.</p> <p>Extinguishing media which should not be used for safety reasons: Product itself is non-combustible</p> <p>Fire extinguishing measures to suit surroundings.</p>
Bifenthrin	Not available	<p><u>Suitable extinguishing media:</u> Carbon dioxide (CO<sub>2</sub>), Foam; Powders</p> <p><u>Not suitable extinguishing media:</u> Water (the product is hazardous for the environment - do not dilute it)</p> <p><u>Specific fire-fighting methods:</u> Isolate fire area. Evacuate downwind. Contain the extinguishing fluids by bunding (the product is hazardous for the environment). Do not attempt to fight the fire without suitable protective equipment. Do not breathe fumes</p> <p><u>Protection of fire-fighters:</u> Self-contained breathing</p>

Pesticide	Combustion Byproduct	Extinguishing Instructions
		apparatus and complete protective clothing
Cyfluthrin	Combustion and/or pyrolysis of cyfluthrin can lead potentially to the production of compounds such as formaldehyde, acrolein, hydrogen cyanide, hydrogen chloride, and hydrogen fluoride (UK PID, 2006)	Not available to-date.

(Source: IVM PEA, USAID, Jan 2007)

### ***Fetal Exposure (Pregnancy Testing)***

All the potential female candidates as spray operators will be tested for pregnancy before being recruited into the spray operations and every thirty days until operations end. Females found to be pregnant should be re-assigned to positions that do not require exposure to insecticides. The same applies to breastfeeding spray operators.

### ***Spray Operator Exposure***

Each spray operator will be provided with safety equipment in accordance with WHO and FAO specifications.

Workers should be closely monitored for acute symptoms, because there will always be some level of exposure. In addition, workday duration should be monitored to limit exposure as required by safety recommendations.

Monitoring of acute exposure of the spray operators will be undertaken by reviewing of the Incident Report Forms that are made available to every spray team and filled daily by supervisors. Any exposure incident is normally recorded as a form of best practice and action taken i.e. immediate treatment following guidance given, or referral to the health facilities for further treatment.

Similarly, residential exposure will be monitored. During the IEC campaign, residents are made aware of the steps to take if exposed and especially if acute symptoms are encountered the advice is to report to the nearest health facility. Thus reported cases at health facilities or by IEC mobilizers will serve as the principal monitoring strategy for exposure incidents.

The individuals recruited for IRS campaigns will receive intensive training on the use, operation, calibration and repair of the spray pumps and practical exercises during a five-days training period prior to the beginning of the spraying campaign. They will also receive training to understand proper hygiene, to recognize the signs and symptoms of poisoning, and to understand the referral procedure for any incidents involving poisoning. This training will be conducted in accordance with WHO's "Manual for Indoor Residual Spraying" (WHO 2002 and the USAID/PMI Best Practices Manual. Potential spray operators must also pass written and practical tests at the end of training.

For most organophosphates, it will be necessary to monitor the level of acetyl cholinesterase in any worker who may have been exposed to contamination. Occupational exposures to OP insecticides are measurable using blood cholinesterases and urinary excretion of chemical biomarkers. PMI will evaluate various approaches for monitoring sprayer exposure to Organophosphates (OP), and will develop

protocols based on these evaluations. PMI will use these protocols to guide the implementation of the OP monitoring program.

**Pesticide Exposure and Treatment.**

The following drugs are recommended for use in case of exposure to the insecticides. The project will ensure that all the health facilities around the spray sites have in their store these recommended drugs and that all the staff responsible receives appropriate training on emergency treatment to pesticide exposure.

Table 12 : Antidotes for Pesticide Classes

Organochlorine (DDT):	Activated Charcoal (priority)	
	Diazepam or Lorazepam (for seizure)	
	Phenobarbital Cholestyramine resin	
Organophosphates:	Atropine sulfate or Glycopyrolate (priority treatment)	
	Furosemide (less critical)	
	Diazepam or Lorazepam (for seizure)	
Carbamates:	Cholestyramine Atropine (priority)	
	Furosemide (less critical)	
	Diazepam (for seizure)	
Pyrethroids:	<i>Name of Drug</i>	<i>Active Ingredient(s)</i>
	Promethazine	Promethazine Hydrochloride
	Panadol	Paracetamol
	Diazepam	Benzodiazapine/Diazepam
	Lorazepam	Lorazepam
	Calamine cream	Calamine, zinc oxide, glycerol, phenol, purified water, sodium citrate, betonite,
	Vit E	Tocopherol, fragrance, mineral oil, deionized water, sodium hydroxide, stearic acid
	Hydrocortisone cream	1% hydrocortisone
	Salbutamol	Salbutamol 100 mcg, suspended inert aerosol
	Salbutamol tablets	Salbutamol sulphate 4 mg
	Activated Charcoal	Activated Charcoal

All the spray operators including the supervisors will receive detailed training on the emergency steps to take if accidental exposure of the chemical occurs including ingestion, eye or dermal contact with the chemical. This training will be conducted by the district health officers and will include drills to test knowledge of the operators.

### ***Warehouse/Storage Risks***

In order to mitigate risks associated with pesticide storage, the following key points will serve as key mitigation steps:

- All primary pesticide storage facilities will be double-padlocked and guarded on a 24 hour basis
- All the storage facilities will be located away from nearby watercourses, domestic wells, markets, schools, hospitals, etc.
- Soap and clean water will be available at all times in all the facilities
- A trained storekeeper will be hired to manage each facility
- Recommended pesticide stacking position and height in the warehouse as provided in the FAO Storage and Stock Control Manual will be followed
- All the warehouses will have at least two exit access routes in case of fire outbreak
- A fire extinguisher will be available in the storage facilities and all workers will be trained on how to use this device.
- Warning notices will be placed outside of the store with skull and crossbones and the local language (Ndebele and Shona)
- All pesticides waiting to be used and any remnants will be stored under lock and key until the next rounds of spraying.

### ***Solid and Liquid Contaminated Wastes***

Mitigation measures are described in the solid waste management section and in the EMMP Summary (**Annex 1**)

### **Pesticide Quality Assurance**

The procurement and use of pesticides that do not meet the necessary quality assurance standards can compromise the overall spray quality and desired vector action while at the same time could expose the residents and spray operators to hazards related to altered toxicological characteristics. In Liberia, the MOA does not currently have a laboratory to do quality assurance tests.

### **Conclusion**

The table below is a decision criteria matrix showing that if all the factors are considered in combination i.e. (diseases management effect, environmental effect, health risk and cost effectiveness etc.), pyrethroids are the most cost effective, have beneficiary and government preference, and are considered less detrimental to human health and the environment, though studies show an increase in mosquito resistance. Organophosphates have the disadvantage of higher human health risk and higher cost, with lower beneficiary preference, and will probably require urine or blood biomonitoring. At the same time, it is important to note that all three pesticide classes, when used with all the compliance and mitigation measures, have acceptable risk to human health and the environment and therefore are considered part of the proposed action.

Table 13: Decision Criteria Matrix

Criteria	Pesticide choice	Susceptibility	Socio-economic Impact	Cost	Country preferences	Human and ecological impacts	Total
IRS in Liberia							
	Pyrethroids	++	+++	+++	+++	-	10
	Carbamates	+++	+++	++	++	-	9
	Organo Phosphates	+++	+++	++	+	--	7
No Action		0	---	--	---	0	-8

**Key/Legend**

0= net zero effect  
 -=net negative effect      +=positive effect  
 --=moderate negative effect    ++=moderate positive effect  
 ---=significant negative effect    +++=significant positive effect

## EMMP IMPLEMENTATION

The implementing partner with the support from the NMCP, CHTs, EPA and MOA will implement the EMMP. The staff in charge of implementation of EMMP will be trained to ensure effectiveness of the mitigation measures during spray operation. Focal persons from each government agency will be identified at county and district levels for monitoring environmental compliance during the IRS campaign.

The implementing partner will work closely with local EPA officials throughout the spray campaign. Environmental compliance inspections are carried out jointly with representatives from NMCP, EPA and MOA to evaluate mitigation measures put in place. These inspection visits will take place before activities commence, during spray operations and at the completion of the spray campaign and will use the pre, during and post BMP checklists. The inspection will endeavor to ensure that all the mitigation measures in the EMMP are being implemented and propose measures for improvement for the next IRS campaign. These compliance inspections achieved the following objectives:

- Create a baseline of current compliance activities for the purpose of evaluating improvement in future IRS programs.
- Observe IRS activities in progress to determine and document whether the intervention is in full compliance with USAID requirements as included in the approved SEA.
- Determine, in consultation with EPA officials, the training and support required to improve and ensure future compliance with the SEA.
- Ensure adherence to relevant international rules and regulations, including USA Regulations.
- Ensure accurate record keeping and daily collection of empty sachets.
- Ensure that progressive rinsing methods were used in all spray sites and ensured that leftover insecticide solution was re-used for spraying the next day to prevent environmental contamination.
- Ensure that SOPs, washers, team leaders and supervisors were knowledgeable of the correct way to handle and apply insecticides.
- Ensure that all persons involved in the spraying campaign used PPE at all the times.

In addition PMI will conduct an independent environment compliance audit to ensure that all the mitigation measures are implemented during the spray campaign. This activity must be in the annual work plan and budget.

## PUBLIC CONSULTATIONS

During the preparation of this SEA, consultation with the various implementing governmental agencies (NMCP, EPA and MOA), community leaders, IRS team leaders, community health officials and beneficiaries was completed to ensure the document met the needs of the malaria control program. The SEA sets out to also meet the needs of the EPA and the Environmental Impact Assessment (EIA) requirements.

Overall, all stakeholders are actively involved in the management and implementation of the IRS program, and the program is well received in the field. The NMCP would like to be able to have total IRS coverage of the country, but are limited by available resources. The Malaria Task Force determines geographic coverage and districts are identified where IRS will be conducted to at least 85% of the structures. Several communities within these Districts complained that they did not receive IRS. There is also a concern that the pesticide is not adequately mixed and therefore it is less effective. The community of Botota in Manta District, Bong County, complained that there was an increase in malaria cases after the spray cycle. This was confirmed at the Health Clinic. There is also an increase in resistance to pyrethroids in the areas receiving IRS, which may limit the pesticide that are effective to carbamates and organophosphates.

It also was obvious during the consultation process that the conditions of the roads will limit the accessibility to many districts during the raining season, therefore reducing the effectiveness of the IRS program if two rounds of spraying are necessary.

PMI Liberia will distribute a draft version of the SEA to NMCP, EPA, MOA and other malaria control partners for review.

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PMI's Liberia Malaria Operational Plan, FY 2008.

**Liberia's Executive Mansion County Development Agendas:**

Bomi County Development Agenda 2008-2012

Bong Country Development Agenda 2008-2012

Margibi County Development Agenda 2008-2012

Montserrado County Development Agenda 2008-2012

Gbarpolu County Development Agenda 2008-2012

Grand Bassa County Development Agenda 2008-2012

Grand Cape Mount Development Agenda 2008-2012

Grand Gedeh Development Agenda 2008-2012

Grand Kru Development Agenda 2008-2012

Lofa County Development Agenda 2008-2012

Margibi County Development Agenda 2008-2012

Maryland Development Agenda 2008-2012

Montserrado County Development Agenda 2008-2012

Nimba County Development Agenda 2008-2012

Rivercess County Development Agenda 2008-2012

River Gee County Development Agenda 2008-2012

Sinoe County Development Agenda 2008-2012

**Websites**

Liberia Ministry of Agriculture website: liberiafisheries.net

[WWW.UNEP.ORG.UNCBD](http://WWW.UNEP.ORG.UNCBD)

<http://www.elastec.com/portableincinerators/mediburn/gallery/>

[http://www.moa.gov.lr/doc/epa\\_act.pdf](http://www.moa.gov.lr/doc/epa_act.pdf)

## ANNEX 1: Environmental Mitigation and Monitoring Plan (EMMP)

Negative Impact	Mitigation Activities	Monitoring Frequency	Monitoring Indicators	Implementation Responsibility
Driver and/or community exposure, or environmental contamination due to improper transport of pesticide	<p>Driver training according to FAO recommendations</p> <p>Provision of appropriate equipment (reliable vehicle with side walls capable of negotiating rugged roads, tie-downs, packing materials, tarps, spill clean-up kit)</p> <p>Cautious driving while transporting chemicals</p> <p>Checking for and repairing leaks from spray equipment prior to transport</p> <p>In case of accident, completion of accident and corrective action report</p>	<p>Once prior to campaign, reinforcement as needed</p> <p>Continuous</p>	<p>Procedures being followed</p> <p>Demonstrated knowledge</p> <p>Existence of training materials</p> <p>Absence of vehicle accidents</p> <p>Vehicle condition</p> <p>Absence of spills during insecticide transport</p>	Drivers, Implementing partners, Pesticide distributors, spray team leaders
Environmental contamination due to improper siting or construction of storage and wash facilities	<p>Use site qualification checklist. Locate storage and wash facilities on high ground, above floodplains, away from sensitive receptors (water bodies, birds, bees, fish, children, etc.).</p> <p>Use appropriate construction materials as specified in FAO recommendations</p>	Once prior to campaign	<p>Storage and wash facilities outside of floodplain and away from sensitive receptors (birds, bees fish, children, etc.)</p> <p>Constructed of suitable material</p> <p>Adequately ventilated</p> <p>Adequate storage space</p>	District Environmental Officers, Implementing partner
Storekeeper and/or community exposure or environmental contamination due to improper storage or pilferage	<p>Provision of secure storage facilities</p> <p>Training of storekeepers, team leaders and supervisors according to FAO recommendations</p> <p>Daily tracking of insecticide sachets issued, used, and returned</p> <p>Storage procedures according to</p>	<p>Once prior to campaign</p> <p>Continuous</p>	<p>Dedicated and trained storekeeper who demonstrates knowledge and uses correct procedures</p> <p>Stock records up-to-date</p> <p>Stocks orderly, rotation system in place</p>	Storekeeper, spray team supervisors, spray team leaders, Implementing partners

Negative Impact	Mitigation Activities	Monitoring Frequency	Monitoring Indicators	Implementation Responsibility
<p>Cont.</p> <p>Storekeeper and/or community exposure or environmental contamination due to improper storage or pilferage</p>	<p>BMPs</p> <p>Storekeepers trained to not issue pesticides for agricultural or any other unauthorized use</p>	<p>Continuous</p>	<p>Expiration dates observed</p> <p>Empty sachets collected, counted and reconciled with amounts issued</p> <p>Ratio of structures sprayed to sachets issued</p> <p>Storehouse temperature measured and recorded</p> <p>No leaks or spills evident</p> <p>Insecticides not stored in same room with food, or medicine, or in inhabited spaces</p> <p>Facility physically secure, padlocked and guarded when not in use</p> <p>No fire, flame, smoking or eating allowed in storage areas</p>	
<p>Personnel handling OPs or carbamates experience cholinesterase inhibition (CI) due to exposure. (Symptoms include tiredness, weakness, dizziness, nausea and blurred vision, headache, sweating, tearing, drooling, vomiting, tunnel vision, and twitching, abdominal cramps, muscular tremors, staggering gait)</p>	<p>For all pesticides, all storage, spray, and wash teams receive training in recognizing effects of pesticide poisoning, remain alert to symptoms amongst their co-workers and respond appropriately.</p> <p>PMI will evaluate various approaches to monitoring sprayer exposure to organophosphate (OP) pesticides and will develop protocols, based on these evaluations, for a monitoring program.</p>	<p>Training: Included in pre-campaign orientation, and in training for new personnel.</p> <p>PMI will use the protocols developed to inform the implementation of PMI program monitoring for organophosphate pesticides.</p>	<p>Demonstrated knowledge of symptoms of poisoning, emergency treatment, and referral protocol by supervisors, team leaders, SWS members</p> <p>Antidotes available at health facilities</p>	<p>MOH, District Health Officers, Implementing partners</p>
<p>Acute effects of pesticide toxicity go untreated (Symptoms include</p>	<p>Employ CI testing as needed</p> <p>Team leaders, storekeepers trained to</p>	<p>Training on symptoms and responses prior to</p>	<p>Demonstrated knowledge of signs and symptoms of poisoning, emergency</p>	<p>Spray team supervisors, spray team leaders. District health officials, and</p>

Negative Impact	Mitigation Activities	Monitoring Frequency	Monitoring Indicators	Implementation Responsibility
<p>tiredness, weakness, dizziness, nausea, blurred vision, headache, sweating, tearing, drooling, vomiting, tunnel vision, twitching, abdominal cramps, muscular tremors, staggering gait)</p>	<p>recognize symptoms and enforce treatment</p> <p>Ensure treatment medicines are available at District health centers.</p> <p>If skin itches after re-entrance into home, wash with soap and water, for eye irritation, flush eyes with water.</p> <p>For respiratory irritation, leave the home for fresh air.</p> <p>For ingestion, or if symptoms persist, contact program staff or go to nearest health facility.</p>	<p>each campaign</p> <p>Continuous observation, reinforcement and enforcement of treatment protocols</p>	<p>treatment, and referral protocol by supervisors, team leaders, storekeepers, spray operators, washpersons (SSW), and residents</p> <p>CI test results</p> <p>Antidotes and treatment medicines available at health facilities</p>	<p>Implementing partners</p>
<p>Exposure of SSW members and/or community during spray operations due to improper spray procedures</p> <p>Failure to realize/receive the benefits of IRS due to improper spray procedures</p>	<p>Training of SSW members, team leaders supervisors, and health workers according to MOH and WHOPES recommendations</p> <p>Proper assembly and calibration of spray equipment</p> <p>Proper spray patterns</p> <p>Proper cleanup and equipment storage procedures</p> <p>Discipline SSW members that do not follow proper procedure in all aspects of operations (handling, spraying, hygiene, cleanup)</p>	<p>Once prior to campaign</p> <p>Continuous</p>	<p>Spray operators, team leaders supervisors and health workers display knowledge by following procedures at all times</p> <p>Frequently agitate spray can</p> <p>Hold pump such that compression gage can be seen</p> <p>Stands parallel to wall being sprayed</p> <p>Stands 45 cm from wall</p> <p>1m/2.5 sec spray rate</p> <p>75 cm swatch width and 5 cm overlap</p> <p>All eaves and interior surfaces sprayed except dedicated kitchens</p>	<p>Spray team supervisors, spray team leaders, Implementing partners</p>

Negative Impact	Mitigation Activities	Monitoring Frequency	Monitoring Indicators	Implementation Responsibility
SSW member or community exposure, or environmental contamination due to equipment or PPE issues	<p>Use of sprayers manufactured and maintained according to WHOPES specifications</p> <p>Proper assembly and calibration of spray equipment</p> <p>Procurement and proper use of PPE by all persons in contact with pesticides</p>	Continuous	<p>All PPE as specified in WHOPES recommendations in good condition and worn by all personnel in contact with pesticides</p> <p>Condition of spray equipment</p> <p>Spray nozzle not dripping during spraying or transportation</p> <p>CI levels</p>	Spray team supervisors, spray team leaders, Implementing partners
Residential Exposure from contaminated household goods	<p>Training of spray operators to refuse to spray houses that are not properly prepared</p> <p>IEC Campaign, instruct residents to:</p> <p>Clear homes of mats or rugs, furniture, cooking implements and foodstuffs prior to spraying</p> <p>If furniture cannot be moved out of the home, then move it to the center of the room and cover with drop cloth</p> <p>Stay outside the home during spraying and for two to four hours after spraying</p> <p>Move and keep (tie-up or cage) all animals outside the home during spraying, and for four hours after spraying</p> <p>Sweep up any insects killed from the spraying or any residual insecticide and drop waste in latrine pits</p>	<p>Training and communication program prior to campaign,</p> <p>Spray operators require household goods removal prior to spraying domicile</p>	<p>IEC materials developed and include specific instructions</p> <p>IEC materials delivered in appropriate fashion</p> <p>Residents outside house during spraying</p> <p>Food and goods outside house during spraying</p> <p>Furniture covered during spraying</p> <p>Residents stay outside for four hours after spraying</p> <p>Residents sweep floor and dispose of waste properly</p> <p>Occurrence of skin/eye/throat irritation</p> <p>Houses not sprayed for lack of preparation</p>	District Environment Office, NEMA, EPA, Implementing partners USAID

Negative Impact	Mitigation Activities	Monitoring Frequency	Monitoring Indicators	Implementation Responsibility
Failure to realize benefits of spraying due to post-spray behavior change	Train residents to continue using bed nets for protection against malaria, and to refrain from re-plastering or painting over the sprayed walls after spraying, re-plaster prior to spraying if necessary	Prior to each campaign	Continued bed net use Walls not plastered after spraying	Village and district leaders
Staff and community exposure in vehicle used to transport spray team and/or pesticides	Frequent washing interior and exterior of program vehicles after pesticide transport using soap and water and PPE	Continuous	Vehicle condition	Cooper, Spray team supervisors, spray team leaders, Implementing partners
SSW personnel exposure due to poor personal hygiene	Training and enforcement in good personal hygiene, daily washing of protective clothes and cleaning of equipment  Prohibition of eating, drinking and smoking during travel, work or before decontamination  Discipline SSW personnel that do not follow proper procedures in all aspects of operations (handling, spraying, hygiene, cleanup)	Training once prior to campaign, continuous reinforcement and enforcement of good personal hygiene	Two uniforms and PPE issued to each spray operator and one set cleaned each day  No eating, drinking or smoking witnessed during operations or prior to washing  Adequate numbers of shower/bathing facilities available  Shower or bath taken, face/neck and hands washed with soap and water.	Spray team supervisors, spray team leaders, Implementing partners
SSW personnel and/or community exposure due to poor waste management procedures	Procurement of barrels for progressive rinse, and wash-tubs for personal hygiene; equipment labeled as District Health Office property to deter sale and domestic use in event of pilferage  Collection, counting, and comparing number of empty sachets to disbursement records, collection of worn/torn gloves and masks  Shipment of all wastes to authorized incinerator, destruction witnessed by Ministry of Health Official	Once prior to campaign          Continuous	Purchase records, inspection reports, waste disposal records from incinerator	District health officials, Implementing partners

Negative Impact	Mitigation Activities	Monitoring Frequency	Monitoring Indicators	Implementation Responsibility
Exposure of residents needing physical assistance during spray operations	<p>Communities establish system to assist the elderly and disabled in removing self and goods from the household.</p> <p>Spray operators enforce removal of household goods</p>	<p>Train operators once prior to campaign</p> <p>Continuous enforcement</p>	IEC campaign adequately addresses issues surrounding the elderly and disabled	District, County, Parish, and Village leaders
<p>Fetal/Infant Exposure due to maternal exposure on spray team</p> <p>Fetal Exposure – Pregnant women in contact with pesticides</p>	<p>Training of stockroom, spray, and wash, (SSW) teams.</p> <p>Pregnancy tests as eligibility criteria for SSW teams;</p> <p>Prohibition of breastfeeding women on SSW teams;</p> <p>Education of women regarding risks of exposure</p> <p>Completion of consent forms</p> <p>Assign pregnant women to tasks that have no occupational exposure to insecticides.</p>	Once prior to campaign, during campaign as necessary	<p>Pregnancy test results</p> <p>Written confirmation from all female SWS workers that they are not breastfeeding</p> <p>Signed consent forms from all female SSW workers</p> <p>Number of females reassigned</p>	Spray team supervisors, spray team leaders, District health officials, Implementing partners
Exposure of aged, infirm, pregnant women or fetus, due to inability to leave the home during spraying	Prohibition of spraying in homes where seriously infirm or immobile persons, or pregnant women are living who cannot move outside the home and stay outside the home during, and 4 hours after spraying	Continuous	<p>Residents outside house during spraying</p> <p>Residents stay outside for four hours after spraying</p> <p>Number of houses not sprayed due to resident immobility</p>	Spray team leaders and supervisors, residents, spray personnel
Pesticide contamination of water resources, (groundwater, rivers, streams, lakes)	<p>Do not spray any residences within 100 meters of principle water resources (other interventions should be implemented such as LLINs or wall lining)</p> <p>Do not dispose of any pesticides anywhere other than IRS triple rinse wash system</p>	Continuous	Evidence of environmental contamination (fish, bird, or bee kills), discoloration or turbidity of water	Spray team leaders, supervisors, district environmental officers, Implementing partners environmental compliance officer

Negative Impact	Mitigation Activities	Monitoring Frequency	Monitoring Indicators	Implementation Responsibility
Loss of biodiversity due to pesticide contamination	Do not spray or wash near sensitive areas or critical habitat (sensitive areas and critical habitats must be identified before activities commence)	Continuous	Individual organism fatalities or impairment	Spray team leaders, supervisors, district environmental officers, Implementing partners environmental compliance officer
Farm, aquaculture or apiary contamination	Train farmers, fish farmers and beekeepers in target areas to guard against contamination of agri/aquaculture or apiary equipment, and to ensure sweeping and disposal of floor residue and dead after IRS in pit latrines prior to storing equipment in home.  Train SSW workers on the dangers of pesticides to food, fish, birds, and bees	Once prior to campaign	Number of post-spraying complaints from agri-aquaculture or apiary practitioners in target area  Reports of fish or bee kills	Spray team leaders and supervisors, spray personnel, Implementing partners
Spray operations have no/reduced impact on vector due to pesticide quality	Collect insecticide samples and test to ensure quality control  Supervise and monitor pesticide make-up procedures	Periodic spot sampling  Continuous monitoring by spray team leaders and supervisors	Pesticide meets specifications  Spray operator usage reports reflect proper house/sachet ratio	Implementing partners, team leaders and supervisors
Loss of efficacy of pesticides due to continuous or inappropriate use	Use pesticide rotation or mosaicing protocol to minimize development of resistance to insecticides. Avoid agricultural use of health-based pesticides.	Continuously re-assess pesticide to be used based on entomological monitoring	Protocol developed	Implementing partners.
Vector develops resistance to insecticide used	Change pesticide used	Monitoring resistance before, during, and after each campaign.	Monitoring results presented in end-of-round report	Implementing partners

Negative Impact	Mitigation Activities	Monitoring Frequency	Monitoring Indicators	Implementation Responsibility
SSW worker or community exposure, or environmental contamination due to negligence	Take disciplinary action against SSW workers that do not follow proper procedure in all aspects of operations (handling, spraying, hygiene, cleanup) up to and including discharge from duties	Continuous monitoring throughout campaign, immediate action upon discovery of non-conformance with procedures	Good hiring and management practices Adequate supervisor to team leader to spray operator ratio Number and severity of incidents reported	Spray team supervisors, spray team leaders, Implementing partners, District Officials
Community exposure, or environmental contamination post- campaign due to inadequate de-mobilization	Spray equipment, uniforms, PPE, wash equipment, , etc. get a final cleaning at end of campaign and are securely stored  Check expiration dates on all leftover pesticide. Transfer any unused pesticide to District secured warehouse for disposal if expired, or use in subsequent spray round(s).	Once at end of campaign	Presence of adequate facilities for end of campaign cleaning and storage  Visual observance of proper de-mobilization  All equipment cleaned and properly stored	District health teams, Implementing partners
Community exposure due to residuals in vehicles used for pesticide transport	End-of-program cleaning/decontamination of interior and exterior of vehicles	Once after campaign	Interiors and exteriors of vehicles cleaned	Drivers/Rental company

## ANNEX 2: General Principles in the Management of Acute Pesticide Poisonings

### Skin Decontamination

Decontamination must proceed concurrently with whatever resuscitative and antidotal measures are necessary to preserve life. Shower patient with soap and water, and shampoo hair to remove chemicals from skin and hair. If there are any indications of weakness, ataxia, or other neurologic impairment, remove the victim's clothing, have the victim lie down, and give the victim a complete bath and shampoo using copious amounts of soap and water. Check for pesticide sequestered under fingernails or in skin folds and wash these areas.

Flush contaminating chemicals from eyes with copious amounts of clean water for 10-15 minutes. If eye irritation is present after decontamination, ophthalmologic consultation is appropriate.

Persons attending the victim should avoid direct contact with heavily contaminated clothing and vomitus. Contaminated clothing should be promptly removed, bagged, and laundered before returning to the patient. Shoes and other leather items cannot usually be decontaminated and should be discarded. Note that pesticides can contaminate the inside surfaces of gloves, boots, and headgear. Decontamination should especially be considered for emergency personnel (such as ambulance drivers) at the site of a spill or contamination. Wear rubber gloves while washing pesticide from skin and hair of patient. Latex and other surgical or precautionary gloves usually do not provide adequate protection from pesticide contamination.

### Airway Protection

Ensure that a clear airway exists. Suction any oral secretions using a large bore suction device if necessary. Intubate the trachea if the patient has respiratory depression or if the patient appears obtunded or otherwise neurologically impaired. Administer oxygen as necessary to maintain adequate tissue oxygenation. In severe poisonings, mechanically supporting pulmonary ventilation for several days may be necessary.

**Note on Specific Pesticides:** There are several special considerations with regard to certain pesticides. In **organophosphate** and **carbamate** poisoning, adequate tissue oxygenation is essential prior to administering atropine.

### Gastrointestinal Decontamination

A joint position statement has recently been released by the American Academy of Clinical Toxicology and the European Association of Poisons Centres and Clinical Toxicologists on various methods of gastrointestinal decontamination. A summary of the position statement accompanies the description of each procedure.

- 1. **Gastric Lavage.** If the patient presents within 60 minutes of ingestion, lavage may be **considered**. Insert an orogastric tube and follow with fluid, usually normal saline. Aspirate back the fluid in an attempt to remove any toxicant. If the patient is neurologically impaired, airway protection with a cuffed endotracheal tube is indicated prior to gastric lavage. Lavage performed more than 60 minutes after ingestion has not proven to be beneficial and runs the risk of inducing bleeding, perforation, or scarring due to additional trauma to already traumatized tissues. It is almost always necessary first to control seizures before attempting gastric lavage or any other method of GI decontamination. Studies of poison recovery have been performed mainly with solid material such as pills. There are no controlled studies of pesticide recovery by these methods. Reported recovery of material at 60 minutes in several studies was 8 percent to 32 percent. There is further evidence that lavage may propel the material into the small bowel, thus increasing absorption.

**Note on Specific Pesticides:** Lavage is contraindicated in hydrocarbon ingestion, a common vehicle in many pesticide formulations.

**Position Statement:** Gastric lavage should not be routinely used in the management of poisons. Lavage is indicated only when a patient has ingested a potentially life-threatening amount of poison and the procedure can be done within 60 minutes of ingestion. Even then, clinical benefit has not been confirmed in controlled studies.

- 2. **Activated Charcoal Adsorption.** Activated charcoal is an effective absorbent for many poisonings. Volunteer studies suggest that it will reduce the amount of poison absorbed if given within 60 minutes. There are insufficient data to support or exclude its use if time from ingestion is prolonged, although some poisons that are less soluble may be absorbed beyond 60 minutes. Clinical trials with charcoal have been done with poisons other than pesticides. There is some evidence that paraquat is well absorbed by activated charcoal. Charcoal has been anecdotally successful with other pesticides.

#### **Dosage of Activated Charcoal:**

- *Adults and children over 12 years:* 25-100 g in 300-800 mL water.
- *Children under 12 years:* 25-50 g per dose.
- *Infants and toddlers under 20 kg:* 1 g per kg body weight.

Many activated charcoal formulations come premixed with sorbitol. Avoid giving more than one dose of sorbitol as a cathartic in infants and children due to the risk of rapid shifts of intravascular fluid. Encourage the victim to swallow the adsorbent even though spontaneous vomiting continues. Antiemetic therapy may help control vomiting in adults or older children. As an alternative, activated charcoal may be administered through an orogastric tube or diluted with water and administered slowly through a nasogastric tube. Repeated administration of charcoal or other absorbent every 2-4 hours may be beneficial in both children and adults, but use of a cathartic such as sorbitol should be avoided after the first

dose. Repeated doses of activated charcoal should not be administered if the gut is atonic. The use of charcoal without airway protection is contraindicated in the neurologically impaired patient.

**Note on Specific Pesticides:** The use of charcoal without airway protection should be used with caution in poisons such as organophosphates, carbamates, and organochlorines if they are prepared in a hydrocarbon solution.

**Position Statement:** Single-dose activated charcoal should not be used routinely in the management of poisoned patients. Charcoal appears to be most effective within 60 minutes of ingestion and may be considered for use for this time period. Although it may be considered 60 minutes after ingestion, there is insufficient evidence to support or deny its use for this time period. Despite improved binding of poisons within 60 minutes, only one study suggests that there is improved clinical outcome. Activated charcoal is contraindicated in an unprotected airway, a GI tract not anatomically intact, and when charcoal therapy may increase the risk of **aspiration** of a hydrocarbon-based pesticide.

**Seizures:** Lorazepam is increasingly being recognized as the drug of choice for status epilepticus, although there are few reports of its use with certain pesticides. Emergency personnel must be prepared to assist ventilation with lorazepam and any other medication used to control seizures. See dosage table below. For organochlorine compounds, use of lorazepam has not been reported in the literature. Diazepam is often used for this, and is still used in other pesticide poisonings.

#### Dosage of Diazepam:

- *Adults:* 5-10 mg IV and repeat every 5-10 minutes to maximum of 30 mg.
- *Children:* 0.2 to 0.5 mg/kg every 5 minutes to maximum of 10 mg in children over 5 years, and maximum of 5 mg in children under 5 years.

#### Dosage of Lorazepam:

- *Adults:* 2-4 mg/dose given IV over 2-5 minutes. Repeat if necessary to a maximum of 8 mg in a 12 hour period.
- *Adolescents:* Same as adult dose, except maximum dose is 4 mg.
- *Children under 12 years:* 0.05-0.10 mg/kg IV over 2-5 minutes. Repeat if necessary .05 mg/kg 10-15 minutes after first dose, with a maximum dose of 4 mg.

Caution: Be prepared to assist pulmonary ventilation mechanically if respiration is depressed, to intubate the trachea if laryngospasm occurs, and to counteract hypotensive reactions.

Phenobarbital is an additional treatment option for seizure control. Dosage for **infants, children, and adults** is 15-20 mg/kg as an IV loading dose. An additional 5 mg/kg IV may

be given every 15-30 minutes to a maximum of 30 mg/kg. The drug should be pushed no faster than 1 mg/kg/minute.

For seizure management, most patients respond well to usual management consisting of benzodiazepines, or phenytoin and phenobarbital.

## ANNEX 3: Summary of Acute Exposure Symptoms and Treatment

Pesticide Type	Human side effects	Treatment
<b>Malathion</b>	Malathion is an indirect cholinesterase inhibitor. The primary target of malathion is the nervous system; it causes neurological effects by inhibiting cholinesterase in the blood and brain. Exposure to high levels can result in difficulty breathing, vomiting, blurred vision, increased salivation and perspiration, headaches, and dizziness. Loss of consciousness and death may follow very high exposures to malathion.	<p>Oral exposure to malathion should be treated with rapid gastric lavage unless the patient is vomiting. Dermal exposures should be treated by washing the affected area with soap and water. If the eyes have been exposed to malathion, flush them with saline or water.</p> <p>People exposed to malathion who exhibit respiratory inefficiency with peripheral symptoms should be treated via slow intravenous injection with 2–4 mg atropine sulfate and 1,000–2,000 mg pralidoxime chloride or 250 mg toxogonin (adult dose).</p> <p>Exposure to high levels of malathion that result in respiratory distress, convulsions, and unconsciousness should be treated with atropine and a re-activator. Morphine, barbiturates, phenothiazine, tranquilizers, and central stimulants are all contraindicated</p>
<b>Fenitrothion</b>	<p>Fenitrothion is the most toxic to man of the insecticides approved for residual house spraying, and has a relatively low margin of safety.</p> <p>Absorbed through the gastrointestinal tract as well as through intact skin and by inhalation. It is also a cholinesterase inhibitor.</p>	<p>Dermal exposure to fenitrothion should be treated by removing contaminated clothing, rinsing the skin with water, washing the exposed areas with soap and water, then seeking medical attention. If fenitrothion gets into the eyes, they should be rinsed with water for several minutes.</p> <p>Contact lenses should be removed if possible and medical attention should be sought. Ingestion of fenitrothion should be treated by rinsing the mouth and inducing vomiting if the person is conscious. Inhalation exposures require removal to fresh air and rest in a half-upright position. Artificial respiration should be administered if indicated and medical attention should be sought.</p>
<b>Pirimiphos-methyl</b>	<p>This is also a cholinesterase inhibitor. Early symptoms of poisoning may include excessive sweating, headache, weakness, giddiness, nausea, vomiting, stomach pains, blurred vision, constricted pupils, slurred speech, and muscle twitching.</p> <p>Later there may be convulsions, coma, loss of reflexes, and loss of sphincter control.</p>	<p>Organophosphate poisoning is a medical emergency and requires immediate treatment. All supervisors and individual spraymen (in the case of dispersed operations) should be trained in first-aid and emergency treatment of organophosphate intoxication.</p> <p>The affected person should stop work immediately, remove any contaminated clothing, wash the affected skin with soap and clean water and flush the skin with large quantities of clean water. Care must be taken not to contaminate others, including medical or paramedical workers.</p> <p>Automatic injectors loaded with atropine sulfate and obidoxime chloride can be made available in the field whenever relatively toxic organophosphate insecticides are used in areas without easy access to medical care.</p> <p><b>Atropine sulfate.</b> Administer atropine sulfate intravenously or intramuscularly if intravenous injection is not possible.</p>

## Annex 4: USA Regulation 22cfr 216.3.(b)

### (b) Pesticide Procedures

(1) **Project Assistance.** Except as provided in §216.3 (b)(2), all proposed projects involving assistance for the procurement or use, or both, of pesticides shall be subject to the procedures prescribed in §216.3(b)(1)(i) through (v). These procedures shall also apply, to the extent permitted by agreements entered into by A.I.D. before the effective date of these pesticide procedures, to such projects that have been authorized but for which pesticides have not been procured as of the effective date of these pesticide procedures.

(i) When a project includes assistance for procurement or use, or both, of pesticides registered for the same or similar uses by USEPA without restriction, the Initial Environmental Examination for the project shall include a separate section evaluating the economic, social and environmental risks and benefits of the planned pesticide use to determine whether the use may result in significant environmental impact. Factors to be considered in such an evaluation shall include, but not be limited to the following:

- (a) The USEPA registration status of the requested pesticide;
- (b) The basis for selection of the requested pesticide;
- (c) The extent to which the proposed pesticide use is part of an integrated pest management program;
- (d) The proposed method or methods of application, including availability of appropriate application and safety equipment;
- (e) Any acute and long-term toxicological hazards, either human or environmental, associated with the proposed use and measures available to minimize such hazards;
- (f) The effectiveness of the requested pesticide for the proposed use;
- (g) Compatibility of the proposed pesticide with target and nontarget ecosystems;
- (h) The conditions under which the pesticide is to be used, including climate, flora, fauna, geography, hydrology, and soils;
- (i) The availability and effectiveness of other pesticides or nonchemical control methods;
- (j) The requesting country's ability to regulate or control the distribution, storage, use and disposal of the requested pesticide;
- (k) The provisions made for training of users and applicators; and
- (l) The provisions made for monitoring the use and effectiveness of the pesticide.

In those cases where the evaluation of the proposed pesticide use in the Initial Environmental Examination indicates that the use will significantly effect the human environment, the Threshold Decision will include a recommendation for the preparation of an Environmental Assessment or Environmental Impact Statement, as appropriate. In the event a decision is made to approve the planned pesticide use, the Project Paper shall include to the extent practicable, provisions designed to mitigate potential adverse effects of the pesticide. When the pesticide evaluation section of the Initial Environmental Examination does not indicate a potentially unreasonable risk arising from the pesticide use, an Environmental Assessment or Environmental Impact Statement shall nevertheless be prepared if the environmental effects of the project otherwise require further assessment.

(ii) When a project includes assistance for the procurement or use, or both, of any pesticide registered for the same or similar uses in the United States but the proposed use is restricted by the USEPA on the basis of user hazard, the procedures set forth in §216.3(b)(1)(i) above will be followed. In addition, the Initial Environmental Examination will include an evaluation of the user hazards associated with the proposed USEPA restricted uses to ensure that the implementation plan which is contained in the Project Paper incorporates provisions for making the recipient government aware of these risks and providing, if necessary, such technical assistance as may be required to mitigate these risks. If the proposed pesticide use is also restricted on a basis other than user hazard, the procedures in §216.3(b)(1)(iii) shall be followed in lieu of the procedures in this section.

(iii) If the project includes assistance for the procurement or use, or both of:

(a) Any pesticide other than one registered for the same or similar uses by USEPA without restriction or for restricted use on the basis of user hazard; or

(b) Any pesticide for which a notice of rebuttable presumption against reregistration, notice of intent to cancel, or notice of intent to suspend has been issued by USEPA,

The Threshold Decision will provide for the preparation of an Environmental Assessment or Environmental Impact Statement, as appropriate (§216.6(a)). The EA or EIS shall include, but not be limited to, an analysis of the factors identified in §216.3(b)(1)(i) above.

(iv) Notwithstanding the provisions of §216.3(b)(1)(i) through (iii) above, if the project includes assistance for the procurement or use, or both, of a pesticide against which USEPA has initiated a regulatory action for cause, or for which it has issued a notice of rebuttable presumption against reregistration, the nature of the action or notice, including the relevant technical and scientific factors will be discussed with the requesting government and considered in the IEE and, if prepared, in the EA or EIS. If USEPA initiates any of the regulatory actions above against a pesticide subsequent to its evaluation in an IEE, EA or EIS, the nature of the action will be discussed with the recipient government and considered in an amended IEE or amended EA or EIS, as appropriate.

(v) If the project includes assistance for the procurement or use, or both of pesticides but the specific pesticides to be procured or used cannot be identified at the time the IEE is prepared, the procedures outlined in §216.3(b)(i) through (iv) will be followed when the specific pesticides are identified and before procurement or use is authorized. Where identification of the pesticides to be procured or used does not occur until after Project Paper approval, neither the procurement nor the use of the pesticides shall be undertaken unless approved, in writing, by the Assistant Administrator (or in the case of projects authorized at the Mission level, the Mission Director) who approved the Project Paper.

**(2) Exceptions to Pesticide Procedures.** The procedures set forth in §216.3 (b)(1) shall not apply to the following projects including assistance for the procurement or use, or both, of pesticides.

(i) Projects under emergency conditions.

Emergency conditions shall be deemed to exist when it is determined by the Administrator, A.I.D., in writing that:

(a) A pest outbreak has occurred or is imminent; and

(b) Significant health problems (either human or animal) or significant economic problems will occur without the prompt use of the proposed pesticide; and

(c) Insufficient time is available before the pesticide must be used to evaluate the proposed use in accordance with the provisions of this regulation.

(ii) Projects where A.I.D. is a minor donor, as defined in §216.1(c)(12) above, to a multidonor project.

(iii) Projects including assistance for procurement or use, or both, of pesticides for research or limited field evaluation purposes by or under the supervision of project personnel. In such instances, however, A.I.D. will ensure that the manufacturers of the pesticides provide toxicological and environmental data necessary to safeguard the health of research personnel and the quality of the local environment in which the pesticides will be used. Furthermore, treated crops will not be used for human or animal consumption unless appropriate tolerances have been established by EPA or recommended by FAO/WHO, and the rates and frequency of application, together with the prescribed preharvest intervals, do not result in residues exceeding such tolerances. This prohibition does not apply to the feeding of such crops to animals for research purposes.

(3) **Non-Project Assistance.** In a very few limited number of circumstances A.I.D. may provide nonproject assistance for the procurement and use of pesticides. Assistance in such cases shall be provided if the A.I.D. Administrator determines in writing that

(i) emergency conditions, as defined in §216.3(b)(2)(i) above exist; or

(ii) that compelling circumstances exist such that failure to provide the proposed assistance would seriously impede the attainment of U.S. foreign policy objectives or the objectives of the foreign assistance program. In the latter case, a decision to provide the assistance will be based to the maximum extent practicable, upon a consideration of the factors set forth in §216.3(b)(1)(i) and, to the extent available, the history of efficacy and safety covering the past use of the pesticide the in recipient country.

## Annex 5: Pesticides Profiles

### Profile for Alpha-Cypermethrin:

CAS Registry Number 67375-30-8

#### *Summary of Insecticide*

##### *Chemical History*

Alpha-cypermethrin is a highly active synthetic pyrethroid insecticide used to control a wide variety of pests in agricultural and public health applications. It is similar to the natural insecticide pyrethrum, which comes from chrysanthemums; however, it is more effective and longer lasting (ATSDR, 2003; IPCS, 1992). Alpha-cypermethrin is available in technical grade formulation, emulsifiable concentrate, ultra-low-volume formulation, suspension concentrate, and in mixtures with other insecticides (HSDB, 2005; IPCS, 1992). For mosquito control, it is used in bed nets and other materials that are dipped in alpha-cypermethrin to protect the user (WHO, 1997, 1998). It is considered one of the best insecticides for impregnation of traps and screens (WHO, 1997). Alpha-cypermethrin is not currently registered for use in the United States (HSDB, 2005), but cypermethrin is.

Alpha-cypermethrin is of low risk to humans when used at levels recommended for its designed purpose (ATSDR, 2003; HSDB, 2005). However, as a synthetic pyrethroid, alpha-cypermethrin exhibits its toxic effects by affecting the way the nerves and brain normally function by interfering with the sodium channels of nerve cells (ATSDR, 2003; HSDB, 2005). It has moderate acute toxicity and is a suspected endocrine disruptor but does not inhibit cholinesterase (PAN, 2005). EPA has not classified synthetic pyrethroids, including alpha-cypermethrin, as endocrine disruptors. Typical symptoms of acute exposure are irritation of skin and eyes, headaches, dizziness, nausea, vomiting, diarrhea, and excessive salivation and fatigue. Inhaled alpha-cypermethrin has been shown to cause cutaneous paraesthesia or a burning, tingling, or stinging of the skin. However, these effects are generally reversible and disappear within a day of removal from exposure (ATSDR, 2003; HSDB, 2005; PAN, 2005). Alpha-cypermethrin is harmful if swallowed (MSDS, n.d.). Inhalation and dermal exposure are the most likely human exposure routes (HSDB, 2005). Environmental levels of significance are unlikely if alpha-cypermethrin is applied at recommended rates (IPCS, 1992).

##### *Description of Data Quality and Quantity*

Comprehensive reviews on the toxicity of alpha-cypermethrin are not widely available but include the following:

- Toxicological Profile for Pyrethrin and Pyrethroids (ATSDR, 2003)
- Environmental Health Criteria 142: Alpha- Cypermethrin (IPCS, 1992)

EPA and ATSDR have developed quantitative oral human health benchmarks (EPA's chronic RfD and ATSDR's acute oral MRL) for cypermethrin. Alpha-cypermethrin makes up one quarter of the racemic mixture cypermethrin and has a similar mode of action. Alpha-cypermethrin is also similar to cypermethrin with regard to the signs of intoxication, target organs effects, and metabolic pathways (IPCS, 1992).

## Summary Table

Duration	Route	Benchmark Value	Units	Endpoint	Reference
Acute, Intermediate, Chronic	Inhalation	4	mg/kg/day	Inhalation NOAEL in rats with UF of 100 applied	
Acute	Oral	0.02	mg/kg/day	Acute oral MRL for cypermethrin based on neurological effects in rats with UF of 1000 applied	ATSDR (2003)
Intermediate	Oral	0.01	mg/kg/day	Adopt chronic RfD as intermediate duration	
Chronic	Oral	0.01	mg/kg/day	Chronic oral RfD for cypermethrin based on neurological effects in dogs with UF of 100 applied	U.S. EPA (2005)
Acute, Intermediate, Chronic	Dermal	5	mg/kg/day	Dermal NOAEL in rats with UF of 100 applied	

For inhalation exposure, a NOAEL of 400 mg/m<sup>3</sup> (447 mg/kg/day)<sup>16</sup> was identified for neurological and respiratory effects in rats exposed to alpha-cypermethrin via inhalation for 4 hours (IPCS, 1992). An uncertainty factor of 100 to account for intra- and interspecies variation was applied, for an inhalation benchmark of 4 mg/kg/day. This value is appropriate for all exposure durations.

Due to limited low-dose oral data for alpha-cypermethrin, health benchmarks for cypermethrin were used and are expected to be protective of human health. The acute oral MRL for cypermethrin of 0.02 mg/kg/day is based on a LOAEL of 20 mg/kg for neurological effects (altered gait and decreased motor activity) in rats with an uncertainty factor of 1,000 applied. Long-Evans rats were given single gavage doses of up to 120 mg/kg cypermethrin. Motor activity and FOB were assessed at 2 and 4 hours post-dosing. A NOAEL was not identified (ATSDR, 2003). The chronic oral RfD for cypermethrin of 0.01 mg/kg/day is based on a NOEL of 1 mg/kg/day for systemic effects with an uncertainty factor of 100 applied. Beagle dogs were dosed with up to 15 mg/kg/day cypermethrin in corn oil for 52 weeks. During the first week, increased vomiting was observed in dogs at all dose levels. Additionally, throughout the study all dogs passed liquid feces; however, the incidence was 10- and 30-fold higher in the 5 and 15 mg/kg/day groups, respectively. The NOEL identified for this study was 1 mg/kg/day (U.S. EPA, 2005).

For dermal exposure, a NOAEL of 500 mg/kg/day was identified in rats dermally exposed to alpha-cypermethrin once for 24 hours (IPCS, 1992). An uncertainty factor of 100 to account

<sup>16</sup> Conversion between mg/m<sup>3</sup> and mg/kg/day assumes, for Fischer-344 rats, an average body weight of 0.152 kg and inhalation rate of 0.17 m<sup>3</sup>/day (U.S. EPA, 1988).

for intra- and interspecies variation was applied, for a dermal benchmark value of 5 mg/kg/day. This value is appropriate for all exposure durations.

### *Insecticide Background*

CASRN:	67375-30-8
Synonyms:	alfamethrin, alphamethrin, alphacypermethrin, alphacypermethrin, alfa-cipermetrina, alfacypermetrin, alfa cipermetrin, [1alpha(S*),3alpha]-(+)-Cyano(3-phenoxyphenyl)methyl 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate, (1R cis S) and (1S cis R) Enantiomeric isomer pair of alpha-cyano-3-phenoxybenzyl-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylate, Pesticide Code 209600(S)-alpha-cyano-3-phenoxybenzyl-(1R)-cis-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate and (R)-alpha-cyano-3-phenoxybenzyl-(1S)-cis-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate, WL 85871, cyano(3-phenoxyphenyl)methyl 3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate (+)-cis isomer, alphamethrin, numerous other systematic and non-systematic names (HSDB, 2005; PAN 2005; ATSDR, 2003; MSDS, n.d.)
Chemical Group:	pyrethroid (PAN, 2005)
Registered Trade Names:	Bestox, Fastac, Concord, Dominex, Fendona, Fendona 1.5 SC, Fendona 10 SC, Fendonal WP, Renegade (HSDB, 2005, IPCS, 1992, WHO, 2002), Tenopa SC (alphacypermethrin + flufenoxuron) (HSDB, 2005; PAN 2005; ATSDR, 2003; MSDS, n.d.)

### *Usage*

Alpha-cypermethrin is a pyrethroid insecticide used to combat a wide variety of chewing and sucking insects on field crops, fruits and vegetables, and in forestry uses. It may be applied to crops as either a curative or preventative treatment. Alpha-cypermethrin is also used in public health applications to control mosquitoes, flies, and other pests. For animal husbandry it is used as an ectoparasiticide and to control flies (HSDB, 2005; IPCS, 1992). Alpha-cypermethrin belongs to the pyrethroid class of insecticides, which have long been used to control mosquitoes, human lice, beetles, and flies (ATSDR, 2003). For mosquito protection, it is used in bed nets and other materials that are dipped into the alpha-cypermethrin to protect the user. Alpha-cypermethrin has been available since 1983 (IPCS, 1992); however, it not currently registered for use in the United States (HSDB, 2005).

### *Formulations and Concentrations*

Alpha-cypermethrin is available in technical grade, emulsifiable concentrates, wettable powder, suspension concentrates, ultra-low-volume liquids, tablets, and in mixtures with other insecticides (HSDB, 2005; IPCS, 1992). Technical grade alpha-cypermethrin is greater than 90 percent pure (HSDB, 2005). Common formulations of alpha-cypermethrin include Fastac, which is available as an emulsifiable concentrate (20–100 g/L), a wettable powder (50 g/kg), a suspension concentrate (15–250 g/L), and an ultra-low-volume liquid (6–15 g/L); and Fendona and Renegade, which are available as an emulsifiable concentrate (50 or 100 g/L), a suspension concentrate (250 g/L), and a wettable powder (50 g/kg). Alpha-cypermethrin is combined with other active ingredients to form other products (IPCS, 1992). WHO has indicated that the content of alpha-cypermethrin in the formulated products must be declared and shall not exceed the listed standards. Technical grade alpha-cypermethrin must have no less than 910 g/kg alphacypermethrin cis 2 ([IR cis] S and [IS cis] R isomers), and the combined content of the cis and trans isomers of alpha-cyano-3-phenoxybenzyl-2,2-dimethyl-3-(2,2-dichlorovinyl-) cyclopropanecarboxylate must be at least 975 g/kg. No more than 1 g/kg of volatile hydrocarbon solvent and 1 mg/kg of triethylamine is permitted. The aqueous suspension concentrate should contain alphacypermethrin cis 2 ([IR cis] S and [IS cis] R isomers) as follows: up to 25 g/kg,  $\pm$  15 percent of the declared content; 25 to 100 g/kg,  $\pm$  10 percent of the declared content. The alphacypermethrin cis 1:cis 2 isomer ratio must be lower than 5:95 (WHO, 1999).

### *Shelf Life*

Alpha-cypermethrin is stable in acidic and neutral environments. However, it hydrolyzes at pH 12–13 and decomposes at temperatures greater than 220 °C. For practical purposes, field studies have indicated that it is stable to sunlight (IPCS, 1992). It is not compatible with strong oxidizing agents (MSDS, n.d.).

### *Degradation Products*

Based on its structure, alpha-cypermethrin is expected to readily biodegrade in the environment. However, in two tests it did not degrade and therefore cannot be considered readily biodegradable. One of the major transformation products in the microbial transformation of technical alpha-cypermethrin is 3-phenoxybenzoic acid, which is then transformed to 4-hydroxy-3-phenoxybenzoic acid (IPCS, 1992).

### *Environmental Behavior*

#### **Fate and Transport in Terrestrial Systems**

Based on its Koc value, alpha-cypermethrin binds tightly to soil, making it almost immobile in most soil types. In moist soil, volatilization is expected to be the major fate process; however its bond to soil lessens this effect. Volatilization is not a major fate process for dry soil. Biodegradation by environmental organisms in non-sterile soil and by sunlight is expected (HSDB, 2005; IPCS, 1992). Studies have shown that within 2 weeks of treatment with 0.5 kg ai/ha (active ingredient per hectare) of a diluted alpha-cypermethrin emulsifiable

concentrate formulation in sandy-clay soil, residues of alpha-cypermethrin were 50 percent less. After 1 year, they were below detection or < 0.01 mg/kg. Similar results were seen after a second and third application to the site indicating that alpha-cypermethrin did not build up in the surface soil. Additionally, no leaching to subsurface soils was observed. Alpha-cypermethrin also does not build up in peat soils (IPCS, 1992).

### **Fate and Transport in Aquatic Systems**

Alpha-cypermethrin binds tightly to suspended solids and sediments in water. It is expected to volatilize from water; however, volatilization is lessened by alpha-cypermethrin's bond with soil. Reported volatilization half-lives are 8 days for a river models and 65 days for a lake model. If adsorption is taken into consideration, the estimated volatilization half-life in a pond model is 125 years. Estimated hydrolysis half-lives are 36 and 4 years at pH 7 and 8 respectively. Alpha-cypermethrin is also expected to undergo photodecomposition. Based on its bioconcentration factor, alpha-cypermethrin has a high potential to bioconcentrate in aquatic organism; however, its potential may actually be lower than this suggests because of the ability of aquatic organisms to rapidly metabolize alpha-cypermethrin (HSDB, 2005).

### *Human Health Effects*

#### **Acute Exposure**

#### *Effects/Symptoms*

Limited data exist on the acute toxicity of alpha-cypermethrin in humans (IPCS, 1992; HSDB, 2005). Occupationally exposed workers reported only mild skin irritation (IPCS, 1992). The main effects reported from acute exposure to alpha-cypermethrin in humans include skin rashes, eye irritation, itching and burning sensation on exposed skin, and paraesthesia (a result of the direct action of this type of pyrethroid on sensory nerve endings, causing repeated firings in these fibers). Acute inhalation exposures may cause upper and lower respiratory tract irritation. Ingestion of alpha-cypermethrin is also harmful (HSDB, 2005; MSDS, n.d.). No acute poisonings have been reported (IPCS, 1992).

In rodents, alpha-cypermethrin has moderate to high oral toxicity (HSDB, 2005; IPCS, 1992). Oral LD<sub>50</sub> values in rats and mice vary greatly and depend on the formulation, concentration, and the vehicle (IPCS, 1992). Acute oral LD<sub>50</sub> values for technical alpha-cypermethrin range from 79 to 400 mg/kg (in corn oil) in rats (HSDB, 2005; IPCS, 1992; MSDS, n.d.). Although the LD<sub>50</sub> of 80 mg/kg is considered representative, higher values have been reported. In mice, the reported acute oral LD<sub>50</sub> of technical alpha-cypermethrin is 35 mg/kg (in corn oil). Oral LD<sub>50</sub> values for formulated alpha-cypermethrin in rats range from 101 to 174 mg/kg for an emulsifiable concentrate formulation (100 g/L), while 1,804 mg/kg was reported for a suspension concentrate formulation (100 mg/L) and 5,838 mg/kg for an ultra-low-volume liquid formulation (15 g/L) (IPCS, 1992). Clinical signs reported in orally exposed animals are associated with central nervous system activity and included ataxia; gait abnormalities; choreoathetosis; "tip-toe" walk; and increased salivation, lacrimation, piloerection, tremor, and clonic convulsions. Acute dermal exposures are

minimally irritating to the skin and eyes of rabbit skin. However, some formulations can cause severe eye irritation that includes corneal opacity and iris damage. Stimulation of the sensory-nerve endings of the skin has been observed in guinea pigs. Reported dermal LD<sub>50</sub> values of greater than 2,000 mg tech/kg are reported for rats and rabbits (HSDB, 2005; IPCS, 1992). No mortality or signs of toxicity were observed in rats or mice after single dermal applications of up to 500 mg/kg or 4-hour inhalation exposure of mice to 400 mg/m<sup>3</sup>. Alpha-cypermethrin is not a dermal sensitizer in guinea pigs (IPCS, 1992).

### ***Treatment***

Pyrethroid insecticides and their metabolites can be detected in blood and urine; however, the methods are not practical to use given how quickly these compounds are broken down in the body (ATSDR, 2003). Alpha-cypermethrin poisoning should be treated the same as a pyrethroid poisoning. There are no antidotes for alpha-cypermethrin exposure. Treatment is supportive and depends on the symptoms of the exposed person. Decontamination is all that is necessary for most exposures. If a person exhibits signs of typical pyrethroid toxicity following alpha-cypermethrin exposure (nausea, vomiting, shortness of breath, tremors, hypersensitivity, weakness, burning, or itching), they should immediately remove any contaminated clothing. Any liquid contaminant on the skin should be soaked up and the affected skin areas cleaned with alkaline soap and warm water. The application of topical vitamin E helps to relieve the symptoms of paraesthesia. Eye exposures should be treated by rinsing with copious amounts of saline or room temperature water for at least 15 minutes. Contact lenses should be removed. Medical attention should be sought if irritation, pain, swelling, lacrimation, or photophobia persists. The treatment of ingestion exposures is mostly symptomatic and supportive. Care should be taken to monitor for the development of hypersensitivity reactions with respiratory distress. Gastric decontamination is recommended if large amounts have been very recently ingested, and oral administration of activated charcoal and cathartic are recommended for ingestion of small amounts or if treatment has been delayed. Vomiting should not be induced following ingestion exposures, but the mouth should be rinsed. The person should be kept calm and medical attention should be sought as quickly as possible. For inhalation exposures, removal to fresh air and monitoring for breathing difficulties, respiratory tract irritation, bronchitis, and pneumonitis are recommended. Oxygen should be administered as necessary (PAN, 2005; HSDB, 2005).

### ***Chronic Exposure***

#### **Noncancer Endpoints**

Little data are available for humans following chronic exposures to alpha-cypermethrin. Chronic exposure to pyrethrins may cause hypersensitivity pneumonitis characterized by chest pain, cough, dyspnea, and bronchospasm. Because alpha-cypermethrin belongs to this class of chemicals, similar effects may be expected (HSDB, 2005).

Chronic toxicity data are also lacking in animals. No animal data are available for long-term toxicity, reproductive toxicity, teratogenicity, or immunotoxicity (HSDB, 2005; IPCS, 1992). However, chronic toxicity data are available for cypermethrin, including rodent multigenerational reproduction, embryotoxicity, and teratogenicity studies. At doses that produced systemic toxicity, no effects on reproductive parameters or fetal development were observed. Therefore, it is likely that alpha-cypermethrin would also cause no reproductive or developmental effects in rodents because it is a component of cypermethrin. Available data do not indicate that alpha-cypermethrin is mutagenic (IPCS, 1992).

### **Cancer Endpoints**

No data are available on the carcinogenic potential of alpha-cypermethrin (IPCS, 1992).

#### *Toxicokinetics*

Like other pyrethroid insecticides, orally administered alpha-cypermethrin, is absorbed via the intestinal tract of mammals, and dermally applied doses are absorbed through intact skin. Little or none is absorbed by inhalation exposures (HSDB, 2005). Most pyrethroids are rapidly broken down by liver enzymes and their metabolites are quickly excreted (HSDB, 2005). The metabolism of synthetic pyrethroids in mammals is generally through hydrolysis, oxidation, and conjugation. Metabolism of alpha-cypermethrin occurs by the cleavage of the ester bond. Studies in rats show that the phenoxybenzyl alcohol and cyclopropane carboxylic acid parts of the molecule are conjugated with sulfate and glucuronide, respectively, before being excreted in urine. Esteric hydrolysis and oxidative pathways occur in rats, rabbits, and humans with esteric hydrolysis being the predominant pathway in humans and rabbits (IPCS, 1992). Within 24 hours of an oral dose of 0.25–0.75 mg in humans, 43 percent was excreted in the urine as free of conjugated cis-cyclopropane carboxylic acid (HSDB, 2005; IPCS, 1992). Orally administered alpha-cypermethrin is eliminated in the urine of rats as the sulfate conjugate of 3-(4-hydroxyphenoxy) benzoic acid. In the faces it is eliminated partly as unchanged compound. Alpha-cypermethrin levels in tissues are low except for fatty tissues. The reported half-life for elimination from fat is 2.5 days for the first phase of elimination and 17 to 26 days for the second phase (IPCS, 1992).

#### *Ecological Effects*

### **Acute Exposure**

#### ***Toxicity in Non-Targeted Terrestrial Organisms***

Alpha-cypermethrin, like other pyrethroids, is very unlikely to harm terrestrial organisms other than its targets (e.g., mosquitoes and other pests). No toxicity data are available for alpha-cypermethrin in birds. However, cypermethrin has a very low toxicity in birds with acute oral LD<sub>50</sub> values of greater than 2,000 mg/kg body weight. In feed, the reported LC<sub>50</sub> values are greater than 10,000 mg/kg diet (IPCS, 1992). As with other pyrethroid insecticides, alpha-cypermethrin is extremely toxic to honey bees. The reported 24-hour oral LD<sub>50</sub> for alpha-cypermethrin emulsifiable concentrate is 0.13 µg/bee and the 24-hour oral LD<sub>50</sub> for alpha-cypermethrin in acetone was 0.06 µg/bee. The reported dermal LD<sub>50</sub>s are

0.03 µg/bee for technical alpha-cypermethrin and 0.11 µg/bee for emulsifiable concentrate (IPCS, 1992). The very high toxicity in bees was not observed in the field, likely as a result of the repellent effect of alpha-cypermethrin, which would limit exposure (IPCS, 1992; HSDB, 2005). Mortality was seen in only 15 percent of honey bees exposed to flowers treated with an emulsifiable concentrate formulation within 48 hours. Other studies using oil-enhanced suspension concentrate formulations showed similarly low toxicity. Additionally, a similar pattern of toxicity was seen in leaf-cutting bees. The toxicity of alpha-cypermethrin to earthworms, Carabid beetles, Syrphid larvae and neuropteran larvae is low while it is relatively high for Linyphiid spiders and Coccinellids (IPCS, 1992).

### ***Toxicity in Non-Targeted Aquatic Systems***

Alpha-cypermethrin is very toxic to fish under laboratory conditions, with emulsifiable concentrate formulations being the most toxic (IPCS, 1992); however, these effects are not seen in field studies. Therefore, the hazard to fish from contamination of waterbodies due to overspraying and drift is negligible (IPCS, 1992). Depending on the formulation, the reported 96-hour LC<sub>50</sub> values range from 0.7 to 350 µg/L (IPCS, 1992). For rainbow trout, the reported 96-hour LC<sub>50</sub> values range from 2.8 to 350 µg/L (HSDB, 2005; IPCS, 1992). The emulsifiable concentrate formulation is 10 to 70 times more toxic to rainbow trout than the wettable powder or suspension concentrate formulations. However, in field studies, the 14-day LC<sub>50</sub> for rainbow trout was just 29 g ai/ha for emulsifiable concentrate formulations and greater than 1,000 g ai/ha for suspension concentrate, wettable powder, and micro-encapsulated formulations. For fathead minnows, the reported 96-hour LC<sub>50</sub> value for technical alpha-cypermethrin was 0.93 µg/L, while the reported 96-hour LC<sub>50</sub> values for carp range from 0.8 to 11 µg/L depending on the formulation. For fish in the early stages of life, alpha-cypermethrin and cypermethrin toxicity are similar (IPCS, 1992). Alpha-cypermethrin has the potential to accumulate in fish, with a bioconcentration factor of 990 (HSDB, 2005). It has also been shown to be highly toxic to some aquatic invertebrates and aquatic insects (IPCS, 1992).

### **Chronic Exposure**

Due to low rate of application and low persistence of alpha-cypermethrin in both terrestrial and aquatic environments, serious adverse effects are not anticipated from chronic exposures (HSDB, 2005). The hazard of alpha-cypermethrin to fish and aquatic invertebrates is in its acute toxicity. There is no evidence of chronic exposure causing cumulative effects (IPCS, 1992).

# Profile for Bendiocarb:

CAS Registry Number 22781-23-3

## *Summary of Insecticide*

### *Chemical History*

Bendiocarb is a broad spectrum carbamate insecticide first registered in the United States in 1980 for use to control a wide variety of nuisance and disease vector insects, such as mosquitoes, flies, wasps, ants, fleas, cockroaches, silverfish, and ticks. It is also effective against a variety of agricultural insects and to treat seeds against pests (U.S. EPA, 1999a, 1999b; EXTTOXNET, 1996). The registration for bendiocarb was voluntarily canceled in 1999 (U.S. EPA, 1999a).

Bendiocarb exhibits its toxic effects through fast-acting, but reversible, cholinesterase inhibition. It has moderate toxicity in mammals (WHO/FAO, 1982), moderate toxicity in birds, and moderate to high toxicity in fish (EXTTOXNET, 1996). In humans, symptoms of poisoning are neurological and include headache, blurred vision, nausea, vomiting, giddiness, slurred speech, excessive sweating and salivation, chest tightness, and twitching muscles (WHO/FAO, 1982). Bendiocarb pesticides were formulated as dusts, granules, wettable powders, pellets, and ultra low volume (ULV) sprays (U.S. EPA, 1999a; EXTTOXNET, 1996).

### *Description of Data Quality and Quantity*

Review data for bendiocarb are limited. Relevant resources include

- Bendiocarb: Revised HED Chapter for the Reregistration Eligibility Decision (RED) Document (U.S. EPA, 1999b)
- Data Sheet on Pesticides No. 52: Bendiocarb (WHO/FAO, 1982)
- Pesticide Information Profile for Bendiocarb (EXTTOXNET, 1996).

EPA has developed quantitative human health benchmarks (acute and chronic oral RfDs and short-, intermediate-, and long-term dermal and inhalation benchmarks) for bendiocarb.

## Summary Table

Duration	Route	Benchmark Value	Units	Endpoint	Reference
Acute, Intermediate, Chronic	Inhalation	0.002	mg/kg/day	Inhalation NOAEL (0.00018 mg/L) for neurological effects with UF of 100 applied	U.S. EPA (1999b)
Acute, Intermediate, Chronic	Oral	0.00125	mg/kg/day	Acute and chronic oral RfDs based on neurological effects; adopt chronic for intermediate duration	U.S. EPA (1999b)

Duration	Route	Benchmark Value	Units	Endpoint	Reference
Acute	Dermal	0.5	mg/kg/day	Dermal NOAEL for neurological effects of 50 mg/kg/day with UF of 100 applied	U.S. EPA (1999b)
Intermediate	Dermal	0.2	mg/kg/day	Dermal LOAEL for neurological effects of 50 mg/kg/day with UF of 300 applied	U.S. EPA (1999b)
Chronic	Dermal	0.00125	mg/kg/day	Oral NOAEL for neurological effects of 0.125 mg/kg/day with UF of 100 applied	U.S. EPA (1999b)

For inhalation exposure, a NOAEL of 0.00018 mg/L (0.2 mg/kg/day)<sup>17</sup> was identified for whole blood cholinesterase inhibition in rats exposed to bendiocarb via inhalation for 6 hours per day, 5 days per week, for 90 days (Coombs et al., 1995). An uncertainty factor of 100 to account for interspecies and intrahuman variation was applied, for an inhalation benchmark of 0.002 mg/kg/day. This value is appropriate for all exposure durations (U.S. EPA, 1999b).

The acute and chronic oral RfDs of 0.00125 mg/kg/day were based on a NOAEL of 0.125 mg/kg for whole blood cholinesterase inhibition (about 25 percent) in rats exposed via gavage five days per week for two weeks (EPA MRID No. 00059269, no additional citation provided), with an uncertainty factor of 100 applied (10 each for interspecies and intrahuman variability). This value was also adopted for intermediate exposure (U.S. EPA, 1999b).

For acute dermal exposures, a NOAEL of 50 mg/kg/day in rats for whole blood cholinesterase inhibition from a single exposure was identified (EPA MRID No. 00122308, no additional citation provided) and an uncertainty factor of 100 was applied (10 each for interspecies and intrahuman variability). For intermediate dermal exposures, a LOAEL of 50 mg/kg/day for whole blood cholinesterase inhibition from repeated dermal exposures was identified (EPA MRID No. 00122308, no additional citation provided) and an uncertainty factor of 300 was applied (10 each for interspecies and intrahuman variability and 3 for the use of a LOAEL). For chronic dermal exposures, the NOAEL that was used to develop the oral RfDs was used with an uncertainty factor of 100 applied (10 each for interspecies and intrahuman variability) (U.S. EPA, 1999b).

### *Insecticide Background*

CAS #: 22781-23-3

<sup>17</sup> Conversion between mg/m<sup>3</sup> and mg/kg/day assumes, for Wistar rats, an average body weight of 0.187 kg and inhalation rate of 0.2 m<sup>3</sup>/day (U.S. EPA, 1988).

Synonyms:	2,3-isopropylidenedioxyphenyl methylcarbamate (EXTOXNET, 1996), Ent-27695; OMS 1394; (WHO/FAO, 1982), 1,3-Benzodioxol-4-ol, 2,2-dimethyl-, methylcarbamate, 1,3-Benzodioxole, 2,2-dimethyl-4-(N-methylamino-carboxylato)-, 105201 (U.S. EPA PC Code), 1924 (CA DPR Chem Code), 2,2-Dimethyl-1,3-benzodioxol-4-yl methylcarbamate, Carbamic acid, methyl-, 2,3-(dimethylmethylenedioxy)-phenyl ester, Carbamic acid, methyl-, 2,3-(isopropylidenedioxy)phenyl ester (PAN, 2005), bencarbate, 1,3-benzodioxole, 2,2-dimethyl-4(n-methylcarbamato), 2,2-dimethyl-1,3-benzodioxol-4-ol methcarbamate, 2,3-isopropylidenedioxyphenyl methylcarbamate, methylcarbamic acid 2,3-(isopropylidenedioxy)phenyl ester (HSDB, 2005)
Chemical Group:	n-methyl carbamate (PAN, 2005)
Registered Trade Names:	Compounds containing bendiocarb: Ficam, Dycarb, Garvox, Multamat, Multimet, Niomil, Rotate, Seedox, Tattoo, Turcam (EXTOXNET, 1996), NC-6897, Ficam D, Ficam plus, Ficam W, Ficam ULV (HSDB, 2005).

### Usage

Bendiocarb is a residual carbamate insecticide that has a variety of indoor and outdoor uses, including the control of mosquitoes, household and ornamental plant pests, and fire ants. It has no registered uses on either food or feed crops (U.S. EPA, 1999b). Most products containing bendiocarb are General Use Pesticides (EXTOXNET, 1996) and are meant for homeowner/residential use. However, some formulations (e.g., wettable powders) are recommended to be used only by pest control operators. Bendiocarb is not a Restricted Use Pesticide (U.S. EPA, 1999b); however, the formulations Turcam and Turcam 2.5 G are classified as *restricted* and may only be used by certified applicators (EXTOXNET, 1996).

Common bendiocarb formulations for both agricultural and public health program uses include wettable powders (800, 500 and 200 g active ingredient/kg [g a.i./kg]), granules for soil and turf treatment (30, 50, and 100 g a.i./kg), dust (10 g a.i./kg), suspension concentrate (500 g a.i./l) for spray or seed treatments, suspension in oil for ULV application (250 g a.i./l), residual sprays, and paint on and granular preparations with bait. The use patterns for bendiocarb in agricultural, horticultural, or forestry applications are reported as follows: soil treatment (300–2,000 g a.i./ha), seed treatment (1–10 g a.i./kg), residual spray (100–1,000 g a.i./ha), and ULV spray (50–500 g a.i./ha). In public health programs, it is reported that the 80 percent wettable powder should be applied only by a professional applicator (WHO/FAO, 1982).

### *Formulations and Concentrations*

- Common formulations of pesticides containing bendiocarb include technical grade, dusts, granules (for soil and turf treatment: 30, 50, and 100 g a.i./kg), wettable powders (800, 500, and 200 g a.i./kg), dust (10 g a.i./kg), suspension concentrate (for spray or seed treatment: 500 g a.i./L) and ULV sprays (in oil: 250 g, a.i./L) (WHO/FAO, 1982; EXTTOXNET, 1996). WHO (1999) indicated that the bendiocarb content in various preparations should be declared and contain the following:
- Technical grade bendiocarb: not less than 940 g/kg
- Wettable Powder: above 250 up to 500 g/kg  $\pm$  5% of the declared content or above 500 g/kg  $\pm$  25 g/kg
- Dustable Powder: shall not differ from the declared content by more than -10% to + 35%.
- ULV Liquid: Above 100 up to 200 g/kg  $\pm$  6% of the declared content (WHO, 1999)

### *Shelf Life*

Bendiocarb is reported to be stable below 40°C. Its half-life in aqueous solutions at 25°C is reported as 48 days at pH 5, 81 hours at pH 7, and 45 minutes at pH 9. Bendiocarb degrades slowly at pH 5. Bendiocarb is resistant to oxidation on nonabsorbant surfaces and at low humidity. In sunlight, bendiocarb photo-oxidizes (WHO/FAO, 1982).

### *Degradation Products*

In moist soils and water, a major fate process for bendiocarb is hydrolysis. This is particularly true in neutral and alkaline environments. In neutral hydrolysis, the products are 2,3-isopropylidenedioxyphenol, methylamine, and carbon dioxide (HSDB, 2005). At pHs less than 5, bendiocarb slowly degrades into pyrogallol and acetone (WHO/FAO, 1982). The major degradation product of terrestrial field dissipation on turf is NC-7312 (U.S. EPA, 1999b).

### *Environmental Behavior*

#### **Fate and Transport in Terrestrial Systems**

Insecticidal carbamates that are applied to plants reach the soil both directly and indirectly. Degradation of carbamates in soil depends on volatility, leaching, soil moisture, absorption, pH, temperature, photodecomposition, microbial degradation, and soil type (IPCS, 1986). With a Koc range of 28 to 200, moderately to very high mobility is expected if bendiocarb is released in soil (HSDB, 2005). The major fate processes are hydrolysis in moist soils and biodegradation, with volatilization being an unimportant fate process for both dry and moist soils due to the low vapor pressure of bendiocarb. In moist soils, bendiocarb may undergo hydrolysis, and hydrolytic degradation depends on pH (HSDB, 2005; U.S. EPA, 1999b). Biodegradation of bendiocarb is expected to be rapid (HSDB, 2005). The half-life of bendiocarb in soil varies from less than 1 week up to 4 weeks, depending on the type of soil and the pH (EXTTOXNET, 1996). The estimated hydrolysis half-life of bendiocarb is 46.5 days at pH 5, 2 days at pH 7, and 0.33 days at pH 9 (U.S. EPA, 1999b). Soil photolysis is important in the photodegradation of bendiocarb in soil. In field dissipation studies on turf, bendiocarb and its degradate NC-7312 are not highly mobile, with intermediate half-lives of

20 days (bendiocarb) and 21 days (NC-7312) (U.S. EPA, 1999b). Bendiocarb degrades before leaching through soil, and degradates remain in the upper layers of soil in low concentrations (U.S. EPA, 1999a, 1999b). It is unlikely that bendiocarb will move through soil to groundwater or to surface water through runoff (U.S. EPA, 1999a). Bendiocarb is of low persistence in soil (EXTOXNET, 1996).

### **Fate and Transport in Aquatic Systems**

Water is an important factor in the transport of carbamates; however, the hazard posed by carbamates under these conditions is limited due to their rapid decomposition under aqueous conditions (IPCS, 1986). In water, bendiocarb is not expected to adsorb to suspended soils and sediments based on its K<sub>oc</sub> range (28 to 200). The major fate processes in water are hydrolysis and biodegradation; volatilization is an unimportant fate process due to the low vapor pressure of bendiocarb. Additionally, direct photolysis is not a major degradation pathway in water (U.S. EPA, 1999b) and depends on the turbidity of the water (IPCS, 1986). In alkaline and neutral environments, hydrolysis is expected to be a major fate process. Half-lives have been reported of 48 days at pH 5, 4 days at pH 7, and 45 minutes at pH 9 (HSDB, 2005). Bendiocarb does not accumulate in water (EXTOXNET, 1996), and based on soil studies, biodegradation in water is expected to be rapid (HSDB, 2005). Because bendiocarb degrades rapidly in water, bioconcentration in fish is unlikely (U.S. EPA, 1999a). The estimated bioconcentration factor is 12 (HSDB, 2005).

### *Human Health Effects*

#### **Acute Exposure**

#### *Effects/Symptoms*

Bendiocarb causes toxic effects by the rapid, but reversible, inhibition of cholinesterase in the blood. It is moderately toxic if absorbed through the skin or ingested (EXTOXNET, 1996). Typical signs of acute poisoning are neurological, and include weakness, excessive sweating and salivation, headache, blurred vision, nausea, vomiting, stomach pain, tightness in the chest, muscular twitching, giddiness, slurred speech, confusion, and muscular incoordination (WHO/FAO, 1982; EXTOXNET, 1996). Death from bendiocarb poisoning can result from paralysis of the respiratory system, severe constriction of the lung openings, or stopped breathing (EXTOXNET, 1996). Little data exist on the human health effects of acute exposure to bendiocarb. In humans, the threshold for mild symptoms and blood cholinesterase inhibition is 0.15–0.20 mg a.i./kg for ingestion. No symptoms were reported following repeated hourly doses of 0.1 mg a.i./kg. Studies in human volunteers have shown that both the onset and recovery from cholinesterase inhibition are very rapid (WHO/FAO, 1982). Case reports of accidental bendiocarb exposures report typical symptoms with reversible cholinesterase inhibition. In one case, cholinesterase was inhibited by 63 percent, and the exposed person recovered in less than 3 hours without any medical treatment. Cholinesterase levels returned to normal within 24 hours. In another case, recovery from symptoms occurred within 2 hours after being decontaminated and treated with atropine,

with complete recovery by the next day. Bendiocarb is also a mild irritant to the skin and eyes (EXTOXNET, 1996).

In animals, bendiocarb is acutely toxic via the oral, inhalation, and dermal routes (U.S. EPA, 1999b). The oral LD<sub>50</sub> values of unformulated bendiocarb in various animal species include 34–156 mg/kg in rats, 35–40 mg/kg in rabbits, and 35 mg/kg in guinea pigs. The reported dermal LD<sub>50</sub> value in rats is greater than 566 mg/kg (EXTOXNET, 1996; IPCS, 1986; WHO/FAO, 1982) and the reported 4-hour LC<sub>50</sub> in rats is 0.55 mg/L (EXTOXNET, 1996). For formulated bendiocarb compounds, an LD<sub>50</sub> of 143–179 mg/kg was reported in rats for an 80 percent a.i. water dispersible powder. A dermal LD<sub>50</sub> of greater than 1,000 mg/kg was reported for an 80 percent a.i. liquid formulation (WHO/FAO, 1982).

As in humans, acute exposure to bendiocarb in animals causes symptoms typical of cholinesterase inhibition (U.S. EPA, 1999a, 1999b). No acute delayed neurotoxicity was observed in hens. Although bendiocarb causes slight eye irritation in animals, it is not considered a skin or eye irritant or a dermal sensitizer (U.S. EPA, 1999b).

### ***Treatment***

Exposure to bendiocarb may be determined through laboratory tests that determine cholinesterase levels in blood; however, the enzyme will only be inhibited for a few hours following exposure. Additionally, bendiocarb metabolites may be identified in urine (WHO/FAO, 1982). Bendiocarb poisoning should be treated in the same way as high-toxicity carbamate poisoning (PAN, 2005). First removing any contaminated clothing and wash affected areas with soap and water. If bendiocarb gets in the eyes, they should be rinsed immediately with isotonic saline or water. Oral exposure to bendiocarb should be treated by rapid gastric lavage with 5 percent sodium bicarbonate if the patient is not already vomiting. Medical attention should be sought. Adults showing signs of bendiocarb toxicity should be treated with 1–2 mg atropine sulfate given intramuscularly or intravenously as needed. Oxygen may be necessary for unconscious patients or those in respiratory distress. Pralidoxime is not effective in treating bendiocarb poisoning (WHO/FAO, 1982).

### ***Chronic Exposure***

#### **Noncancer Endpoints**

The effects of chronic exposure to bendiocarb in humans have not been well described in the literature, although it is not expected to be toxic at the levels applied to control mosquitoes. When used as a residual mosquito insecticide, few adverse effects were reported by occupationally exposed workers. Those effects that were reported were transient and mild. Additionally, no effects were reported by residents of villages where it was applied (WHO/FAO, 1982).

Subchronic and chronic exposure studies in rats, mice, and dogs have shown that bendiocarb inhibits cholinesterase activity in whole blood, plasma, red blood cells, and the brain (U.S. EPA, 1999a, 1999b; WHO/FAO, 1982). No macroscopic pathology or histological evidence of dermal irritation or treatment-related mortality was observed in a 21-day dermal study in

rats. Rats exposed to bendiocarb for 90 days via inhalation showed whole-blood cholinesterase inhibition (U.S. EPA, 1999b). Additionally, bendiocarb does not accumulate in mammalian tissue. There was no evidence of cumulative toxicity in rats or dogs fed bendiocarb for 90 days (WHO/FAO, 1982).

Bendiocarb is not expected to cause reproductive effects in humans. In rats, no effect on fertility and reproduction was seen in rats fed diets containing bendiocarb for three generations. However, very high doses were toxic to dams and pups, as indicated by decreased survival rate and decreased pup weight (EXTOXNET, 1996). No teratogenicity was seen in rats or rabbit fetuses or offspring following pre- and/or postnatal exposures to bendiocarb (U.S. EPA 1999a, 1999b; WHO/FAO, 1982). No evidence of mutagenicity was observed following *in vivo* or *in vitro* exposures to bendiocarb (U.S. EPA, 1999a, 1999b; EXTOXNET, 1996; WHO/FAO, 1982). No irreversible or delayed neurotoxicity has been reported in animals following long-term bendiocarb exposure (WHO/FAO, 1982).

### **Cancer Endpoints**

EPA has classified bendiocarb as a Group E chemical, noncarcinogenic to humans (U.S. EPA, 1999b). The classification is based on the lack of increase in tumors in rat and mouse studies and is supported by the lack of mutagenicity in somatic cells (U.S. EPA, 1999b). No human data are available.

### *Toxicokinetics*

Bendiocarb can be absorbed through oral, dermal, and inhalation pathways; dermal absorption is especially rapid and is the main route of absorption. Absorption from inhalation, except inhalation of airborne dusts or fine spray mists, is unlikely due to bendiocarb's low vapor pressure (EXTOXNET, 1996; WHO/FAO, 1982). Animal metabolism studies indicate that bendiocarb is rapidly absorbed following oral exposure (U.S. EPA, 1999b). Liver microsome enzymes readily conjugate and metabolize bendiocarb, and it is rapidly excreted. Because of its rapid metabolism and excretion, bendiocarb does not accumulate in mammalian tissues (WHO/FAO, 1982). The majority of an orally administered dose is eliminated in the urine (U.S. EPA, 1999b). In rats fed diets containing up to 10 mg/kg bendiocarb, 89 to 90 percent of the dose was excreted in the urine, 2 to 6 percent was excreted in the feces, and 2 to 6 percent was exhaled. A human subject orally exposed to bendiocarb exhibited a similar excretion pattern (EXTOXNET, 1996). Bendiocarb is excreted mainly as sulfate and beta-glucuronide conjugates of the phenol derivative (WHO/FAO, 1982).

### *Ecological Effects*

#### **Acute Exposure**

When applied at the maximum registered application rate, bendiocarb poses acute risk to nontarget terrestrial organisms, such as mammals and birds (WHO/FAO, 1982; U.S. EPA, 1999a). Single broadcast applications on turf may result in high risk to birds, and multiple applications may result in repeated acute effects (U.S. EPA, 1999a). Oral LD<sub>50</sub> values range

from 3.1 mg a.i./kg body weight in mallard ducks to 137 mg a.i./ kg body weight in domestic hens (WHO/FAO, 1982; U.S. EPA, 1999a). However, bendiocarb does not affect avian reproductive parameters (WHO/FAO, 1982). Additionally, bendiocarb has been found to be highly toxic to bees (WHO/FAO, 1982; EXTTOXNET, 1996; U.S. EPA, 1999a), with an oral LD<sub>50</sub> of 0.0001 mg/bee (EXTTOXNET, 1996). Additionally, bendiocarb severely affects earthworms under treated turf (EXTTOXNET, 1996).

Bendiocarb poses acute risks to freshwater fish, and estuarine and marine animals (U.S. EPA, 1999a). It is moderately to highly toxic to fish, with LC<sub>50</sub> values ranging from 0.7 to 1.76 mg a.i./L in various species (U.S. EPA, 1999a; WHO/FAO, 1982). The 96-hour LC<sub>50</sub> for rainbow trout is 1.55 mg/L (EXTTOXNET, 1996). When applied at the maximum registered rate, bendiocarb also poses acute risks to freshwater invertebrates (U.S. EPA, 1999a).

### **Chronic Exposure**

Very little data exist for chronic exposure to bendiocarb in nonterrestrial target organisms. In birds, multiple applications of the maximum registered application rate to turf are expected to result in repeated acute effects. The reproductive effects of chronic exposures cannot be assessed due to limited data (U.S. EPA, 1999a).

Little data exist for chronic exposure to bendiocarb in marine or estuarine organisms. When applied at the maximum registered rate, bendiocarb poses chronic risks to freshwater invertebrates. However, it poses no chronic risk to freshwater fish (U.S. EPA, 1999a).

## **Profile for Bifenthrin:**

CAS Registry Number 82657-04-3

### ***Summary of Insecticide***

#### *Chemical History*

Bifenthrin is a pyrethroid insecticide and acaricide used in agricultural and human health applications (EXTTOXNET, 1995; WHO/FAO, 1992). It is primarily available as a wettable powder or an emulsifiable concentrate (EXTTOXNET, 1995). Bifenthrin is used to control pests on crops and indoor pests (ATSDR, 2003). For mosquito protection, it is used on bed nets and other materials that are dipped in bifenthrin to protect the user. Bifenthrin is a restricted use pesticide due to its potential toxicity to aquatic organisms, and it may only be purchased and used by certified applicators (ATSDR, 2003; EXTTOXNET, 1995).

As a synthetic pyrethroid, bifenthrin exhibits its toxic effects by affecting the way the nerves and brain normally function by interfering with the sodium channels of nerve cells (Choi and Soderlund, 2006; EXTTOXNET, 1995). Symptoms of acute exposure may include skin and eye irritation, headache, dizziness, nausea, vomiting, diarrhea, excessive salivation, fatigue, irritability, abnormal sensations of the face and skin, and numbness (PAN, 2005). Inhalation

of pyrethrins may cause a localized reaction of the upper and lower respiratory tracts (HSDB, 2005). In mammals, pyrethroids are generally of low toxicity due to their rapid biotransformation (HSDB, 2005). EPA has classified bifenthrin as a Class II chemical or moderately toxic. EPA has not classified synthetic pyrethroids, including bifenthrin, as endocrine disruptors. Bifenthrin is highly toxic to fish and other aquatic organisms (EXTOXNET, 1995).

*Description of Data Quality and Quantity*

Several comprehensive reviews on the toxicity of bifenthrin have been prepared or updated in recent years:

- Toxicological Profile for Pyrethrin and Pyrethroids (ATSDR, 2003)
- Pesticide Residues in Food—1992 Evaluation, Part II: Toxicology—Bifenthrin (WHO/FAO, 1992)
- IRIS summary review (U.S. EPA, 2006)
- Pesticide Information Profile for Bifenthrin (EXTOXNET, 1995).

EPA has developed quantitative human health benchmarks (acute and chronic oral RfDs, intermediate-term oral, and short-, intermediate-, and long-term dermal and inhalation benchmarks) for bifenthrin.

**Summary Table**

<b>Duration</b>	<b>Route</b>	<b>Benchmark Value</b>	<b>Units</b>	<b>Endpoint</b>	<b>Reference</b>
Acute, Intermediate	Inhalation	0.007	mg/kg/day	Oral NOAEL for neurological effects in dogs at 2.21 mg/kg/day with UF of 300 applied	U.S. EPA (2003)
Chronic	Inhalation	0.004	mg/kg/day	Oral NOAEL for neurological effects in dogs at 1.3 mg/kg/day with UF of 300 applied	U.S. EPA (2003)
Acute	Oral	0.033	mg/kg/day	Acute RfD based on neurotoxicity in rats	U.S. EPA (2003)
Intermediate	Oral	0.007	mg/kg/day	Oral NOAEL for neurological effects in dogs at 2.21 mg/kg/day with UF of 300 applied	U.S. EPA (2003)
Chronic	Oral	0.004	mg/kg/day	Chronic RfD based on neurological effects in dogs	U.S. EPA (2003)
Acute, Intermediate, Chronic	Dermal	0.2	mg/kg/day	Dermal NOAEL for neurological effects in rats at 47 mg/kg/day with UF of 300 applied	U.S. EPA (2003)

For oral exposure, an acute RfD of 0.033 mg/kg/day was derived based on a NOAEL of 32.8 mg/kg/day for neurological effects observed in rats exposed to bifenthrin (study citations not provided), with an uncertainty factor of 1,000 applied to account for the lack of a

developmental neurotoxicity study and for interspecies and intrahuman variability (U.S. EPA, 2003). An intermediate NOAEL of 2.21 mg/kg/day was identified for tremors in dogs exposed for 90 days and an uncertainty factor of 300 was applied, resulting in a benchmark of 0.007 mg/kg/day (U.S. EPA, 2003). A chronic oral RfD of 0.004 mg/kg/day was derived based on a NOAEL of 1.3 mg/kg/day for tremors in dogs exposed for 1 year, with an uncertainty factor of 300 applied (U.S. EPA, 2003).

For inhalation exposure, an oral NOAEL of 2.21 mg/kg/day was identified for tremors in dogs exposed for 90 days and an uncertainty factor of 300 was applied (U.S. EPA, 2003). This value (0.007 mg/kg/day) is appropriate to use for short- and intermediate-term inhalation exposures. An oral NOAEL of 1.3 mg/kg/day was identified for tremors in dogs exposed for 1 year and an uncertainty factor of 300 was applied (U.S. EPA, 2003). This value (0.004 mg/kg/day) is appropriate to use for long-term inhalation exposures.

For dermal exposure, a NOAEL of 47 mg/kg/day for neurological effects (staggered gait and exaggerated hind limb flexion) was identified in rats dermally exposed to bifenthrin for 21 days. An uncertainty factor of 300 was applied, for a dermal benchmark value of 0.2 mg/kg/day. This value is appropriate for all exposure durations (U.S. EPA, 2003).

#### *Insecticide Background*

CASRN: 82657-04-3

Synonyms: (2-methyl[1,1'-biphenyl]-3-yl)methyl 3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropanecarboxylate, [1 $\alpha$ , 3 $\alpha$ (z)]-(+ -)-3-(2-Chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropanecarboxylic acid (2-methyl[1,1'-biphenyl]-3-yl)methyl ester, 2-Methylbiphenyl-3-ylmethyl (z)-(1RS,3RS)-3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2-dimethylcyclopropanecarboxylate, [1  $\alpha$ , 3  $\alpha$ (z)]-(+ -)-(2-Methyl[1,1'-biphenyl]-3-yl)methyl 3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropanecarboxylate (ATSDR, 2003; EXTTOXNET, 1995; HSDB, 2005)

Chemical Group: pyrethroid (PAN, 2005; EXTTOXNET, 1995)

Registered Trade Names: Talstar, Bifenthrine, Biphenate, Brigade, Bifentrina, Biflex, Capture, FMC 54800, FMC 54800 Technical, OMS3024, Torant (with Clofentezine), and Zipak (with Amitraz), Tarstar (HSDB, 2005; EXTTOXNET, 1995; ATSDR, 2003; PAN, 2005)

#### *Usage*

Bifenthrin is used as a broad spectrum insecticide and acaricide to combat indoor pests and those on a variety of crops (EXTTOXNET, 1995; ATSDR, 2003). It is used to control

mosquitoes, beetles, weevils, houseflies, lice, bedbugs, aphids, moths, cockroaches, and locusts. Crops on which bifenthrin is used include alfalfa hay, beans, cantaloupes, cereals, corn, cotton, field and grass seed, hops, melons, oilseed rape, potatoes, peas, raspberries, watermelons, and squash. Bifenthrin belongs to the pyrethroid class of insecticides, which have long been used to control mosquitoes, human lice, beetles, and flies. For mosquito protection, it is used on bed nets and other materials that are dipped into the bifenthrin to protect the user. Bifenthrin for agricultural use is restricted by EPA due to its potential toxicity to aquatic organisms, and it may only be purchased and used by certified applicators (ATSDR, 2003).

#### *Formulations and Concentrations*

Bifenthrin is available in technical grade, emulsifiable concentrate, suspension concentrate, wettable powder, ultra-low volume (ULV) liquid, and granules (HSDB, 2005; EXTOXNET, 1995; WHO, 2001). Technical grade bifenthrin may be mixed with carriers or solvents, resulting in the commercial formulations. The label of products containing bifenthrin must contain the word “warning” (EXTOXNET, 1995). Technical grade bifenthrin must have no less than 920 g/kg bifenthrin. The wettable powder should contain > 25–100 g/kg +/- 10% of the declared content, 100–250 g/kg +/- 6% of the declared content, or > 250–500 g/kg +/- 5% of the declared content (WHO, 2001). Bifenthrin that is used on bed nets for malaria control comes in a suspension concentrate dose of 25 mg a.i./m<sup>2</sup> (WHO, n.d.).

#### *Shelf Life*

Bifenthrin is photostable and stable to hydrolysis. It volatilizes minimally and is generally stable when stored (EXTOXNET, 1995). Bifenthrin is stable for 2 years at 25–50°C. It is most stable in acidic environments and at pHs from 5 to 9, it is stable for 21 days. Pyrethrins, in general, are stable for a long time in water-based aerosols (HSDB, 2005).

#### *Degradation Products*

Pyrethroid insecticides are often formulated with synergists that prevent the breakdown of enzymes and thus enhance the activity of the pyrethroid (ATSDR, 2003). The primary metabolic pathway for the breakdown of bifenthrin is ester hydrolysis (HSDB, 2005). The major degradate of bifenthrin metabolism in soil, biota, and water is 4'-hydroxy bifenthrin (Fecko, 1999).

#### *Environmental Behavior*

##### **Fate and Transport in Terrestrial Systems**

With Koc values ranging from 131,000 to 320,000, the mobility of bifenthrin in soil ranges from low to immobile (HSDB, 2005; EXTOXNET, 1995). Bifenthrin has a low mobility in soils with large amounts of clay, silt, organic matter and in sandy soils without much organic matter (EXTOXNET, 1995). In moist soils, volatilization is a major fate process, although this is lessened by absorption in the soil (HSDB, 2005). Depending on soil type and the amount of air in the soil, the half-life of bifenthrin ranges from 7 days to 8 months

(EXTOXNET, 1995). Bifenthrin is expected to biodegrade readily based on its structure and the biodegradation rates of pyrethroids in general (HSDB, 2005). It is not absorbed by plants and does not translocate in plants (EXTOXNET, 1995).

### **Fate and Transport in Aquatic Systems**

Bifenthrin is fairly insoluble in water, so it is unlikely to leach to groundwater and cause significant contamination (EXTOXNET, 1995). Volatilization is a major fate process from surface water; however, because bifenthrin is expected to adsorb to suspended soils and sediments, volatilization is attenuated. Volatilization half-lives of 50 days for a model river and 555 days for a model lake have been reported, but if adsorption is considered, the volatilization half-life of a model pond is 3,100 years. Bifenthrin has a high potential to accumulate in aquatic organisms, with an estimated bioconcentration factor of 190. However, bioconcentration is likely to be lower due to the ability of aquatic organisms to readily metabolize bifenthrin (HSDB, 2005).

### *Human Health Effects*

#### **Acute Exposure**

#### *Effects/Symptoms*

There are limited data on the acute toxicity of bifenthrin in humans. Bifenthrin is classified as having moderate acute toxicity in mammals (EXTOXNET, 1995; WHO/FAO, 1992; PAN, 2005). Incoordination, irritability to sound and touch, tremors, salivation, diarrhea, and vomiting have been caused by high doses. In humans, no skin inflammation or irritation has been observed; however, bifenthrin can cause a reversible tingling sensation (EXTOXNET, 1995).

In animals, the main signs of acute toxicity include clonic convulsions, tremors, and oral discharge (WHO/FAO, 1992). Reported LD<sub>50</sub> values for bifenthrin include 54–56 mg/kg in female rats, 70 mg/kg in male rats (EXTOXNET, 1995; WHO/FAO, 1992; HSDB, 2005) and 43 mg/kg in mice (WHO/FAO, 1992). Bifenthrin is slightly toxic through dermal contact, with dermal LD<sub>50</sub>s of over 2,000 mg/kg in rabbits (WHO/FAO, 1992; HSDB, 2005). Neurotoxicity is a key effect of pyrethroids and is caused by interfering with the sodium channels of nerve cells (ATSDR, 2003; Choi and Soderlund, 2006). In mammals, acute exposure to pyrethroids causes tremors, hyperexcitability, salivation, paralysis, and choreoathetosis. However, delayed neurotoxicity has not been observed (HSDB, 2005). Bifenthrin is not a dermal sensitizer in guinea pigs (EXTOXNET, 1995; HSDB, 2005; WHO/FAO, 1992) and did not irritate either abraded or non-abraded skin of rabbits (WHO/FAO, 1992). In rabbits, it is only slightly irritating to the eyes (EXTOXNET, 1995; WHO/FAO, 1992; HSDB, 2005). Bifenthrin is also a suspected endocrine disruptor (ATSDR, 2003; PAN, 2005).

### ***Treatment***

Bifenthrin and its metabolites can be detected in blood and urine during the first few days following exposure (but not later, because these compounds are rapidly broken down in the body) (ATSDR, 2003). Treatment depends on the symptoms of the exposed person. Most casual exposures require only decontamination and supportive care (HSDB, 2005). If a person exhibits signs of typical pyrethroid toxicity following bifenthrin exposure, affected skin areas should be washed promptly with soap and warm water. Medical attention should be sought if irritation or paresthesia occurs. Paresthesia may be prevented or stopped with Vitamin E oil preparations. Corn oil and Vaseline® are less effective and less suitable, and zinc oxide should be avoided (PAN, 2005; HSDB, 2005).

Eye exposures should be treated by rinsing with copious amounts of water or saline. Contact lenses should be removed. Medical attention should be sought if irritation persists (PAN, 2005; HSDB, 2005). Following oral exposures, the person should be kept calm and medical attention should be sought as quickly as possible. Medical personnel will treat severe intoxications with a sedative and anticonvulsant. Ingestion of large amounts of bifenthrin should be treated with gastric lavage, and small ingestions should be treated with activated charcoal and cathartic (PAN, 2005). For sublethal exposures, vomiting may be induced by ipecac and followed by saline cathartic and an activated charcoal slurry, as long as the person is alert and has a gag reflex (HSDB, 2005).

### ***Chronic Exposure***

#### **Noncancer Endpoints**

No data are available for humans following chronic exposures to bifenthrin (EXTOXNET, 1995). Dietary studies in dogs, rats, and mice indicate that oral exposure to bifenthrin causes neurological effects such as tremors (U.S. EPA, 2006; WHO/FAO, 1992) but not cholinesterase inhibition (PAN, 2005). In a 1-year feeding study in dogs and a lifetime feeding study in mice, intermittent tremors were observed (U.S. EPA, 2006; WHO/FAO, 1992). In subchronic duration exposure studies in dogs and rats, tremors were also seen at higher exposure levels (U.S. EPA, 2006; WHO/FAO, 1992).

Bifenthrin has the potential to be reproductive toxin (PAN, 2005). Reproductive toxicity has been observed in rats and rabbits at doses lower than those that cause tremors (EXTOXNET, 1995). Teratogenicity was not observed in a 2-generation rat study (EXTOXNET, 1995) or a rabbit teratogenicity study (WHO/FAO, 1992; HSDB, 2005).

Additional effects observed in chronic exposure animal studies include increased body weight and organ-to-body ratios (U.S. EPA, 2006). The mutagenicity data are inconclusive for bifenthrin (EXTOXNET, 1995), but it is unlikely to pose a genetic hazard (WHO/FAO, 1992).

## **Cancer Endpoints**

EPA has classified bifenthrin as Class C, possible human carcinogen (EXTOXNET, 1995; PAN 2005). A 2-year, high dose dietary exposure study in rats reported no evidence of cancer. In mice, however, a significant dose-related increase in urinary bladder tumors was observed in male mice. An increased incidence of lung tumors was observed in female mice (U.S. EPA, 2003; EXTOXNET, 1995).

### *Toxicokinetics*

Bifenthrin is readily absorbed through intact skin (EXTOXNET, 1995; HSDB, 2005) and the gastrointestinal tract (WHO/FAO, 1992). It breaks down in the same way as other pyrethroids (EXTOXNET, 1995). Hydrolysis and hydroxylation are the primary steps in the transformation of bifenthrin. In poultry, bifenthrin metabolism begins with hydroxylation of the 2-methyl carbon of the cyclopropane ring, followed by fatty acid conjugation (WHO/FAO, 1992). Oral administration of radioactive pyrethroids have been shown to distribute to every tissue examined (HSDB, 2005). Bifenthrin can accumulate in fatty tissues such as skin and ovaries (EXTOXNET, 1995). Bifenthrin metabolism and excretion are rapid. In rats given 4–5 mg/kg bifenthrin, 70 percent of the dose was excreted in urine within 7 days, and 20 percent was excreted in feces (EXTOXNET, 1995). However, another study in rats showed that following oral administration of bifenthrin, 70 to 80 percent was eliminated in the feces within 48 hours while only 5 to 10 percent was eliminated in the urine. Biliary excretion ranged from 20 to 30 percent (WHO/FAO, 1992).

### *Ecological Effects*

#### **Acute Exposure**

##### ***Toxicity in Non-Targeted Terrestrial Organisms***

Bifenthrin, like other pyrethroids, is unlikely to harm terrestrial organisms other than its targets, such as mosquitoes and other pests, due to its low persistence in the environment (HSDB, 2005). Bifenthrin has a moderate toxicity in birds (EXTOXNET, 1995). The 8-day dietary LC<sub>50</sub> values range from 1,280 ppm in mallard ducks to 4,450 ppm in bobwhite quail. Oral LD<sub>50</sub> values range from 1,800 mg/kg in bobwhite quail to 2,150 mg/kg in mallard ducks. Additionally, concerns about bioaccumulation in birds have been reported. As with other pyrethroid insecticides, bifenthrin is extremely toxic to honey bees (EXTOXNET, 1995; HSDB, 2005).

##### ***Toxicity in Non-Targeted Aquatic Systems***

Bifenthrin is also known to be toxic to a wide variety of aquatic organisms, including fish, crustaceans, aquatic insects, mollusks, nematodes, flatworms, phytoplankton, and zooplankton (PAN, 2005). Bifenthrin is very toxic to fish (EXTOXNET, 1995); however, because it is not very water soluble and has a high affinity for soil, the risk to aquatic systems is not expected to be high (EXTOXNET, 1995). The high toxicity in fish is illustrated by the low exposures that cause lethality. The reported 96-hour LC<sub>50</sub> is 0.00015

mg/L in rainbow trout and 0.00035 mg/L in bluegill sunfish (EXTOXNET, 1995; HSDB, 2005). Average LC<sub>50</sub> values are 17.5 µg/L in sheepshead minnow and 0.36 µg/L in gizzard shad (PAN, 2005). In Daphnia, the reported 48-hour LC<sub>50</sub> is 0.0016 mg/L (HSDB, 2005). The risk of bioaccumulation of the bifenthrin formulation Talstar®100EC in aquatic organisms is reported to be very high (ASTRACHEM, n.d.). The whole-body bioconcentration factor values for fathead minnow in water T a concentration of 0.0037 µg/L were 21,000 (over 127 days) and 28,000 (over 254 days) (CalDFG, 2000).

### **Chronic Exposure**

#### ***Toxicity in Non-Targeted Terrestrial Organisms***

No data were located on the chronic toxicity to nontarget terrestrial organisms.

#### ***Toxicity in Non-Targeted Aquatic Systems***

Chronic exposure of fathead minnow to a 95.7 percent bifenthrin formulation for 246 days resulted in a reported LOEC of 0.41 µg/L, NOEC of 0.30 µg/L, and MATC of 0.351 µg/L. Chronic exposure of fathead minnow to a 96.2 percent bifenthrin formulation for 346 days resulted in a reported LOEC of 0.090 µg/L, NOEC of 0.050 µg/L, and MATC of 0.067 µg/L (CalDFG, 2000).

## **Profile for Cyfluthrin:**

CAS Registry Number 68359-37-5

### ***Summary***

#### ***Chemical History***

Cyfluthrin is a synthetic pyrethroid insecticide first registered by EPA in 1987. It is used in agricultural and human health applications against a wide variety of pests. It is similar to the natural insecticide pyrethrum, which comes from chrysanthemums; however, it is more effective and longer lasting (ATSDR, 2003). Cyfluthrin has both contact and stomach poison action (EXTOXNET, 1998) and it interferes with nervous system transmissions through inhibition of the sodium channel system (Choi and Soderlund, 2006; WHO, 2004). It is available as the technical product, emulsifiable concentrate, wettable powder, aerosol, granule, liquid, oil-in-water emulsion, dust, concentrate, and ultra-light-volume oil spray (EXTOXNET, 1998; IPCS, 1997). For mosquito control, it is used in bed nets and other materials that are treated with cyfluthrin to protect the user (WHO, 1998). Cyfluthrin can be found in both restricted use pesticides and general use pesticides (EXTOXNET, 1998). When used, it is applied by spraying, dusting, fogging, or impregnation (WHO, 2004; IPCS, 1997). It is considered moderately toxic to mammals (EXTOXNET, 1998). EPA has not classified synthetic pyrethroids, including cyfluthrin, as endocrine disruptors. Typical symptoms of acute human exposure are skin and eye irritation. Dermal irritation may

include itching, burning, or stinging, which may lead to a numbness that lasts up to 24 hours. Skin irritation may occur immediately following exposure or be delayed for 1 to 2 hours (EXTOXNET, 1998). In animals, very high doses have been shown to cause nervous system effects, including irritability, excessive salivation, uncoordinated gait, tremors, convulsions, and death (EXTOXNET, 1998; ATSDR, 2003).

*Description of Data Quality and Quantity*

EPA has developed a quantitative human health benchmark for cyfluthrin (EPA’s chronic oral RfD). Several reviews on the toxicity of cyfluthrin have been prepared or updated in recent years and recommended resources include the following:

- Toxicological Profile for Pyrethrin and Pyrethroids (ATSDR, 2003)
- IRIS summary review (U.S. EPA, 2005b)
- Pesticide Information Profiles: Cyfluthrin (EXTOXNET, 1998)
- Toxicological Evaluation of Certain Veterinary Drug Residues in Food. WHO Food Additives Series 39: Cyfluthrin (IPCS, 1997)
- Specifications and Evaluations for Public Health Pesticides: Cyfluthrin (WHO, 2004).

**Summary Table**

Duration	Route	Benchmark Value	Units	Endpoint	Reference
Acute	Inhalation	0.0007	mg/kg/day	Inhalation NOAEL in rats with UF of 100 applied	U.S. EPA (2005a)
Intermediate, Chronic	Inhalation	0.0002	mg/kg/day	Inhalation NOAEL in rats with UF of 100 applied	U.S. EPA (2005a)
Acute	Oral	0.02	mg/kg/day	Acute RfD based on mammalian neurotoxicity	U.S. EPA (2005a)
Intermediate	Oral	0.024	mg/kg/day	Adopt chronic RfD for intermediate duration	
Chronic	Oral	0.024	mg/kg/day	Chronic RfD based on neurological effects in dogs	U.S. EPA (2005a)
Acute, Intermediate, Chronic	Dermal	3	mg/kg/day	Dermal NOAEL in rabbits with UF of 100 applied	

For inhalation exposure, a NOAEL of 0.00026 mg/L (0.07 mg/kg/day) was identified for body weight effects in rats exposed to beta-cyfluthrin via inhalation for 28 days. A NOAEL of 0.00009 mg/L (0.02 mg/kg/day) was identified for neurological and body weight effects in rats exposed to cyfluthrin via inhalation for 13 weeks. An uncertainty factor of 100 to account for inter- and intraspecies variation was applied, for a short-term inhalation benchmark of 0.0007 mg/kg/day and an intermediate- and long-term inhalation benchmark of 0.0002 mg/kg/day.

For oral exposure, an acute oral RfD of 0.02 mg/kg/day was derived based on a NOAEL of 2 mg/kg/day for acute mammalian neurotoxicity following exposure to beta-cyfluthrin. An uncertainty factor of 100 was applied for inter- and intraspecies variability (U.S. EPA, 2005a). A chronic oral RfD of 0.024 mg/kg/day was derived based on a NOAEL of 2.4 mg/kg/day for neurological effects in dogs exposed to cyfluthrin for 53 weeks. An uncertainty factor of 100 was applied for inter- and intraspecies variability (U.S. EPA, 2005a). An intermediate oral RfD of 0.024 mg/kg/day was derived based on a NOAEL of 2.4 mg/kg/day for neurological effects in dogs exposed to beta-cyfluthrin for 90 days. An uncertainty factor of 100 was applied for inter- and intraspecies variability (U.S. EPA, 2005a).

For dermal exposure, a NOAEL of 250 mg/kg/day (85 percent purity) was identified in rabbits dermally exposed to cyfluthrin 5 times a week for 6 hr/day for 3 weeks (IPCS, 1997). An uncertainty factor of 100 to account for inter- and intraspecies variation was applied, for a dermal benchmark value of 3 mg/kg/day. This value is appropriate for all exposure durations.

#### *Insecticide Background*

CASRN: 68359-37-5

Synonyms: Cyano(4-fluoro-3-phenoxyphenyl) methyl 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate; BAY-FCR 1272; (R,S)-alpha-Cyano-4-fluoro-3-phenoxybenzyl-(1R,S)-cis,trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate; 3-(2,2-Dichloroethenyl)-2,2-diethylcyclopropanecarboxylic acid cyano(4-fluoro-3-phenoxyphenyl)methyl ester; Cyfluthrine; FCR 1272; (RS)-alpha-Cyano-4-fluoro-3-phenoxybenzyl (1RS, 3RS: 1RS, 3SR)-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate (ATSDR, 2003; HSDB 2005)

Chemical Group: pyrethroid (ATSDR, 2003)

Registered Trade Names: Attotox, Baythroid, Baygon aerosol, Baythroid H, Cyfoxlate, Contur, Laser, Responsar, Solfac, Tempo, Tempo H (ATSDR, 2003; EXTOWNET, 1998)

#### *Usage*

Cyfluthrin is effective in combating a broad spectrum of insect pests in agricultural, public health, and structural applications (WHO, 2004; EXTOWNET, 1998). The main agricultural use of cyfluthrin is against chewing and sucking insects on crops (EXTOWNET, 1998; HSDB, 2005; ATSDR 2003). In public health applications, it is used to control mosquitoes, houseflies, and cockroaches (HSDB, 2005). It is primarily a contact insecticide and is applied by residual spraying, fogging, or impregnation (WHO, 2004).

### *Formulations and Concentrations*

Cyfluthrin is available in technical grade, emulsifiable concentrate, wettable powder, aerosol, granules, liquid, oil-in-water emulsion, and ultra-light-volume oil sprays (EXTOXNET, 1998; HSDB 2005). Technical grade cyfluthrin may be mixed with carriers or solvents resulting in the commercial formulations. These commercial formulations may also include ingredients that may potentiate the toxicity compared to technical grade cyfluthrin (EXTOXNET, 2005). WHO indicates that the content of cypermethrin in the formulated products must be declared and shall not exceed the listed standards. Technical grade cyfluthrin must have no less than 920 g/kg cyfluthrin and should contain the four diastereoisomers as follows:

- Diastereoisomer I, (R)-alpha-cyano-4-fluoro-3-phenoxybenzyl-(1R)-cis -3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate + (S)-alpha, (1S)-cis: 23–27 percent
- Diastereoisomer II, (S)-alpha-cyano-4-fluoro-3-phenoxybenzyl-(1R)-cis -3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate + (R)-alpha, (1S)-cis: 17–21 percent
- Diastereoisomer III, (R)-alpha-cyano-4-fluoro-3-phenoxybenzyl-(1R)-trans -3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate + (S)-alpha, (1S)-trans: 32–36 percent
- Diastereoisomer IV, (S)-alpha-cyano-4-fluoro-3-phenoxybenzyl-(1R)-trans -3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate + (R)-alpha, (1S)-trans: 21–25 percent.

The wettable powder should contain 100 g/kg cyfluthrin +/- 10 percent of the declared content. The oil-in-water emulsion shall contain 50 g/kg or g/L cyfluthrin +/- 10 percent of the declared content at 20 +/- 2 °C (WHO, 2004, ATSDR, 2003). For malaria control, a 10 percent wettable powder formulation has been found to be safe and effective for indoor residual spraying against malaria vectors at target doses of 15 to 50 mg/m<sup>2</sup>, while a 5 percent oil in water emulsion is effective and safe for use in impregnation of bed nets at a dose of 50 mg/m<sup>2</sup> (WHO, 1998).

### *Shelf Life*

Cyfluthrin in water-based aerosols is stable for a long time. It is thermally stable at room temperature. Topical cyfluthrin preparations made with piperonyl butoxide should be stored at temperatures below 40 °C (and optimally at 15 to 30 °C) and in tightly closed containers (HSDB, 2005). Australian researchers reported that cyfluthrin is stable and does not break down for up to 52 weeks when used on stored wheat (EXTOXNET, 1998).

### *Degradation Products*

Pyrethroid insecticides are often formulated with synergists that act to prevent the breakdown of enzymes and thus enhance the activity of the pyrethroid (ATSDR, 2003). Cyfluthrin's breakdown products include 4-fluoro-3-phenoxybenzoic acid (PAN, 2005). In soil, the primary breakdown products include carbon dioxide and 4-fluoro-3-phenyl-benzaldehyde (a compound of considerably lower toxicity than the parent compound) (EXTOXNET, 1998).

## *Environmental Behavior*

### **Fate and Transport in Terrestrial Systems**

The use of cyfluthrin as an insecticide may result in its release into the environment via a variety of waste streams (HSDB, 2005). Once in the environment, cyfluthrin is expected to be highly immobile in the soil based on its Koc value (HSDB, 2005; EXTOXNET, 1998). Because it is immobile in soil, cyfluthrin does not easily leach into groundwater (EXTOXNET, 1998).

Cyfluthrin is one of the more persistent pyrethroids and as a result, it is used more often in agricultural applications (ATSDR, 2003). It can be broken down by sunlight, and in surface soils, the reported half-life ranges from 48 to 72 hours. Reported half-lives in German loam and sandy loam soils are 51 to 63 days. Persistence under anaerobic conditions is similar. The persistence of cyfluthrin in soil is not significantly affected by soil moisture content (EXTOXNET, 1998; ATSDR, 2003).

The major fate processes for cyfluthrin in soil are biodegradation and photolysis. Under anaerobic conditions, more than 90 percent biodegradation was reported during an incubation period of 140 days. Anaerobic biodegradation of cyfluthrin initially produces 3-(2,2-dichlorovinyl)2,2-dimethylcyclopropanecarboxylic acid and 4-fluoro-3-phenoxybenzoic acid. Photodegradation was observed when cotton fabric was irradiated for 96 hours in simulated natural sunlight, resulting in almost 75 percent photo-degradation (HSDB, 2005). Volatilization is not expected to be a major fate process from either moist or dry soils (HSDB, 2005).

### **Fate and Transport in Aquatic Systems**

Cyfluthrin binds tightly to soil, is practically insoluble in water, and is less dense than water, allowing it to float on the surface film of natural water (EXTOXNET, 1998; HSDB, 2005). It is stable in water under acidic conditions but hydrolyzes rapidly under basic conditions (EXTOXNET, 1998). On surface waters, cyfluthrin breaks down by photolysis and is not expected to volatilize (EXTOXNET, 1998; HSDB, 2005). In aqueous solutions, an experimental half-life of 16 hours was identified when irradiated by environmentally significant wavelengths of light (HSDB, 2005). Aqueous hydrolysis does not play an important role in the environmental fate of cyfluthrin. Hydrolysis half-lives of 231 days and 2 days were identified at pH 7 and 8, respectively (ATSDR, 2003). Cyfluthrin has a high potential to bioconcentrate in aquatic organisms (HSDB, 2005).

## *Human Health Effects*

### **Acute Exposure**

#### ***Effects/Symptoms***

Limited data are available on the acute toxicity of cyfluthrin in humans, because pyrethroid poisonings are uncommon. Cases of acute occupational or accidental exposure to pyrethroids resulted in burning, itching, and tingling of the skin which resolved after several

hours. Reported systemic symptoms included dizziness, headache, anorexia, and fatigue. Vomiting occurred most commonly after ingestion of pyrethroids. Less commonly reported symptoms included tightness of the chest, paresthesia, palpitations, blurred vision, and increased sweating. In serious cases, coarse muscular fasciculations (twitching), convulsions, and coma were reported (IPCS, 1997). Cyfluthrin is of low toxicity to humans largely due to its poor absorption from the bloodstream and rapid breakdown and excretion. Acute effects of cyfluthrin exposure in humans consist primarily of immediate or delayed skin irritation and immediate eye irritation. Itching, burning, and stinging of exposed skin can progress to cutaneous paresthesias, which can last up to 24 hours. Sweating, heat, and water can make dermal symptoms worse (WHO, 2004; EXTOXNET, 1998; HSDB, 2005; IPCS, 1997).

As a pyrethroid, cyfluthrin inhibits cholinesterase (HSDB, 2005), and symptoms of acute toxicity in animals may include irritability, excessive salivation, uncoordinated gait, tremors, convulsions, and death (HSDB, 2005; EXTOXNET, 1998). Cyfluthrin is a type II pyrethroid, a class which is known to produce a complex poisoning syndrome involving a progressive development of symptoms. In rats, this manifests as burrowing behavior, coarse tremors, clonic seizures, sinuous writhing, and profuse salivation without lacrimation (HSDB, 2005). Nervous system effects have been reported in acute high-dose exposures of animals to cyfluthrin by oral routes (EXTOXNET, 1998). Neurological effects (e.g., disturbed posture, abnormal motor activity, restlessness, and agitated gate) have also been seen following acute inhalation exposures (ATSDR, 2003). Neurological symptoms following daily dermal doses of  $\geq 1,845$  mg/kg in rats for up to 7 days included pawing and whole body tremors (ATSDR, 2003).

The vehicle used in formulating cyfluthrin significantly affects its toxicity (WHO, 2004). Reported LD<sub>50</sub> values range from 16 to 1,189 mg/kg body weight, depending on the vehicle used (WHO, 2004). The reported oral LD<sub>50</sub>s range from 500 to 1,271 mg/kg in rats, 1,401 to 609 mg/kg in mice, greater than 100 mg/kg in dogs, greater than 1,000 mg/kg in rabbits, and greater than 1,000 mg/kg in sheep (EXTOXNET, 1998; HSDB, 2005). The oral LD<sub>50</sub>s for cyfluthrin in polyethylene glycol and xylene are 500 and 270 mg/kg, respectively (HSDB, 2005), while the oral LD<sub>50</sub> for a 5 percent water emulsion preparation is reported as 2,100 mg/kg body weight in rats (WHO, n.d.). Inhalation exposures in rats have resulted in 4-hour LC<sub>50</sub>s ranging from 469 to 592  $\mu\text{g}/\text{L}$  and a reported 1-hour LC<sub>50</sub> greater than 1,089  $\mu\text{g}/\text{L}$  (EXTOXNET 1998). The 4-hour LC<sub>50</sub>s for aerosol and dust exposures in rats are reported as 0.1 mg/L and 0.53 mg/L, respectively (HSDB, 2005). Cyfluthrin is not considered highly toxic via the dermal route of exposure, with a dermal LD<sub>50</sub> of greater than 5,000 mg/kg in rats (EXTOXNET, 1998; HSDB, 2005). Additionally, it is not a dermal sensitizer or irritant in guinea pigs and rabbits (WHO, 2004; EXTOXNET, 1998; HSDB, 2005) but did induce eye irritation in rabbits (WHO, 2004; HSDB, 2005).

### ***Treatment***

Cyfluthrin and its metabolites can be detected in blood and urine; however, the methods are not practical given how quickly these compounds are broken down in the body (ATSDR,

2003). There are no antidotes for cyfluthrin exposure. Treatment depends on the symptoms of the exposed person. If a person exhibits signs of typical pyrethroid toxicity following cyfluthrin exposure (nausea, vomiting, shortness of breath, tremors, hypersensitivity, weakness, burning, or itching), they should immediately remove any contaminated clothing. Any liquid contaminant on the skin should be soaked up and the affected skin areas cleaned with alkaline soap and warm water. Eye exposures should be treated by rinsing with copious amounts of 4 percent sodium bicarbonate or water. Contact lenses should be removed. Vomiting should not be induced following ingestion exposures, but the mouth should be rinsed. The person should be kept calm and medical attention should be sought as quickly as possible. Medical personnel will treat severe intoxications with a sedative and anticonvulsant. Ingestion of large amounts of cyfluthrin should be treated with gastric lavage using a 5 percent bicarbonate solution followed by powdered activated charcoal. Skin irritation may be treated with a soothing agent; exposure to light should be avoided (PAN, 2005; HSDB, 2005).

### *Chronic Exposure*

#### **Noncancer Endpoints**

Little data are available for humans following chronic exposures to cyfluthrin, although it is not likely to cause long-term problems when used under normal conditions (ATSDR, 2003). Available animal data suggest that chronic toxicity is highest by inhalation exposure, with lower toxicity by oral exposure. Dermal exposure has the lowest chronic toxicity (WHO, 2004). Cyfluthrin does not appear to be a reproductive or developmental toxin in animals (HSDB, 2005; WHO, 2004; ATSDR, 2003; EXTOXNET, 1998; WHO/FAO, 1997). However, treatment-related reductions in viability, decreased lactation, and decreased birth weight or weight gain were observed in one 3-generation rat study (ATSDR, 2003; EXTOXNET, 1998; U.S. EPA, 2005b). No developmental or teratogenic effects were observed in several animal studies (HSDB, 2005; EXTOXNET 1998; U.S. EPA, 2005b). In a 1-year dog feeding study, high doses of cyfluthrin caused slight ataxia, increased vomiting, and increased pasty or liquid feces. Decreased body weights were seen in males (U.S. EPA, 2005b). Cyfluthrin does not show any mutagenic potential (HSDB, 2005; WHO, 2004; EXTOXNET, 1998; WHO/FAO, 1997). Decreased weight gain and organ weight changes secondary to body weight are the only significant effects observed in long-term feeding studies in rats, mice, and dogs (WHO/FAO, 1997; EXTOXNET, 1998; U.S. EPA, 2005b). Additionally, reversible damage to the sciatic nerve was observed (EXTOXNET, 1998).

#### **Cancer Endpoints**

No evidence of carcinogenic potential has been reported in rats and mice exposed to cyfluthrin (WHO, 2004; EXTOXNET, 1998; WHO/FAO, 1997).

### *Toxicokinetics*

Pyrethroids are rapidly absorbed via inhalation as is indicated by the excretion of their metabolites within 30 minutes of exposures. In workers, plasma cyfluthrin levels confirmed

absorption. Oral exposure to pyrethroids results in absorption from the gastrointestinal tract. Cyfluthrin metabolites were identified in the urine of an orally exposed volunteer. Minimal oral absorption was estimated based on the recovery of urinary cyfluthrin metabolites (ATSDR, 2003).

As with other synthetic pyrethroids, biotransformation in mammals exposed to cyfluthrin occurs through hydrolysis of the central ester bond, oxidative attacks at several sites, and conjugation reactions that produce water-soluble metabolites that are excreted in urine and feces. For cypermethrin, the rapid hydrolytic cleavage of the ester bond is followed by oxidation, which results in carboxylic acid derivatives and phenoxybenzoic acid derivatives that are then excreted as alcohols; phenols; carboxylic acids; and their glycine, sulfate, glucuronide, or glucoside conjugates (ATSDR, 2003). The metabolism of cyfluthrin is biphasic with a rapid initial phase and a slower second phase. This is demonstrated by the elimination of 60 percent of an intravenous dose within the first 24 hours followed by 6 percent elimination during the second 24 hours. Similarly, in feces 20 percent was eliminated on the first day and 3 to 4 percent was eliminated on the second day. Additionally, a single oral dose of cyfluthrin was shown to be 98 percent eliminated within 48 hours (EXTOXNET, 1998). Inhalation of a single dose of cyfluthrin in humans resulted in urinary metabolites within 30 minutes of exposure (ATSDR, 2003; WHO/FAO, 1997).

Elimination of cyfluthrin following inhalation exposure follows first-order kinetics with 93 percent of the dose being excreted within 24 hours of exposure. The elimination half-times for cis-/trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylic acid (DCCA) and, 4-fluoro-3-phenoxybenzoic acid (FPBA) metabolites and their isomers range from 5.3 to 6.9 hours and remain constant over a range of exposure levels (ATSDR, 2003). Based on occupational human exposure studies, the elimination half-time for cyfluthrin is estimated at 0.5 to 2 hours for plasma and 5 hours for urine (ATSDR, 2003). Oral exposures to cyfluthrin resulted in approximately 60 to 70 percent of the dose being eliminated in the urine and the rest eliminated in the feces (WHO/FAO, 1997).

### *Ecological Effects*

#### **Acute Exposure**

##### ***Toxicity in Non-Targeted Terrestrial Organisms***

Cyfluthrin has a very low toxicity in birds (EXTOXNET, 1998; HSDB, 2005). Oral LD<sub>50</sub> values range from greater than 2,000 mg/kg in acute tests in bobwhite quail to greater than 5,000mg/kg in subacute tests in mallards and bobwhite quail (EXTOXNET, 1998). Other reported oral LD<sub>50</sub>s are 4,500 to greater than 5,000 mg/kg in hens (depending on the vehicle used), greater than 2,000 mg/kg in Japanese quail, and 250 to 1,000 mg/kg in canaries (EXTOXNET, 1998; HSDB, 2005). As with other pyrethroid insecticides, cyfluthrin is extremely toxic to honey bees in laboratory tests. The reported LD<sub>50</sub> is 0.037 mg/bee (EXTOXNET, 1998). However, in the field, serious adverse effects have not been seen due to low application rates and low environmental persistence (HSDB, 2005). Cyfluthrin is also

highly toxic to other beneficial insects (EXTOXNET, 1998) but of low toxicity to earthworms (WHO, 2004).

### ***Toxicity in Non-Targeted Aquatic Systems***

As with other pyrethroids, cyfluthrin is very toxic to marine and freshwater fish and invertebrates (EXTOXNET, 1998; WHO, 2004). The high toxicity in fish is illustrated by the low exposures that cause lethality. The reported 48-hour LC<sub>50</sub> for rainbow trout is 0.00068 mg/L, while in bluegill, carp, and golden orfe, the reported LC<sub>50</sub>s are 0.0015, 0.022, and 0.0032 mg/L, respectively. In sheepshead minnow, an LC<sub>50</sub> of 0.004 mg/L is reported (EXTOXNET, 1998). The 96-hour LC<sub>50</sub> values range from 28 ng/L in bluegill sunfish to 330.9 ng/L in golden orfe (HSDB, 2005). In marine and estuarine invertebrates, extreme sensitivity to cyfluthrin is also seen. Reported LC<sub>50</sub>s include 2.42 ng/L for mysid shrimp. An EC<sub>50</sub> of 3.2 ng/L was seen in eastern oysters (EXTOXNET, 1998). Cyfluthrin has a high potential to bioconcentrate in aquatic organisms based on the measured BCF of the structurally similar insecticide cypermethrin (HSDB, 2005).

### **Chronic Exposure**

Due to low rate of application and low persistence of cyfluthrin in both terrestrial and aquatic environments, serious adverse effects are not anticipated from chronic exposures (HSDB, 2005).

## **Profile for Deltamethrin:**

CAS Registry Number 52918-63-5

### ***Summary of Insecticide***

#### *Chemical History*

Deltamethrin is a broad spectrum synthetic pyrethroid insecticide used in agricultural and human health applications. It was first marketed in 1977 (IPCS, 1990; EXTOXNET, 1995; WHO/FAO, 2001) and has been in use longer than any alpha-cyano pyrethroid with an excellent safety record (WHO/FAO, 1999). It is similar to the natural insecticide pyrethrum, which comes from chrysanthemums; however, it is more effective and longer lasting (EXTOXNET, 1995; WHO/FAO, n.d.; IPCS, 1990). Deltamethrin is considered the most powerful synthetic pyrethroid (EXTOXNET, 1995). For mosquito control, it is used on bed nets and other materials that are dipped in deltamethrin to protect the user (Barlow et al., 2001; EXTOXNET, 1995; WHO/FAO, 2001). Deltamethrin is typically formulated as emulsifiable concentrates, wettable powders, ultra-light-volume (ULV) and flowable formulations, and granules either alone or combined with other pesticides (EXTOXNET, 1995; IARC, 1991). A dispersible tablet is also used to treat mosquito nets (Barlow et al.,

2001). Deltamethrin is of moderate toxicity to mammals because it metabolizes rapidly and does not accumulate (WHO/FAO, n.d.; WHO/FAO, 1999). It is of low risk to humans when used at levels recommended for its designed purpose (ATSDR, 2003; WHO, 2004). General population exposures are expected to be very low and to occur mostly through public health uses and dietary residues. As a synthetic pyrethroid, deltamethrin exhibits its toxic effects by affecting the way the nerves and brain normally function by interfering with the sodium channels of nerve cells (Choi and Soderlund, 2006). EPA has not classified synthetic pyrethroids, including deltamethrin, as endocrine disruptors. Typical symptoms of acute exposure are irritation of skin and eyes, severe headaches, dizziness, nausea, anorexia, vomiting, diarrhea, excessive salivation, and fatigue. Tremors and convulsions have been reported in severe poisonings. Inhaled deltamethrin has been shown to cause cutaneous paraesthesia (a burning, tingling, or stinging). However, these effects are generally reversible and disappear within a day of removal of the exposure (Barlow et al., 2001; WHO, 2004; ATSDR, 2003; IPCS, 1989, 1990). In animals, the critical effect is neurotoxicity (WHO, 2004).

*Description of Data Quality and Quantity*

Adequate dose-response studies on the toxicity of deltamethrin exist for oral, dermal, and inhalation exposures. Most are oral exposure studies (WHO, 2004). Several comprehensive reviews on the toxicity of deltamethrin have been prepared or updated in recent years:

- Environmental Health Criteria 97: Deltamethrin (IPCS, 1990)
- Health and Safety Guide No. 30: Deltamethrin Health and Safety Guide (IPCS, 1989)
- A review article by Barlow et al. (2001)
- Pesticide Information Profiles (PIP) for Deltamethrin (EXTOXNET, 1995)
- Data Sheets on Pesticides No. 50—Deltamethrin (WHO/FAO, n.d.)
- A Generic Risk Assessment Model for Insecticide Treatment and Subsequent Use of Mosquito Nets (WHO, 2004)
- Malaria Vector Control—Insecticides for Indoor Spraying (WHO/FAO, 2001)

EPA has developed quantitative human health benchmarks (acute and chronic oral RfDs, intermediate-term oral, and short-, intermediate-, and long-term dermal and inhalation benchmarks) for deltamethrin.

**Summary Table**

Duration	Route	Benchmark Value	Units	Endpoint	Reference
Acute, Intermediate, Chronic	Inhalation	0.01	mg/kg/day	Oral NOAEL for clinical signs in dogs at 1 mg/kg/day with UF of 100 applied	U.S. EPA (2004)
Acute	Oral	0.01	mg/kg/day	Acute RfD based on neurological effects in rats	U.S. EPA (2004)

Intermediate	Oral	0.01	mg/kg/day	Oral NOAEL for clinical signs in dogs at 1 mg/kg/day with UF of 100 applied	U.S. (2004)	EPA
Chronic	Oral	0.01	mg/kg/day	Chronic RfD based on clinical signs in dogs	U.S. (2004)	EPA
Acute, Intermediate, Chronic	Dermal	10	mg/kg/day	Dermal NOAEL of 1000 mg/kg/day in rats with a UF of 100 applied	Barlow et al. (2001)	

For oral exposure, an acute RfD of 0.01 mg/kg/day was derived based on a NOAEL of 1 mg/kg/day for neurological effects (reduced motor activity) observed in rats exposed to deltamethrin (Crofton et al., 1995), with an uncertainty factor of 100 applied to account for interspecies and intrahuman variability (U.S. EPA, 2004). A chronic oral RfD of 0.01 mg/kg/day was derived based on a NOAEL of 1 mg/kg/day for clinical signs and reduced weight gain in dogs (study citation not provided), with an uncertainty factor of 100 applied (U.S. EPA, 2004). The chronic RfD is appropriate to use for intermediate-term exposures (U.S. EPA, 2004).

For inhalation exposures, the chronic RfD is also appropriate for short-, intermediate-, and long-term exposures (U.S. EPA, 2004).

For dermal exposure, a NOAEL of 1,000 mg/kg/day was identified in rats dermally exposed to deltamethrin for 21 days (study citation not provided). An uncertainty factor of 100 was applied to account for interspecies and intrahuman variability, for a dermal benchmark value of 10 mg/kg/day. This value is appropriate for all dermal exposure durations (Barlow et al., 2001). The large difference between the oral and dermal NOAELs is due to rapid absorption of deltamethrin from the gastrointestinal tract versus low dermal absorption (WHO, 2004; Barlow et al., 2001).

### *Insecticide Background*

CASRN: 52918-63-5

Synonyms: cyano(3-phenoxy-phenyl)methyl;2-(2,2dibromoethenyl)-2,2-dimethylcyclopropanecarboxylate (CA); alpha-cyano-m-phenoxybenzyl,(1R,3R)-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropanl-carboxylate, (S)-alpha-cyano-3-phenoxybenzyl (1R)-cis-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropane-carboxylate, decamethrine, FMC 45498, NRDC 161, OMS 1998, RU 22974, RUP 987 (EXTOXNET, 1995; IARC, 1991; WHO/FAO, n.d.).

Chemical Group: pyrethroid (PAN, 2005)

Registered Trade Names: Products containing deltamethrin (NRDC 161 and RU 22974): Butoflin, Butoss, Butox, Cislin, Cislin 2.5% EC, Cislin 2.5%

WP, Cislin RTU, Crackdown, Cresus, Decis, Decis-Prime, K-Othrin, K-Orthine, K-Otek, Kordon, Sadethrin (EXTOXNET, 1995; WHO/FAO, n.d.; ATSDR, 2003; IPCS, 1989; IARC, 1991; FPA, 2002).

### *Usage*

Deltamethrin is used to combat pests on a variety of crops, including cotton, fruit, vegetables, coffee, maize, wheat, rapeseed, hops, and soybeans (ATSDR, 2003; EXTOXNET, 1995; IPCS, 1989, 1990). It is also used to control insects in stored grains, to protect cattle from infestation, and in public health applications. It may be applied to foods, field crops, gardens, orchards, and vineyards (WHO/FAO, n.d.). Public health uses include malaria control in Central America and Africa (IPCS, 1990). Deltamethrin belongs to the pyrethroid class of insecticides, which have long been used to control mosquitoes, human lice, beetles, and flies (ATSDR, 2003). For mosquito protection, it is used on bed nets and other materials that are dipped into the deltamethrin to protect the user. All concentrated formulations of deltamethrin were restricted by EPA due to its potential toxicity to aquatic organisms, and it may only be purchased and used by certified applicators (ATSDR, 2003).

### *Formulations and Concentrations*

Deltamethrin is available in technical grade (> 98 percent pure), suspension concentrate, emulsifiable concentrate (25–100 g/L), ultra-low-volume (ULV) concentrate (1.5–30 g/L), wettable powder (25–50 g/kg), flowable powder (7.5–50 g/L), dust powder (0.525 g/kg), and granules (0.5 and 1.0 g/kg) alone or combined with other pesticides (IPCS, 1989, 1990; WHO/FAO, n.d.). Deltamethrin that is marketed for use as a bed net treatment comes in a single 400 mg tablet form (WHO, 2004).

### *Shelf Life*

In storage conditions at 40°C, deltamethrin is stable to light, heat, and air for 6 months and to light and air for 2 years. It is most stable in acidic media and unstable in alkaline environments (EXTOXNET, 1995; IPCS, 1989, 1990; WHO/FAO, n.d.).

### *Degradation Products*

Deltamethrin's major metabolites are free and conjugated Br<sub>2</sub>CA, *trans*-hydroxymethyl-Br<sub>2</sub>CA, and 3-(4-hydroxyphenoxy)benzoic acid formed by ester cleavage, oxidation, and conjugation (IPCS, 1990).

### *Environmental Behavior*

#### **Fate and Transport in Terrestrial Systems**

Deltamethrin is not expected to be mobile in soil, with a K<sub>oc</sub> ranging from 46,000 to 1,630,000 (HSDB, 2005). Additionally, it binds tightly to soil particles, is insoluble in water, and has low application rates (IPCS, 1989, 1990). Volatilization is a major environmental fate process from moist soils but this is lessened by its adsorption to soil. Another major fate

process is biodegradation, with a half-life of several weeks to greater than 100 days (HSDB, 2005). As with other synthetic pyrethroids, deltamethrin degrades rapidly in soil and plants (IPCS, 1990). Degradation occurs within 1 to 2 weeks for soil, and no residues remain on plants after 10 days (EXTOXNET, 1995). Deltamethrin does not bioaccumulate in terrestrial systems (IPCS, 1990).

### **Fate and Transport in Aquatic Systems**

Because deltamethrin binds tightly to soil and is practically insoluble in water, very little leaching into groundwater is expected. In pond water, deltamethrin was absorbed rapidly by sediment, uptake by plants, and evaporation (EXTOXNET, 1995). Volatilization is a major environmental fate process in surface waters but is lessened by soil adsorption. Deltamethrin breaks down quickly in water with reported half-lives of 2 to 4 hours. The estimated volatilization half-life in a model river is 30 hours, and in a model lake, 500 hours. In a model pond, the estimated volatilization half-life is 7 years if adsorption is considered. Deltamethrin has a high potential to bioconcentrate in aquatic organisms. It has an estimated bioconcentration factor of 270. The reported estimated hydrolysis half-life was 36 years at pH 7 and 3.6 years at pH 8 (HSDB, 2005).

### *Human Health Effects*

#### **Acute Exposure**

#### *Effects/Symptoms*

There are limited data on the acute toxicity of deltamethrin in humans. Acute effects in humans include irritability, headache, salivation, sweating, fever, anxiety, rapid heart beat, diarrhea, dyspnea, tinnitus, runny nose, vomiting, edema, hepatic microsomal enzyme induction, peripheral vascular collapse, serum alkaline phosphatase elevation, tremors, ataxia, convulsions leading to muscle fibrillation and paralysis, and death due to respiratory failure (EXTOXNET, 1995; WHO/FAO, n.d.; IPCS, 1990). Dermatitis is expected after dermal exposures, which often occur as a result of inadequate handling safety precautions during agricultural use (EXTOXNET, 1995; IPCS, 1990). Coma was caused within 15 to 20 minutes at oral exposure levels of 100 to 250 mg/kg (EXTOXNET, 1995). Facial paraesthesia is a common indicator of exposure of humans to high levels (WHO/FAO, n.d.).

In clinical studies in humans, slight irritation but no skin damage was reported in patch tests of deltamethrin put on faces of volunteers (IPCS, 1990). Acute occupational exposures to deltamethrin have resulted mostly in dermal symptoms including itching, burning, and paraesthesia. These are an early, reversible signs of exposure and are due to local, not systemic, exposures (Barlow et al., 2001; IPCS, 1990; EXTOXNET, 1995). Neurological signs such as headaches, dizziness, fatigue, nausea, anorexia, transient EEG changes, muscular fasciculation, and convulsions have also been reported following acute occupational exposures (Barlow et al., 2001; EXTOXNET, 1995). Loss of consciousness, muscle cramps, myosis, and tachycardia were reported in a 13-year-old girl who attempted suicide by ingesting 5 g of deltamethrin (200 mL of a 2.5% EC formulation). After

appropriate medical intervention, she recovered completely within 48 hours. Only digestive and hepatic signs were observed in a 23-year-old man who attempted suicide by ingesting 1.75 g of deltamethrin (70 mL of a 2.5% EC formulation) (IPCS, 1990).

Animal studies have indicated that deltamethrin has low acute toxicity; however, this varies greatly depending on the route of administration and the vehicle used (WHO, 2004; Barlow et al., 2001). In acute exposure studies, the mouse is the species most susceptible to deltamethrin toxicity (WHO/FAO, n.d.). Reported oral LD<sub>50</sub> values range from 19 to 34 mg/kg in mice, 52 to over 5,000 mg/kg in male rats, 30 to 139 mg/kg in female rats, and over 300 mg/kg in dogs (EXTOXNET, 1995; IPCS, 1990; WHO/FAO, n.d.; WHO/FAO, 2001; Barlow et al., 2001). Following acute dermal exposure, the reported LD<sub>50</sub> is greater than 2,940 mg/kg in rats and dogs and greater than 2,000 mg/kg in rabbits (EXTOXNET, 1995; IPCS, 1990; WHO/FAO, n.d.; WHO/FAO, 2001). The reported inhalation 6-hour LD<sub>50</sub> in rats is 600 mg/m<sup>3</sup> (IPCS, 1990).

Hyperactivity and hypersensitivity are general characteristics of pyrethroid poisonings. However, the signs of acute deltamethrin poisoning are different from other pyrethroids in that it produces a unique set of effects that occur in a specific sequence in animals. They begin with chewing, pawing, and burrowing behavior; excessive salivation; and coarse tremors advancing to choreoathetosis and sometimes terminal clonic seizures. Rolling convulsions are especially characteristic of deltamethrin poisoning (WHO/FAO, n.d.; EXTOXNET, 1995). In rabbits and guinea pigs, no primary skin irritation or sensitization was observed following acute dermal exposure to 0.5 g/animal, although transitory ocular irritation was seen in rabbits without immediate rinsing (EXTOXNET, 1995; WHO/FAO, n.d.). However, another study reported skin irritation in rats and guinea pigs (EXTOXNET, 1995). Cardiovascular effects include a rapid fall in blood pressure, severe bradycardia, and EKG changes in intravenously exposed dogs (WHO/FAO, n.d.)

### ***Treatment***

Deltamethrin and its metabolites can be detected in blood and urine; however, the methods are not practical given how quickly these compounds are broken down in the body (ATSDR, 2003; WHO/FAO, n.d.). Levels of the degradation products bromide, cyanide, and 3-phenoxybenzyl in urine may be useful indicators in cases of severe toxicity (WHO/FAO, n.d.).

There are no antidotes for deltamethrin exposure (IPCS, 1989; WHO/FAO, n.d.). Treatment depends on the symptoms of the exposed person. If a person exhibits signs of typical pyrethroid toxicity following deltamethrin exposure (nausea, vomiting, shortness of breath, tremors, hypersensitivity, weakness, burning, or itching), they should immediately remove any contaminated clothing. Any liquid contaminant on the skin should be soaked up and the affected skin areas cleaned with alkaline soap and warm water. Eye exposures should be treated by rinsing with copious amounts of 4 percent sodium bicarbonate or water. Contact lenses should be removed. Vomiting should not be induced following ingestion exposures, but the mouth should be rinsed. The person should be kept calm and medical attention

should be sought as quickly as possible (PAN, 2005; WHO/FAO, n.d.). Medical personnel will treat severe intoxications with a sedative and anticonvulsant (IPCS, 1989). Ingestion of large amounts of deltamethrin should be treated with gastric lavage using a 5 percent bicarbonate solution followed by powdered activated charcoal. Skin irritation may be treated with a soothing agent and exposure to light should be avoided (WHO/FAO, n.d.)

### *Chronic Exposure*

#### **Noncancer Endpoints**

Little data are available for humans following chronic exposures to deltamethrin; however, it is not likely to cause long-term problems when used under normal conditions. In humans, suspected chronic effects include choreoathetosis, hypotension, prenatal damage, and shock (EXTOXNET, 1995). Chronic occupational exposure to deltamethrin caused skin and eye irritation; however, no long-term effects were seen (Barlow et al., 2001; EXTOXNET, 1995). After 1 year of using bednets treated with a target dose of 25 mg/m<sup>2</sup> deltamethrin, skin irritation occurred one week after treatment, and runny nose and sneezing in the first days of use were reported for target doses of 10–30 mg/m<sup>2</sup>. No chronic effects were reported (Barlow et al., 2001). Data in animals indicate that oral exposure to deltamethrin is not highly toxic (Barlow et al., 2001; EXTOXNET, 1995; WHO/FAO, n.d.).

In studies of reproductive toxicity in rats, no effects were seen on male or female fertility; number of implantation sites; litter size at birth; or pre- or postnatal survival in rats, mice, and rabbits (Barlow et al., 2001). No effects on reproduction were observed in a 3-generation rat study, but slight embryotoxicity was seen (EXTOXNET, 1995; Barlow et al., 2001). Dose-related decreases in maternal weight gain were seen in pregnant mice dosed with deltamethrin on gestational days 7 to 16. However, no effect on the number of implants, fetal mortality, fetal weight, or malformations was seen (EXTOXNET, 1995). Deltamethrin is not teratogenic in mice, rats, or rabbits at doses that produced clinical signs of toxicity in pregnant dams (Barlow et al., 2001; EXTOXNET, 1995; WHO/FAO, n.d.). Mutagenicity studies in mice, rats, and rabbits indicate that deltamethrin is not mutagenic (Barlow et al., 2001; EXTOXNET, 1995; WHO/FAO, n.d.)

#### **Cancer Endpoints**

IARC (1991) has classified deltamethrin as a Group 3 chemical, “not classifiable as to its carcinogenicity in humans.” No human carcinogenicity data are available for deltamethrin (IARC, 1991; EXTOXNET, 1995). Long-term dietary studies in rats, mice, and dogs did not find evidence of carcinogenicity (IPCS, 1990). Microbial, mammalian cell, and *in vivo* mammalian mutagenicity studies support the evidence that deltamethrin is not carcinogenic (WHO/FAO, n.d.).

### *Toxicokinetics*

Deltamethrin metabolism has not been well studied in humans. It is expected to be similar to metabolism in rodents (Barlow et al., 2001). Deltamethrin is readily absorbed via the gastrointestinal tract, inhalation, and less so through intact skin. The rate at which it is

absorbed depends on the carrier or solvent used. Once absorbed, deltamethrin is readily metabolized and excreted (Barlow et al., 2001; IPCS, 1989, 1990; WHO/FAO, n.d.). Similar metabolism and excretion patterns have been observed in extensive studies in rats, mice, and cows. Deltamethrin is metabolized in the liver by microsomal esterases and oxidases. It is distributed to the gut wall and liver. The parent compound is cleaved into cyclopropanecarboxylic acid and 3-phenoxybenxyl alcohol, which is then oxidized to 3-phenolbezoic acid. 3-Phenoxybenzoic acid is the major excretion compound. Hydroxylation of this moiety can occur before or after hydrolysis (Barlow et al., 2001; WHO/FAO, n.d.; EXTOXNET, 1995; IPCS, 1990). In rats, approximately 13 to 21 percent of deltamethrin is eliminated unchanged in the urine and feces within 2 to 4 days; however, the metabolites of the cyano substituent are eliminated more slowly. The half-life of deltamethrin in the brains of rats is 1 to 2 days. Levels of the metabolites remain higher, especially in the skin, stomach, and body fat, with a half-life of 5 days in body fat (Barlow et al., 2001; EXTOXNET, 1995). Following oral exposure, deltamethrin is completely eliminated within 6 to 8 days (WHO/FAO, n.d.). In feces, 7 to 15 percent of the oral dose is found as the parent compound and its hydroxylates; the hydrolysis products are mainly excreted in the urine. A smaller amount is found in the skin as thiocyanate (WHO/FAO, n.d.)

### *Ecological Effects*

#### **Acute Exposure**

##### ***Toxicity in Non-Targeted Terrestrial Organisms***

Deltamethrin, like other pyrethroids, is very unlikely to harm terrestrial organisms other than its targets, such as mosquitoes and other pests (EXTOXNET, 1996). It has a very low toxicity in birds (IPCS, 1990; IPCS, 1989). Oral LD<sub>50</sub> values range from greater than 1,800 mg/kg in grey partridge to greater than 4,000 mg/kg in ducks (IPCS, 1989). An 8-hour LD<sub>50</sub> of more than 4,640 mg/kg diet was reported in ducks, and the 8-hour LD<sub>50</sub> in quail was greater than 10,000 mg/kg diet (EXTOXNET, 1995). As with other pyrethroid insecticides, deltamethrin is extremely toxic to honey bees, with a 24-hour LD<sub>50</sub> of 0.079 for technical deltamethrin and 0.4 µg ai/bee for the EC formulation. The contact LD<sub>50</sub> for bees is reported to be 0.05 µg ai/bee. However, in real-life applications, serious effects have not been noticed due to low application rates and lack of environmental persistence. Deltamethrin is also very toxic to *Typhodromum pyri*, a predatory mite; *Encarsia Formosa*, a parasitic wasp; and spiders (EXTOXNET, 1995; IPCS, 1990).

##### ***Toxicity in Non-Targeted Aquatic Systems***

In the laboratory, deltamethrin is very toxic to fish and aquatic arthropods. However, under normal use conditions in the environment, no deleterious effects have been observed due to its low application rates and lack of persistence (EXTOXNET, 1995; IPCS, 1990). The reported 96-hour LC<sub>50</sub> value for technical deltamethrin ranges from 0.39 µg/L in rainbow trout to 3.5 µg/L in *Sarotherodon mossambicus*. For the emulsifiable concentrate, LC<sub>50</sub> values range from 0.59 µg/L in *Salmo salar* (96-hour) to 4.7 µg/L in brown trout (48-hour). For ultra-light volume concentrate, LC<sub>50</sub> value ranges from 82 µg/L in bleak to 210 µg/L in

common carp. In *Daphnia*, the reported 48-hour LC<sub>50</sub> for technical deltamethrin is 5 µg/L (IPCS, 1990). Deltamethrin can accumulate in fish. Fathead minnows accumulated deltamethrin without any effect on mortality (EXTOXNET, 1995). Deltamethrin is also highly toxic to aquatic macroinvertebrates such as lobster (IPCS, 1989).

#### *Chronic Exposure*

Due to low application rates and low persistence of deltamethrin in both terrestrial and aquatic environments, serious adverse effects are not anticipated from chronic exposures (HSDB, 2005).

## **Profile for Etofenprox:**

CAS Registry Number 80844-07-1

### ***Summary of Insecticide***

#### *Chemical History*

Etofenprox is a non-ester pyrethroid-like insecticide and acaricide used in agricultural, horticultural, and public health applications. Its toxicity and mode of action (acting on the central nervous system) are similar to other pyrethroids (WHO/FAO, 1993; WHO, 1999; NIH, 2005). For mosquito control, etofenprox is used on bed nets and other materials that are dipped in it to protect the user. WHO has classified etofenprox as low risk for acute toxicity in humans under normal use conditions (WHO, 1999). Typical symptoms of acute exposure are likely to be similar to other pyrethroid insecticides. At high doses, hunched posture, lethargy, body tremors, and respiratory distress were reported in laboratory animals. Etofenprox does not inhibit cholinesterase activity. At high doses, long-term exposure can affect organs such as the thyroid and kidneys. Reproductive and developmental effects are not expected. Etofenprox is available as the technical product and formulated wettable powders and emulsifiable concentrates. Etofenprox is classified as Group C, possible human carcinogen.

#### *Description of Data Quality and Quantity*

The available data on etofenprox are limited. Relevant references include the following:

- Pesticide Residues in Food – 1993. Evaluation Part II Toxicology. Etofenprox (WHO/FAO, 1993)
- Etofenprox Evaluation (FAO, 1993)
- Summary of Toxicology Data: Etofenprox (CalEPA, 2003)

## Summary Table

Duration	Route	Benchmark Value	Units	Endpoint	Reference
Acute, Intermediate, Chronic	Inhalation	0.1	mg/kg/day	NOAEL for systemic effects in rats with UF of 100 applied	NYSDEC (2005)
Acute, Intermediate, Chronic	Oral	0.037	mg/kg/day	Proposed chronic RfD based NOEL in rats with UF of 100 applied	NYSDEC (2005)
Acute, Intermediate	Dermal	0.4	mg/kg/day	LOAEL (skin lesions) in rats with UF of 1,000 applied	NYSDEC (2005)
Chronic	Dermal	0.037	mg/kg/day	Adopt chronic oral RfD; assume no first pass effects and 100% absorption	NYSDEC (2005)
Cancer	Inhalation, Oral, Dermal	0.0051	per mg/kg/day	CSF for thyroid adenomas and carcinomas in rats	NYSDEC (2005)

For inhalation exposure, a NOEL of 0.04 mg/L (equivalent to 10.6 mg/kg/day) was identified for hematological and systemic effects in rats (study citation not provided) exposed to etofenprox for 90 days (NYSDEC, 2005). An uncertainty factor of 100 was applied to account for intrahuman and interspecies variation. This value is appropriate for all exposure durations.

For oral exposure, EPA calculated a chronic RfD of 0.037 mg/kg/day based on a NOEL in a chronic rat feeding study (study citation not provided). An uncertainty factor of 100 was applied. EPA's Integrated Risk Information System (IRIS) has not yet adopted this value (NYSDEC, 2005). This value is appropriate for all exposure durations.

For dermal exposure, a LOAEL of 400 mg/kg/day for skin lesions was reported (study citation not provided) in a 28-day dermal study in rats (no systemic effects were observed). An uncertainty factor of 1,000 was applied to account for the use of a LOAEL and intrahuman and interspecies variation (NYSDEC, 2005). This value is appropriate for short- and intermediate-term exposures. For long-term exposures, the chronic oral RfD was adopted for dermal exposures.

EPA has classified etofenprox as Group C, possible human carcinogen. To assess potential carcinogenic risks, EPA derived a cancer slope factor (CSF) of  $5.1 \times 10^{-3}$  per mg/kg/day based on increased thyroid follicular cell adenomas and carcinomas in a two-year rat feeding study (NYSDEC, 2005).

### *Insecticide Background*

CASRN: 80844-07-1

Synonyms: Ethofenprox. Ethophenprox, Ephofenprox, 1-((2-(4-Ethoxyphenyl)-2-methylpropoxy)methyl)-3-phenoxy benzene, 3-Phenoxybenzyl 2-(4-ethoxyphenyl)-2-methylpropyl ether,

MTI 500, BRN, 707478121 percent Etofenprox aerosol, 1 percent Etofenprox Fogger, 2-(4-Ethoxyphenyl)-2-methylpropyl 3-phenoxybenzyl ether, Benzene, 1-((2-(4-ethoxyphenyl)-2-methylpropoxy)methyl)-3-phenoxy-, Benzene, 1-((2-(4-ethoxyphenyl)-2-methylpropoxy)methyl)-3-phenoxy- (9CI) RF 316, SAN 811 I (NIH, 2005; FAO, 1993; PAN, 2005)

Chemical Group: non-ester pyrethroid (Hemingway, 1995)

Registered Trade Names: Carancho 2.5 EC, Polido 2.5 EC, Trebon 10 EC, Trebon 10 EW, Trefic 20 WP, Vectron 10 EW, Vectron 20 WP, Zoecon RF-316 (WHO, 2002; FAO, 1993; PAN, 2005)

### *Usage*

Etofenprox is used as a broad spectrum insecticide to combat a wide variety of pests on an assortment of crops including rice, fruits, vegetables, corn, soybeans, and tea. Etofenprox is effective against Lepidoptera, Hemiptera, Coleoptera, Diptera, Thysanoptera, and Hymenoptera at low rates. Because of its pyrethroid-like activity, it is active against insects that are resistant to carbamate or organophosphorus insecticides, including strains of rice green leafhopper and planthoppers (WHO/FAO, 1993; FAO, 1993). Etofenprox is also used in public health applications, including mosquito control, and on livestock (WHO/FAO, 1993; Hemingway, 1995). Etofenprox is a WHO Pesticide Evaluation Scheme (WHOPES)-recommended insecticide for the indoor spraying of malaria vectors. Application of 0.1 to 0.3 mg/m<sup>2</sup> is effective for 3 to 6 months (WHO, 2003). Technical grade etofenprox (97 percent etofenprox) is labeled for use in pesticide formulations for use in residential, commercial, and industrial uses. Etofenprox aerosol (1 percent) is labeled to kill cockroaches, ants, fleas, ticks, spiders, and other listed insects in residential, commercial, and industrial applications (NYSDEC, 2005). Etofenprox is not a restricted use chemical (PAN, 2005).

### *Formulations and Concentrations*

Etofenprox is available in technical grade, emulsifiable concentrates, and wettable powder formulations (WHO, 1999; FAO, 1993). Technical grade etofenprox is typically 96.3 percent etofenprox with < 1 percent impurities (FAO, 1993). It may be mixed with carriers or solvents resulting in the commercial formulations. The most common formulations are a 20 percent wettable powder and a 20 percent emulsifiable concentrate. These may be used on all crops; however 10 percent or 30 percent formulations are used in some countries (FAO, 1993). WHO indicated that the content of etofenprox in the formulated products must be declared and shall not exceed the listed standards. Technical grade etofenprox must have no less than 985 g/kg etofenprox. The wettable powder should contain > 25–100 g/kg +/- 10% of the declared content, 100–250 g/kg +/- 6% of the declared content, or > 250–500 g/kg +/- 5% of the declared content (WHO, 1999). For mosquito netting treatment,

etofenprox is a WHOPEs-recommended insecticide at doses of 200 mg ai/m<sup>2</sup> of netting of a 10 percent EW formulation. The amount of etofenprox that is recommended for treatment of mosquito netting is 30 ml of a 10 percent EW formulation (WHO, 2003).

#### *Shelf Life*

Etofenprox is stable to temperatures up to 80°C for up to 3 months. At 100°C, it degrades partially. A half-life of 4 days was calculated for radiolabeled etofenprox exposed to high intensity heat lamps (FAO, 1993).

#### *Degradation Products*

In soil, etofenprox is broken down by oxidation. The main degradation products are 2-(4-ethoxyphenyl)-2-methylpropyl 3-phenoxybenzoate and 2-(4-ethoxyphenyl)-2-methylpropyl 3-hydroxybenzyl ether. It is metabolized by desethylation of the ethoxyphenyl group, hydroxylation of the phenoxy ring, and oxidation of the benzyl moiety followed by cleavage of the ether linkage to form polar compounds. In animals, conjugates are formed (FAO, 1993).

#### *Environmental Behavior*

##### **Fate and Transport in Terrestrial Systems**

Studies of adsorption and leaching of etofenprox in Yamanashi sandy loam (78 percent sand, 11 percent silt, 11 percent clay), Chiba light clay (28 percent sand, 39 percent silt, 32 percent clay), and Shizuoka light clay (43 percent sand, 26 percent silt, 31 percent clay) revealed low translocation. Unchanged etofenprox was not found in deeper layers of the soil when it was applied just before application of glass columns. When radiolabeled soil was preincubated, the majority of the radioactivity remained in the top 5 cm of soil. Unchanged etofenprox was not found in the elutes (FAO, 1993).

Under laboratory conditions the half-life of etofenprox in soil is 6 to 9 days, with only minor differences between Yamanashi sandy soil, Chiba light clay soil, and Shizuoka light clay soil. Etofenprox content decreased 15 percent over 3 weeks. Degradation occurred by oxidation to 2-(4-ethoxyphenyl)-2-methylpropyl 3-phenoxybenzoate and 2-(4-ethoxyphenyl)-2-methylpropyl 3-hydroxybenzyl ether. In nonsterile soil, 80 percent of the applied etofenprox was decomposed within two weeks; no degradation occurred in sterile soil (FAO, 1993).

In field studies, the half-life of etofenprox was approximately 79 days in loam soil (8.2 percent clay, 7.5 percent organic carbon), 62 days in clayish loam soil (21 percent clay, 2.4 percent organic carbon), 39 days in volcanic ash loam (10 percent clay, 6.2 percent organic carbon), and 9 days in alluvial clayish loam (2 percent clay, 2.8 percent organic carbon) (FAO, 1993).

Photodegradation may be an important fate process for etofenprox on plant surfaces. Similar degradation pathways have been shown in laboratory studies of photodegradation from glass disc surfaces and in studies on bean leaves (FAO, 1993).

## **Fate and Transport in Aquatic Systems**

Under laboratory conditions, etofenprox is stable in aqueous solutions of 1N NaOH or 1N HCl for a period equal to or greater than 10 days (FAO, 1993). It is stable in neutral and acidic environments at 25°C and in darkness, with an estimated half-life of greater than 1 year. However, a more rapid breakdown is seen under real life conditions. In city water treated with 200 g/L etofenprox, 70 percent degradation was observed after 1 week and 93 percent after 3 weeks. The rapid degradation was attributed to the presence of sunlight.

### *Human Health Effects*

#### **Acute Exposure**

##### *Effects/Symptoms*

There are limited data on the acute toxicity of etofenprox in humans. Because its toxicity and mode of action are similar to other pyrethroids, the general symptoms of pyrethroid exposure are expected to occur following acute etofenprox exposure. Technical grade etofenprox is not expected to present an acute hazard to humans under normal use conditions (WHO, 2005; WHO/FAO, 1993).

In mice, rats, and dogs, etofenprox and 1 percent Etofenprox Aerosol have low acute toxicity by oral, dermal, and inhalation routes of exposure (WHO/FAO, 1993, PAN, 2005, NYSDEC, 2005). Reported LD<sub>50</sub> values for mice exposed to etofenprox (96 percent) were >107.2 for oral exposures and >2.14 g/kg for dermal (24-hour) exposures. In rats, an oral LD<sub>50</sub> of >42.88 g/kg, a dermal 24-hour LD<sub>50</sub> of 2.14 g/kg bw, and an inhalation LC<sub>50</sub> of > 5.9 g/m<sup>3</sup> were reported. The oral LD<sub>50</sub> in dogs was reported as >5.0 g/kg. The oral LD<sub>50</sub> of Trebon 20 EC (20 percent etofenprox emulsifiable concentrate) is reported as >5 g/kg in both mice and rats, and the dermal LD<sub>50</sub> is reported as > 2 g/kg in rats (WHO/FAO, 1993).

Acute oral studies of high-dose exposure to etofenprox showed central nervous system effects in both mice and rats. Dose-related decreases in spontaneous motor activity were observed in mice at high doses. In rats, a dose-related effect on EEG of the frontal lobe was seen at a similarly high dose. In rabbits, a 1 percent etofenprox formulation did not produce much skin or eye irritation. However, technical etofenprox is moderately irritating to the skin but not the eyes. No dermal sensitization was observed in tests on guinea pigs (NYSDEC, 2005; WHO/FAO, 1993). In subchronic (13-week) dietary studies in mice and rats, growth retardation and increased liver weights were observed at lower doses and hunched posture, lethargy, body tremors, and respiratory distress were reported at the highest dose tested (WHO/FAO, 1993).

#### ***Treatment***

Etofenprox's toxicity and mode of action are similar to other pyrethroids. No chemical-specific data were located on the treatment of etofenprox exposure; however, generalized treatment for pyrethroids should be appropriate. Treatment of etofenprox exposure depends on the symptoms of the exposed person. If a person exhibits signs of typical pyrethroid

toxicity following etofenprox exposure (nausea, vomiting, shortness of breath, tremors, hypersensitivity, weakness, burning, or itching), they should immediately remove any contaminated clothing. Any liquid contaminant on the skin should be soaked up and the affected skin areas cleaned with alkaline soap and warm water. Eye exposures should be treated by rinsing with copious amounts of 4 percent sodium bicarbonate or water. Contact lenses should be removed. Vomiting should not be induced following ingestion exposures, but the mouth should be rinsed. The person should be kept calm and medical attention should be sought as quickly as possible. Medical personnel will treat severe intoxications with a sedative and anticonvulsant. Ingestion of large amounts of etofenprox should be treated with gastric lavage using a 5 percent bicarbonate solution followed by powdered activated charcoal. Skin irritation may be treated with a soothing agent and exposure to light should be avoided (WHO, 1999)

### *Chronic Exposure*

#### **Noncancer Endpoints**

Little data are available for humans following chronic exposures to etofenprox. No compound-related effects were reported in workers occupationally exposure to unspecified concentrations of technical etofenprox for 1.5 to 5.5 years. Blood pressure measurements, X-rays, hematology measurements, blood chemistry analysis, urinalysis, and EKGs were taken and interviews conducted (WHO/FAO, 1993).

In chronic animal studies, rodents appear to be the most sensitive species (WHO/FAO, 1993). Following long-term oral exposure, systemic organ toxicity has been observed, including effects on the thyroid, kidneys, and liver in rats, mice, and dogs (NYSDEC, 2005; CalEPA, 2003; WHO/FAO, 1993). A 90-day inhalation exposure of rats resulted in increased heart, lung, liver, and kidney weights (NYSDEC, 2005). Etofenprox is not a cholinesterase inhibitor (PAN, 2005).

Etofenprox exposure does not produce significant reproductive or developmental toxicity in animals (NYSDEC, 2005; CalEPA, 2003). No adverse effects on reproductive parameters were seen in a two-generation feeding study or in segment I and II gavage study where rats were exposed to high levels in the diet and by gavage, respectively (CalEPA, 2003; WHO/FAO, 1993; NYDEC, 2005). No significant developmental toxicity in the absence of maternal toxicity has been reported following etofenprox exposure in animals (NYSDEC, 2005; CalEPA, 2003). Some developmental effects (increased incidence of malformations and visceral abnormalities) have been reported in rat offspring; however, they only occurred at doses that also caused maternal toxicity (WHO/FAO, 1993). Reduced fetal body weight and increased postimplantation loss were observed in rabbits at maternally toxic levels (NYSDEC, 2005).

Etofenprox is not mutagenic. Results from genotoxicity studies in bacteria, mammalian cells, *in vitro*, and *in vivo* in mice were all negative (WHO/FAO, 1993; CalEPA, 2003).

## **Cancer Endpoints**

EPA has classified etofenprox as Category C, possible human carcinogen, and calculated a cancer potency slope factor of  $5.1 \times 10^{-3}$  per mg/kg/day (NYSDEC, 2005). The available animal data show evidence of carcinogenicity in the absence of any human data (PAN, 2005). An increased incidence of thyroid follicular cell adenomas was seen in a two-year rat feeding study (WHO/FAO, 1993; CalEPA, 2003; NYSDEC, 2005).

### *Toxicokinetics*

Etofenprox is readily absorbed from the gastrointestinal tract of rats given oral doses. Absorption ranged from 48–93 percent; absorption is dose dependent (WHO/FAO, 1993; FAO, 1993). Dermal absorption studies in male rats revealed that more than 90 percent of the total dose of 5, 59, or 184 g/cm<sup>2</sup> was recovered up to 96-hours after applications of <sup>14</sup>C-labeled etofenprox. Most of the radioactivity was recovered in the skin wash prior to sacrifice. The absorbed radioactivity was less than 7 percent after 96 hours (CalEPA, 2003). Etofenprox is distributed to fat as the parent compound, where the highest tissue concentrations are observed. Following oral administration, it is rapidly excreted, mainly in feces. Within 5 days, 85 to 90 percent was excreted in the feces, with lesser amounts (3 to 4 percent) in the urine. Only 3 to 4 percent remained in the body after 5 days. Etofenprox is not excreted in bile. It is excreted unchanged in the milk of dairy cows fed diets containing etofenprox. In rats, biotransformation mainly involves desethylation of the ethoxyphenyl group, hydroxylation of the phenoxy ring and oxidation of the benzyl methylene group. Although gastrointestinal absorption occurred at a slower rate in dogs than rats, the major routes of biotransformation were the same (WHO/FAO, 1993; FAO, 1993; CalEPA, 2003).

### *Ecological Effects*

#### **Acute Exposure**

##### ***Toxicity in Non-Targeted Terrestrial Organisms***

No data are available on the toxicity of etofenprox in birds or other non-target terrestrial organisms.

##### ***Toxicity in Non-Targeted Aquatic Systems***

Etofenprox is toxic to aquatic organisms (WHO, 1999). In fish, etofenprox is slightly to moderately toxic. Slight toxicity is supported by the reported average LC<sub>50</sub> of 49,000 µg/L in Japanese eel, while moderate toxicity is supported by the reported average LC<sub>50</sub> of 1,845 µg/L in Mozambique tilapia. In addition to mortality, behavioral, biochemical, and physiological changes have been reported in fish exposed to etofenprox. Behavioral changes were reported in Mozambique tilapia exposed to 1,305 µg/L of the etofenprox formulation Trebon. Biochemical changes were seen in carp exposed to 600 µg/L of a 30 percent emulsifiable concentrate of Trebon for 24 hours, and effects were seen at a mean exposure of 300 µg/L for 15 days. Hematological effects and oxygen consumption changes were seen

in Mozambique tilapia at concentrations of 1,400 µg/L of 96.3 percent etofenprox (PAN, 2005)

*Chronic Exposure*

Due to low application rates and low persistence of etofenprox in both terrestrial and aquatic environments, serious adverse effects are not anticipated from chronic exposures (HSDB, 2005). No specific chronic data are available.

# Profile for Fenitrothion:

CAS Registry Number 122-14-5

## *Summary*

### *Chemical History*

Fenitrothion is a general use organophosphate insecticide that is nonsystemic and nonpersistent. It is mostly used in the control of chewing and sucking insects on a wide variety of agricultural crops and in forests, as well as for public health purposes. It is also used as a residual contact spray against mosquitoes, flies, and cockroaches. Fenitrothion is used residentially to control household and nuisance insects (EXTOXNET, 1995; WHO, 2003). Fenitrothion was introduced in 1959 as a less toxic alternative to parathion, with which it shares similar insecticidal properties. Fenitrothion is used heavily in countries that have banned parathion (EXTOXNET, 1995). In the United States, the use of fenitrothion for mosquito control was voluntarily cancelled by the manufacturer in 1995 (U.S. EPA, 1995) and the only registered use is for containerized ant and roach baits (U.S. EPA, 2000b).

The primary route of occupational exposure to fenitrothion is dermal, although inhalation exposures are also possible (U.S. EPA, 1995). Exposure to fenitrothion can cause overstimulation of the nervous system due to cholinesterase inhibition. This may result in nausea, dizziness, confusion, and respiratory paralysis and death at very high exposures (U.S. EPA, 2000b).

### *Description of Data Quality and Quantity*

EPA has developed quantitative human health benchmarks (acute and chronic oral RfDs and inhalation and dermal benchmarks) for fenitrothion. Relevant review data resources include the following

- Reregistration Eligibility Decision (RED) Fenitrothion (U.S. EPA, 1995)
- Pesticide Information Profiles (PIP) for Fenitrothion (EXTOXNET, 1995)
- Specifications for Pesticides Used in Public Health: Fenitrothion (WHO, 1999)
- Pesticide Residues in Food 2000: Fenitrothion (IPCS, 2000).

## Summary Table

Duration	Route	Benchmark Value	Units	Endpoint	Reference
Acute, Intermediate, Chronic	Inhalation	0.0004	mg/kg/day	Inhalation NOAEL of 0.2 µg/L (0.2 mg/kg/day) for neurological effects in rats with UF of 100 applied and adjusted for intermittent exposure	U.S. EPA (1999a)
Acute	Oral	0.13	mg/kg/day	Acute oral RfD based on neurological	U.S. EPA

				effects in rats	(1999a)	
Intermediate	Oral	0.0013	mg/kg/day	Adopt chronic RfD for intermediate duration	U.S. (1999a)	EPA
Chronic	Oral	0.0013	mg/kg/day	Chronic oral RfD for based on NOEL for systemic and neurological effects in dogs	U.S. (1999a)	EPA
Acute, Intermediate, Chronic	Dermal	0.01	mg/kg/day	Dermal LOAEL of 3 mg/kg/day for dermal effects in rabbits	U.S. (1999a)	EPA

For inhalation exposure, a NOAEL of 0.2 µg/L (0.2 mg/kg/day)<sup>18</sup> was identified in rats (Coombs et al., 1988) exposed to fenitrothion via inhalation for 6 hours per day, 5 days per week, for 90 days (U.S. EPA, 1999a; IPCS, 2000). The concentration was adjusted for intermittent exposure<sup>19</sup> (0.04 mg/kg/day) and an uncertainty factor of 100 was applied to account for interspecies and intrahuman variation, for an inhalation benchmark of 0.0004 mg/kg/day. This value is appropriate for all exposure durations.

For oral exposure, an acute oral RfD was estimated at 0.13 mg/kg/day based on a NOAEL of 12.5 mg/kg/day for acute neurotoxicity in rats (Beyrouthy et al, 1992). An uncertainty factor of 100 was applied to account for interspecies and intrahuman variability (U.S. EPA, 1999a). A chronic oral RfD of 0.0013 mg/kg/day was developed by EPA (1995, 1999a) based on a NOAEL of 0.125 mg/kg/day for systemic effects and plasma acetylcholinesterase inhibition in a long-term feeding study in dogs (Spicer, 1986). An uncertainty factor of 100 was applied to account for interspecies and intrahuman variability (U.S. EPA, 1995, 1999a). The chronic RfD was adopted to represent intermediate-term exposures.

For dermal exposure, a LOAEL of 3 mg/kg/day for dermal irritation and desquamation of the epidermis was identified from 21-day dermal rabbit study (Suetake, 1991); no neurological effects were observed at this concentration (U.S. EPA, 1995). An uncertainty factor of 300 was applied to account for interspecies and intrahuman variability and the use of a less serious LOAEL, resulting in a dermal benchmark of 0.01 mg/kg/day. This value is appropriate for all exposure durations.

### *Insecticide Background*

CAS# 122-14-5

<sup>18</sup> Conversion between mg/m<sup>3</sup> and mg/kg/day assumes, for female Wistar rats, an average body weight of 0.156 kg and inhalation rate of 0.17 m<sup>3</sup>/day (U.S. EPA, 1988).

<sup>19</sup> Adjustment for intermittent exposure is the product of air concentration and exposure of 6/24 hours/day and 5/7 days/week.

Synonyms:	O,O-dimethyl O-(4-nitro-m-tolyl) phosphorothioate (U.S. EPA, 1995) methylnitrophos (Eastern Europe) (EXTOXNET, 1995)
Chemical Group:	Organophosphate (EXTOXNET, 1995; U.S. EPA, 2000a)
Registered Trade Names:	Accothion, Agrothion, Bay 41831, Bayer 41831, Bayer S 5660, Cyfen, Cytel, Dicofen, Dybar, Fenitox, Fenstan, Folithion, Kaleit, Mep, Metathion, Micromite, Novathion, Nuvanol, Pestroy, Sumanone, Sumithion, and Verthion (U.S. EPA, 1995; EXTOXNET, 1995)

### *Usage*

Fenitrothion is a broad spectrum organophosphate insecticide and acaricide (IPCS, 2000) most commonly used in agriculture to control chewing and sucking insects on crops such as rice, cereals, fruits, vegetables, stored grains, and cotton. It is also used in forested areas and to control flies, mosquitoes, and cockroaches, and in public health programs (WHO, 2004). In the United States, fenitrothion is only registered for use as a containerized ant and roach bait. In Australia, it is used on stored wheat (U.S. EPA, 2000b).

### *Formulations and Concentrations*

There are several formulations for fenitrothion, each containing varying amounts of the active ingredient. The typical formulations for fenitrothion are dusts (2 percent, 2.5 percent, 3 percent, or 5 percent), emulsifiable concentrate (50 percent), flowable, fogging concentrate (95 percent), and wettable powder (40 or 50 percent). It is also available in granules and ultra-low-volume, oil-based liquid spray (EXTOXNET, 1995). Registered formulation types include 0.01563 percent and 1 percent pellets and granular baits. Emulsifiable concentrates are not registered in the United States (U.S. EPA, 2000b). The fenitrothion content for various formulations should be declared as follows: technical grade fenitrothion (no less than 910 g/kg), fenitrothion emulsifiable concentrate and wettable powder (above 250 up to 500 g/kg + 5% of declared content, above 500 g/kg + 25 g/kg) (WHO, 1999).

### *Shelf-Life*

Like many insecticides, fenitrothion should be stored in a locked, well-ventilated facility, preferably one designated only for insecticide storage. It should not be exposed to sunlight and should be stored away from animal feed and foodstuffs (IPCS, 1991).

Fenitrothion is stable for up to two years if stored between 20 and 25°C; storage temperatures should not exceed 40°C. Fenitrothion is unstable when heated above 100°C and may undergo Pischchemuka isomerization and decompose explosively. Decomposition of fenitrothion is promoted by iron. Therefore, fenitrothion should be stored in enamel, aluminum, or glass containers. Fenitrothion is not stable in alkaline environments (EXTOXNET, 1995). Residues of fenitrothion are stable for up to 147 days in wheat and 174 days in wheat gluten when frozen (-18°C) (U.S. EPA, 1995).

### *Degradation Products*

In water, fenitrothion is degraded through photolysis and hydrolysis, with degradation accelerated in the presence of microflora. In soil, fenitrothion is primarily broken down by biodegradation with photolysis also playing a role (WHO, 2003, 2004). Carbon monoxide is the major degradate for aerobic soil metabolism and photolysis. The major nonvolatile degradates for aerobic soil metabolism, anaerobic aquatic metabolism, and photolysis include 3-methyl-4-nitro-phenol (approximately 1 to 22 percent of applied); aminofenitrothion (approximately 13 percent of applied); acetyl-aminofenitrothion (approximately 13 percent of applied); formylaminofenitrothion (4.9 percent of applied); o,o-dimethyl o-(3-carboxy-4-nitrophenyl)phosphorothionate (12.4 percent of applied); fenitrooxon ( $\leq 4.3$  percent of applied); demethylate fenitrothion (approximately 1 percent of applied); and desmethylfenitrooxon ( $\leq 4.3$  percent of applied). Other degradates are present at concentrations less than or equal to 2 percent and include o,o-dimethyl o-(3-methyl-4-nitrophenyl)phosphorothioate-3-methyl-4-nitrophenol; o-methyl (5-methyl o-(3-methyl-4-nitrophenyl)phen-phorothioate; o-methyl o-hydrogen o-(3-methyl-4-nitro-phenyl)phosphate; o,o-dimethyl o-(3-carboxy-4-nitrophenyl)phosphate; 5-methylfenitrothion; and carboxyfenitrooxon. The major degradates in pH 5 and pH 9 solutions are demethylated fenitrothion (10.3 percent of applied) and 3-methyl-4-nitrophenol (1.7 percent of applied). In pH 9 solution, the major degradate is 3-methyl-4-nitrophenol (15.1 percent of the applied), while demethylated fenitrothion accounts for up to 5.6 percent of applied. The major degradate from hydrolysis in pH 5 and pH 7 buffered solutions is demethylated fenitrothion. The major degradate in pH 9 buffered solution is 3-methyl-4-nitrophenol. Seven degradates were identified from photodegradation in soil. In loam soil, the major nonvolatile degradates from aerobic soil metabolism was 3-methyl-4-nitrophenol. Additional degradates included fenitrooxon, desmethylfenitrooxon, and 3-methyl-4-nitroanisole. The major volatile degradate was carbon monoxide (U.S. EPA, 1995).

### *Environmental Behavior*

#### **Fate and Transport in Terrestrial Systems**

In most soil types, fenitrothion degrades rapidly with a half-life ranging from 3 to 25 days (U.S. EPA, 1995). Fenitrothion is mostly found in the top six inches of soil and is not very mobile and only slightly persistent in soil (U.S. EPA, 1995). In nonsterile muck and sandy loam soils, a half-life of less than one week is reported. Fenitrothion is intermediately mobile in soils ranging from sandy loam to clay (EXTOXNET, 1995). However, when applied to silty clay loam, silty clay, and sandy loam under laboratory conditions, fenitrothion appears to be immobile (U.S. EPA, 1995). Fenitrothion leaches very slowly into groundwater from most soils; however, some runoff can occur (WHO, 2004).

#### **Fate and Transport in Aquatic Systems**

On lakes, surface foam can trap fenitrothion from aerial spraying (EXTOXNET, 1995). In water, fenitrothion is unstable in the presence of sunlight or microbial contamination (WHO, 2003). Laboratory studies at 23°C and pH 7.5 in the dark resulted in a half-life of 21.6 days

for buffered lake water and 49.5 days for natural lake water. However, in field experiments, the half-life was 1.5-2 days at pH 7.0-7.5 and 19-23°C (EXTOXNET, 1995). Phenyl labeled [<sup>14</sup>C]-fenitrothion had a half-life of 4-7 days, while the anaerobic aquatic half-life is reported at 0.82 days. In fish, fenitrothion accumulates rapidly but at low concentrations (U.S. EPA, 1995).

### *Human Health Effects*

#### **Acute Exposure**

#### *Effects / Symptoms*

Acute oral and dermal experimental data are available for human exposures to fenitrothion. No effect on acetylcholinesterase activity was observed in volunteers following a single oral dose of up to 0.33 mg/kg body weight or repeated doses of up to 0.36 mg/kg body weight/day for 4 days. Volunteers ingested technical-grade fenitrothion via capsule at doses of 0.18 mg/kg/day followed 2 weeks to 5 months later by 0.36 mg/kg/day, with each daily dose continued for 4 consecutive treatments. No significant effect of treatment was seen on blood pressure or pulse, and observed clinical signs were not considered to be treatment related. Transient decreases in erythrocyte cholinesterase activity were observed in two volunteers, but no treatment-related changes in hematological or clinical chemistry parameters were observed. No dermal irritation and no effects on cholinesterase activity were observed in volunteers exposed to up to 0.5 mg/kg/day fenitrothion orally followed by 0.1 mg/kg/day dermally to the arms and face for 9 days (IPCS, 2000).

Case reports of humans accidentally or intentionally ingesting fenitrothion indicate that fenitrothion is lethal at oral doses of 3 g. Additionally, death from respiratory insufficiency was observed 6 days after a man ingested 60 mL of a 50 percent emulsion in a suicide attempt. Other acute oral effects included paralysis at 1.5 to 6 g. In patients exhibiting paralysis, plasma cholinesterase was inhibited by 40 percent to more than 80 percent. In patients who consumed 50 to 100 mL of a 50 percent fenitrothion solution either accidentally or in suicide attempts, 6 of 16 died within 5 to 22 days, despite receiving medical attention. Intermediate syndrome, characterized by muscular weakness affecting the neck, proximal limb, and respiratory muscles, was observed in 7 of 10 survivors. Of those with intermediate syndrome, plasma cholinesterase activity was not observed at time of hospitalization. Recovery ranged from 5 weeks to more than 10 weeks in patients with intermediate syndrome, versus 2 to 4 weeks in those without (IPCS, 2000).

No clinical signs were observed in spray operators or villagers one week after exposure to a 5 percent fenitrothion spray. However, a 40–60 percent decrease in cholinesterase activity was observed in spray operators using fenitrothion indoors for 4 weeks in the absence of clinical symptoms of organophosphate toxicity. Orchard spray operators who inhaled a mean concentration of 0.011 µg/L fenitrothion for 3 consecutive days also showed no clinical signs but had lower maximum plasma concentration of fenitrothion than unexposed operators, with relatively rapid clearance from plasma (IPCS, 2000).

In animals, the acute toxicity of fenitrothion is low. The oral LD<sub>50</sub> ranges from 240 to 1,700 mg/kg in rats, 715 to 1,400 mg/kg in mice, and 500 mg/kg in guinea pigs (EXTOXNET, 1995; IPCS, 2000). The acute dermal LD<sub>50</sub> is reported to be 890–5,000 mg/kg in rats and greater than 3,000 mg/kg in mice (EXTOXNET, 1995; IPCS 2000). The acute inhalation LC<sub>50</sub> ranges from 2.2 to 5.0 mg/L in rats (EXTOXNET, 1995; IPCS 2000). In cats, acute oral toxicity was 142 mg/kg (IPCS, 2000). Toxicity is dependent on sex and vehicle used; males are sensitive than females (IPCS, 2000). This is illustrated by the reported acute toxicity of the fenitrothion preparation Sumithion Technical (97.2 percent); the oral LD<sub>50</sub> is 330 mg/kg in males and 800 mg/kg in females, and the dermal LD<sub>50</sub> is 890 mg/kg in males and 1,200 mg/kg in females (U.S. EPA, 1995).

The signs of acute fenitrothion toxicity in animals are consistent with cholinesterase inhibition (IPCS, 2000). In hens, no evidence of delayed neurotoxicity or increased neurological lesions was seen following a single dose (WHO, 2004) or acute administration of Sumithion Technical (97.2 percent) (U.S. EPA, 1995). However, the fenitrothion product Sumithion 50EC has been shown to cause delayed neurotoxicity in adult rats as well as humans (EXTOXNET, 1995). In rats, cholinergic signs and erythrocyte and brain cholinesterase inhibition were seen at a number of doses, but cholinergic signs were seen only when brain cholinesterase was inhibited by more than 58 percent or erythrocyte acetyl cholinesterase was inhibited by more than 38 percent (WHO, 2004).

Technical grade fenitrothion (95 percent) does not cause dermal or ocular irritation in rabbits or dermal sensitization in guinea pigs (IPCS, 2000; U.S. EPA, 1995). However, mild dermal irritation was seen following exposure to Sumithion 8-E (77 percent ai) (U.S. EPA, 1995). Other acute effects in animals include those caused by O,O,S-trimethyl phosphorothioate, one of the contaminants of fenitrothion, including cytotoxic effects in rat lungs and modulated immune response in mice (EXTOXNET, 1995).

### ***Treatment***

Dermal exposure to fenitrothion should be treated by removing contaminated clothing, rinsing the skin with water, washing the exposed areas with soap and water, then seeking medical attention. If fenitrothion gets into the eyes, they should be rinsed with water for several minutes. Contact lenses should be removed if possible and medical attention should be sought. Ingestion of fenitrothion should be treated by rinsing the mouth and inducing vomiting if the person is conscious. Inhalation exposures require removal to fresh air and rest in a half-upright position. Artificial respiration should be administered if indicated and medical attention should be sought (PAN, 2005).

### ***Chronic Exposure***

#### **Noncancer Endpoints**

Limited data are available on the chronic toxicity of fenitrothion in humans. Chronic symptoms of toxicity in humans include general malaise, fatigue, headache, loss of memory and ability to concentrate, anorexia, nausea, thirst, loss of weight, cramps, muscular

weakness, and tremors. At sufficient exposure levels, typical symptoms of cholinergic poisoning may be seen (EXTOXNET, 1995). Mild clinical signs such as nausea and dizziness and whole-blood cholinesterase inhibition were observed in spray operators following occupational exposure to fenitrothion used during a 30-day malaria control operation. However, no treatment-related effects were seen in operators spraying fenitrothion for 5 hours/day, 5 days a week, intermittently for 2 years (IPCS, 2000).

The main toxicological finding from long-term animal studies was cholinesterase activity inhibition (red blood cell, plasma, and brain) in all species studied (IPCS, 2000; U.S. EPA, 1995; EXTOXNET, 1995). Signs of poisoning and cholinergic stimulation were also reported at higher levels.

In animals, reproductive and developmental toxicity are of concern. Developmental effects were seen at doses that were maternally toxic in rats. Reduced body weight, viability, and lactation indices were seen in offspring. In rats and rabbits, no fetal toxicity or treatment-induced malformations were seen at the highest dose tested in the presence of maternal cholinergic signs and decreased body weight gain (WHO, 2004). Others have reported an increase in fetal and skeletal variations at doses causing maternal toxicity (U.S. EPA, 1998). Behavioral effects were observed in rat pups following maternal exposure to Sumithion 50EC on gestation days 7 to 15 and included differences in simple behavioral measures and complex measures, which persisted up to 104 days after birth. No effects were seen at lower levels (EXTOXNET, 1995).

Fenitrothion is not teratogenic, mutagenic, or genotoxic in chronically exposed animals and is not expected to cause those effects in humans (EXTOXNET, 1995). Additionally, fenitrothion did not induce immunotoxicity (WHO, 2004).

### **Cancer Endpoints**

Data on the carcinogenic potential of fenitrothion indicate that it is unlikely to pose a carcinogenic risk to humans. EPA has classified fenitrothion as a Group E chemical, “evidence of noncarcinogenicity for humans” (U.S. EPA, 1995, 1999a). Evidence from animal studies suggests that fenitrothion is not carcinogenic in animals.

### *Toxicokinetics*

Fenitrothion is readily absorbed from the intestinal tract of most mammalian species, with about 90 to 100 percent of the dose absorbed (IPCS, 2000; EXTOXNET, 1995). In rats, oral absorption is approximately 90 to 100 percent within 72 hours, while in humans, it is about 70 percent in 96 hours (IPCS, 2000). Within 24 hours of dermal application, about 45 percent of the applied dose is absorbed (WHO, 2004; IPCS, 2000). In rats, a dermal absorption rate of slightly over 1 percent is suggested as fenitrothion disappeared rapidly during the first hour (EXTOXNET, 1995). Fenitrothion is widely distributed in the body. In rats, the highest concentrations after 48 hours are found in the liver, kidneys, and fat. It is rapidly activated and deactivated (IPCS, 2000). In the liver, fenitrothion is activated by oxidative desulfuration to the activated metabolite fenitrooxon (WHO, 2004; IPCS, 2000). It

is then rapidly degraded by demethylation and hydrolysis into the inactive metabolites 3-methyl-4-nitrophenol and dimethylphosphate. Further oxidation to 3-carboxyl-4-nitrophenol is involved in a minor metabolic pathway. In dermally exposed rats, the area of highest concentration (other than skin) of fenitrothion after 31 hours was the cartilaginous part of the bones (EXTOXNET, 1995). Within 24 hours of oral exposures, up to 93 percent of the dose is excreted via the urine, and 5 to 15 percent is excreted in the feces (WHO, 2004; IPCS, 2000; U.S. EPA, 1995). In rats, rabbits, and dogs, seventeen metabolites have been isolated in the urine, and the parent compound was not detected (U.S. EPA, 1995).

Toxicokinetic studies in humans have shown the time to maximal plasma concentration was 1 hour in volunteers who ingested two capsules 12 hours apart that contained 0.09 or 0.18 mg fenitrothion/kg body weight for 4 days. The elimination half-time ranged from 2 to 3 hours for both doses. The maximal plasma concentration following a single oral dose was 0.09 mg/kg body weight 1 day after exposure and 0.84 ng/mL 4 days after exposure. Higher doses resulted in higher maximal concentrations on days 1 and 4 after exposure (1.8 ng/mL and 7.7 ng/mL, respectively). In addition, the elimination half-time of fenitrothion was 2 to 4.5 hours (WHO, 2004; IPCS, 2000). Human studies also indicate that fenitrothion does not accumulate. In humans, doses of 2.5 and 5 mg/man/day administered for 5 days were all excreted within 12 hours without accumulation. Urinary excretion of the metabolite 3-methyl-4-nitrophenol was almost complete within 24 hours in subjects given single oral doses of approximately 0.042 to 0.33 mg/kg body weight fenitrothion. Peak excretion occurred after 12 hours and plasma cholinesterase inhibition was seen in only one subject at the highest dose (EXTOXNET, 1995).

### *Ecological Effects*

#### **Acute Exposure**

Fenitrothion has been shown to be moderately to highly toxic to birds (WHO, 2004; U.S. EPA, 1995) and highly toxic to honeybees (U.S. EPA, 1995). It is also toxic to spider mites and has a long residual action (EXTOXNET, 1995). The toxicity of fenitrothion in birds ranges from highly toxic in game birds to slightly toxic in waterfowl. The oral LC<sub>50</sub> in pheasants was reported as 450–500 ppm for 2-week-old pheasants fed fenitrothion in the diet for 5 days (EXTOXNET, 1995). In bobwhite quail, an LC<sub>50</sub> of 157 ppm and an LD<sub>50</sub> of 23.6 mg/kg have been reported (U.S. EPA, 1995; EXTOXNET, 1995). An LD<sub>50</sub> of 1,190 mg/kg is reported in mallard ducks (EXTOXNET, 1995). The oral LD<sub>50</sub> for chickens is reported as 28 mg/kg and fenitrothion was negative for delayed neurotoxicity in hens (EXTOXNET, 1995). In honeybees, the oral LD<sub>50</sub> is reported between 0.02 and 0.38 µg/bee. In mammals, the acute oral toxicity data indicate that fenitrothion is moderately toxic to small mammals. Fenitrothion was acutely toxic to rats at 330 to 355 mg/kg (U.S. EPA, 1995). Additionally, fenitrothion was acutely toxic to mule deer at 727 mg/kg (EXTOXNET, 1995).

Fenitrothion has been shown to be moderately toxic to both warm and coldwater fish (WHO, 2004; U.S. EPA, 1995). Acute 96-hour LC<sub>50</sub> values range from 1.7 ppm for brook trout to 3.8 ppm for bluegill sunfish, while the 48-hour LC<sub>50</sub> ranges from 2.0 to 4.1 mg/L in carp. In

various North American freshwater fish, the 96-hour LC<sub>50</sub> values range from 2 to 12 µg/L (EXTOXNET, 1995). Studies have shown that the toxicity of fenitrothion in rainbow trout was dependent on the developmental stage of the fish during exposure and the water temperature. Fingerlings and adult fish were the most sensitive, the sac fry stage was intermediate, and embryos were least sensitive to the toxic effects of fenitrothion. Additionally, the toxicity increased as water temperatures increased. In fish, sublethal effects of fenitrothion exposure include morphological and anatomical changes, behavioral changes, biochemical changes, respiratory effects, and effects on growth (EXTOXNET, 1995). Because fenitrothion breaks down rapidly, it does not accumulate in fish (WHO, 2004).

Fenitrothion is highly toxic in freshwater invertebrates. Acute exposure to 95 percent fenitrothion resulted in EC<sub>50</sub>/LC<sub>50</sub> values ranging from 4.3 ppb in *Gammarus* to 11 ppb in *Daphnia magna* (U.S. EPA, 1995). It is also moderately to very highly toxic to estuarine organisms. Acute exposure to 75 percent fenitrothion resulted in EC<sub>50</sub>/LC<sub>50</sub> values ranging from 1.5 ppb in pink shrimp to > 1,000 ppb in Sheepshead minnow (U.S. EPA, 1995).

#### *Chronic Exposure*

Chronic toxicity data for non-target terrestrial organisms are limited. Fenitrothion has been shown to cause reproductive impairment in birds. Chronic exposure to 17 ppm fenitrothion reduced egg production in bobwhite quail, with a NOEL of 13 ppm (U.S. EPA, 1995).

Limited data for chronic duration exposures of aquatic organisms were located. In fish, the chronic toxicity of fenitrothion is generally considered to be low (EXTOXNET, 1995). In freshwater fish, studies have reported effects in rainbow trout chronically exposed to 94.5 percent fenitrothion. A LOEL of 88 ppb was determined for weight and length effects, with a NOEL of 46 ppm. In freshwater aquatic invertebrates, chronic exposure to 94.5 percent fenitrothion resulted in a 21 day LOEL of 0.23 ppb for adult daphnid survival in *Daphnia magna* with a NOEL of 0.087 ppb (U.S. EPA, 1995).

## **Profile for Lambda-Cyhalothrin:**

CAS Registry Number 91465-08-6

#### ***Summary***

#### *Chemical History*

The synthetic pyrethroid lambda-cyhalothrin is a relatively new addition to this insecticide group. It was developed in 1977 and consists of one enantiomeric (i.e., nonsuperimposable, mirror image) pair of isomers and is a more biologically active form than cyhalothrin (IPCS, 1990a). It is used in the control of pests, including mosquitoes, in agricultural and public and animal health settings (EXTOXNET, 1996). The risks of occupational exposures and

exposures to the general public are expected to be very low if proper precautions are followed. At the recommended application rates, lambda-cyhalothrin is not expected to cause adverse environmental effects. As is typical of synthetic pyrethroids, the typical symptoms for acute exposure are neurological and include tingling, burning, or numbness sensations (particularly at the point of skin contact), tremors, incoordination of movements, paralysis or other disrupted motor functions. These effects are generally reversible because lambda-cyhalothrin breaks down rapidly in the body (IPCS, 1990a; EXTTOXNET, 1996). EPA has not classified synthetic pyrethroids, including lambda-cyhalothrin, as endocrine disruptors.

#### *Description of Data Quality and Quantity*

Lambda-cyhalothrin and cyhalothrin are basically the same chemical and differ only in their stereo chemistry and the number of isomers in each mixture (U.S. EPA, 2002a). Cyhalothrin consists of four stereo isomers while lambda-cyhalothrin is a mixture of only two isomers. The two lambda-cyhalothrin isomers are contained in cyhalothrin and they represent 40 percent of the cyhalothrin mixture. The majority of toxicity studies available were conducted using cyhalothrin as the test chemical. Evidence based on subchronic studies in rats suggests that the two mixtures are not biologically different with respect to their mammalian toxicity (U.S. EPA, 2002a).

EPA and ATSDR have developed quantitative human health benchmarks for cyhalothrin (EPA's acute and chronic oral RfDs and short-, intermediate-, and long-term dermal and inhalation benchmarks, and ATSDR's acute and intermediate oral MRLs).

#### Recommended resources include:

- Environmental Health Criteria 99: Cyhalothrin (IPCS, 1990a)
- Toxicological Profile for Pyrethrin and Pyrethroids (ATSDR, 2003a)
- Pesticide Information Profiles (PIP) for Lambda-cyhalothrin (EXTTOXNET, 1996)
- Specifications and Evaluations for Public Health Pesticides for Lambda-cyhalothrin (WHO, 2003)
- Integrated Risk Information System (IRIS) summary review for cyhalothrin (U.S. EPA, 2005b).

## Summary Table

Duration	Route	Benchmark Value	Units	Endpoint	Reference	
Acute, Intermediate, Chronic	Inhalation	0.0008	mg/kg/day	Inhalation NOAEL for neurotoxicity in rats at 0.08 mg/kg/day (0.3 µg/L) with uncertainty factor (UF) of 100 applied	U.S. (2002b)	EPA
Acute	Oral	0.005	mg/kg/day	Acute RfD based on neurotoxicity in dogs	U.S. (2002b)	EPA
Intermediate	Oral	0.001	mg/kg/day	Adopt chronic RfD for intermediate duration		
Chronic	Oral	0.001	mg/kg/day	Chronic RfD based on neurological effects in dogs	U.S. (2002b)	EPA
Acute, Intermediate, Chronic	Dermal	0.1	mg/kg/day	Dermal NOAEL in rats with UF of 100 applied	U.S. (2002b)	EPA

For inhalation exposure, a NOAEL of 0.3 µg/L (0.08 mg/kg/day) was identified for neurotoxicity, decreased body weight, and slight changes in urinalysis parameters in rats exposed to lambda-cyhalothrin via inhalation for 21 days. An uncertainty factor of 100 was applied, for an inhalation benchmark value of 0.0008 mg/kg/day. This value is appropriate for all exposure durations (U.S. EPA, 2002a).

For oral exposure, an acute RfD of 0.005 mg/kg/day was derived based on a NOAEL of 0.5 mg/kg/day for neurotoxicity (ataxia) observed in dogs exposed to lambda-cyhalothrin, with an uncertainty factor of 100 applied (U.S. EPA, 2002a). A chronic oral RfD of 0.001 mg/kg/day was derived based on a NOAEL of 0.1 mg/kg/day for gait abnormalities in dogs exposed to lambda-cyhalothrin, with an uncertainty factor of 100 applied (U.S. EPA, 2002a). The chronic RfD was adopted to represent intermediate exposures.

For dermal exposure, a NOAEL of 10 mg/kg/day was identified in rats dermally exposed to lambda-cyhalothrin for 21 days. An uncertainty factor of 100 was applied, for a dermal benchmark value of 0.1 mg/kg/day. This value is appropriate for all exposure durations (U.S. EPA, 2002a).

### Background

CAS #:	91465-08-6
Synonyms:	none (WHO, 2003)
Chemical Group:	synthetic pyrethroid
Registered Trade Names:	Charge, Excaliber, Grenade, Karate, Hallmark, Icon, OMS 0321, PP321, Saber, Samurai, Sentinel, and Matador (EXTOXNET, 1996)

### *Usage*

Lambda-cyhalothrin is a synthetic pyrethroid (IPCS, 1990a) most commonly used for pest control, especially mosquitoes; the insecticide is usually sprayed on interior walls or used to impregnate bed nets (EXTOXNET, 1996). This insecticide is a restricted use pesticide, so it can be purchased and used only by certified applicators (EXTOXNET, 1996). Lambda-cyhalothrin has adulticidal, ovicidal, and larvicidal activity (IPCS, 1990a). In addition to mosquitoes, it is effectively used to control: cockroaches, ticks, fleas, aphids, Colorado beetles, cutworms and butterfly larvae (EXTOXNET, 1996; IPCS, 1990a).

### *Formulations and Concentrations*

There are several formulations for lambda-cyhalothrin, each containing varying amounts of the active ingredient. The typical formulations for lambda-cyhalothrin are

- Technical grade (not less than 810 g/kg lambda-cyhalothrin)
- Emulsifiable concentrate (at 20 +/- 2°C: up to 25 g/l +/- 15% declared content; > 25 g/l to 100 g/l +/- 10% of declared content)
- Wettable powder (up to 25 +/- 15% of declared content: > 25-100 +/- 10 % of declared content)
- Slow release capsule suspension (at 20 +/- 2°C: up to 25 g/l +/- 15% declared content).

The main formulation used for agricultural purposes is the emulsifiable concentrate. The wettable powder formulation is mainly used for public health reasons (WHO, 2003). Lambda-cyhalothrin is commonly mixed with buprofezin, pirimicarb, dimethoate, or tetramethrin, resulting in the usual product (WHO, 2003; EXTOXNET, 1996).

### *Shelf-Life*

This insecticide, like many others, needs to be stored in a cool, dry, and well-ventilated facility (IPCS, 1990a). Lambda-cyhalothrin should not be stored or transported with foodstuffs and household supplies to the limit the potential for cross contamination and human exposure (IPCS, 1990a).

### *Degradation Products*

In the environment, lambda-cyhalothrin degrades through biological and photochemical reactions (IPCS, 1990a). Biological reactions are thought to be more important. Lambda-cyhalothrin will degrade rapidly in soils, remain relatively stable in water, and is usually not found in air due to its low vapor pressure. The main degradation products are 3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2, 2-dimethyl-cyclopropanecarboxylic acid, the amide derivative of cyhalothrin, and 3-phenoxybenzoic acid. The degradation is a result of the cleavage of the ester linkage to give two main degradation products, which are further degraded to carbon dioxide. Lambda-cyhalothrin degrades fairly quickly in alkaline conditions, in comparison to neutral or acidic media. It is strongly absorbed in soils and sediments with little tendency for bioaccumulation (IPCS, 1990a).

In water, lambda-cyhalothrin is stable at pH 5. Racemization at the alpha-cyano carbon occurs at pH 7 to pH 9, creating a one to one mixture of enantiomer pairs A and B. The ester bond is hydrolyzed at pH 9. Additionally, a moderately high rate of photolysis is seen in dilute aqueous solutions (IPCS, 1990a).

#### *Environmental Behavior*

##### **Fate and Transport in Terrestrial Systems**

In most soil types, lambda-cyhalothrin is not very mobile. Its high reported organic carbon partitioning coefficient (K<sub>oc</sub>) value reflects its strong affinity for soil. It is retained more in soil with low sand content or high organic matter content (EXTOXNET, 1996). Studies have shown that lambda-cyhalothrin and its degradation products do not leach through soils into groundwater nor are they transported to other compartments of the environment following agricultural uses (IPCS, 1990a).

Lambda-cyhalothrin is moderately persistent in soil with a soil half-life ranging from 4 to 12 weeks. A longer in-field half-life of approximately 30 days is reported for most soils (EXTOXNET, 1996). The half-life is variable because it is dependent on the availability of sunlight, which speeds degradation (IPCS, 1990a).

##### **Fate and Transport in Aquatic Systems**

Lambda-cyhalothrin is not expected to be prevalent in surface or groundwater because it has extremely low water solubility and binds tightly to soil. Lambda-cyhalothrin enters surface water largely through surface runoff. Even so, lambda-cyhalothrin is most likely to stay bound to sediment and settle to the bottom. Studies have shown that hydrolysis of lambda-cyhalothrin occurs rapidly at a pH of 9 but not at a pH of 7, though isomerization was observed at a pH of 7. No hydrolysis or isomerization was seen at a pH of 5.

#### *Human Health Effects*

##### **Acute Exposure**

##### ***Effects/Symptoms***

No data on accidental human poisonings have been reported. Additionally, no quantitative epidemiological studies are available (IPCS, 1990a). However, under normal use conditions, acute exposure to lambda-cyhalothrin is not expected to represent a hazard in humans. Transient skin sensations such as periorbital facial tingling and burning have been reported following direct skin exposure in laboratory workers and manufacturing workers handling synthetic pyrethroids. This sensation is possibly due to repetitive firing of sensory nerve terminals and usually lasts for a few hours up to 72 hours post-exposure. No neurological abnormalities have been observed upon medical examination (IPCS, 1990a). Lambda-cyhalothrin can irritate the eyes, skin, and upper respiratory tract. Additionally, oral exposure can cause neurological effects, including tremors and convulsions. Ingestion of liquid formulations may result in aspiration of the solvent into the lungs, resulting in

chemical pneumonitis. Based on the acute oral toxicity data, lambda-cyhalothrin has been classified as “Moderately Hazardous” (Class II) (WHO, 2003).

In animals, the technical form of lambda-cyhalothrin is moderately toxic; however, toxicity depends on both the formulation (concentration of active ingredient and solvent vehicle) and the route of exposure (EXTOXNET, 1996). Laboratory data indicate that acute oral exposure to lambda-cyhalothrin is moderately to highly toxic in rats and mice and that mice are more susceptible to the toxic effects than rats (WHO, 2003). The oral LD<sub>50</sub> for lambda-cyhalothrin in corn oil has been reported to range from 56 mg/kg in female rats up to 79 mg/kg in males. A similar LD<sub>50</sub> is reported for technical grade lambda-cyhalothrin in rats at 64 mg/kg (EXTOXNET, 1996). The oral LD<sub>50</sub> in mice is reported as 20 mg/kg (IPCS, 1990a). The effects of acute oral exposure are typical of pyrethroid toxicity, including abnormal motor function (WHO, 2003).

Acute inhalation exposures are also highly toxic to animals (WHO, 2003). In the formulated product Karate, the 4-hour LC<sub>50</sub> in rats is reported as 0.175 mg/L in females and 0.315 mg/L in males (EXTOXNET, 1996).

Lambda-cyhalothrin is less toxic in animals via acute dermal exposure (WHO, 2003). In rats, dermal LD<sub>50</sub>s of 632 mg/kg for males and 696 mg/kg for females have been reported for the technical product. Studies have also shown the technical product produced no skin irritation to rabbits and is nonsensitizing in guinea pigs. Mild eye irritation was observed in rabbits. However, dermal exposure to the formulated product Karate causes severe primary skin irritation in rabbits and mild skin sensitization in guinea pigs. Other acute dermal effects are related to the nervous system and include tingling, burning sensations, or numbness (EXTOXNET, 1996).

### ***Treatment***

Lambda-cyhalothrin and its breakdown products can be detected in blood and urine, but only within a few days of the last exposure (ATSDR, 2003a). Dermal exposure to lambda-cyhalothrin exposure should be treated by removing contaminated clothing and washing the exposed areas with soap and water. If lambda-cyhalothrin gets into the eyes, they should be rinsed with water for several minutes. Contact lenses should be removed if possible and medical attention should be sought. Vomiting should not be induced following ingestion of lambda-cyhalothrin, and medical attention sought. Inhalation exposures require removal to fresh air and rest (IPCS, 1990b)

### ***Chronic Exposure***

#### **Noncancer Endpoints**

Based on the available data, it is unlikely that lambda-cyhalothrin would cause chronic effects in humans under normal conditions. No specific target organs have been identified in the available chronic studies (EXTOXNET, 1996). Decreased body weight gain and mild neurological effects have been observed in some animal studies (EXTOXNET, 1996; IPCS, 1990a).

Lambda-cyhalothrin is not expected to be teratogenic, mutagenic, or genotoxic in humans. Studies in animals have found no teratogenic or fetotoxic effects in rats or rabbits. Additionally, it was negative in five test strains in the Ames mutagenicity assay (IPCS, 1990a). No mutagenic or genotoxic effects were seen in other in vitro cytogenic assays or chromosomal aberration tests (EXTOXNET, 1996).

### **Cancer Endpoints**

Data on the carcinogenic potential suggest that lambda-cyhalothrin is not carcinogenic in humans. In rats and mice exposed to cyhalothrin, no carcinogenic effects were observed. EPA has classified lambda-cyhalothrin as a Group D chemical, “not classifiable as to human carcinogenicity” (U.S. EPA, 2002a).

### *Toxicokinetics*

Animal studies have been conducted in various species to investigate the toxicokinetics of cyhalothrin and lambda-cyhalothrin. Oral cyhalothrin is readily absorbed, metabolized thoroughly, and eliminated as polar conjugates in the urine (IPCS, 1990a). Studies with lambda-cyhalothrin have shown that it also is rapidly metabolized into less toxic water-soluble compounds and excreted in the urine and feces (EXTOXNET, 1996). In mammals, cyhalothrin is metabolized as a result of ester cleavage to cyclopropanecarboxylic acid and 3-phenoxybenzoic acid, and eliminated as conjugates. Tissue levels decline after exposure stops and residues in the body are low (IPCS, 1990a).

### *Ecological Effects*

#### **Acute Exposure**

#### ***Toxicity to Non-Target Terrestrial Organisms***

Like other synthetic pyrethroids, lambda-cyhalothrin has been shown to be toxic to honey bees but has little effect on birds and domestic animals (EXTOXNET, 1996). In birds, the toxicity of lambda-cyhalothrin ranges from nontoxic to slightly toxic. Oral LD<sub>50</sub> values in mallard duck are reported as greater than 3,950 mg/kg. Dietary LC<sub>50</sub> values of 5,300 ppm are reported in bobwhite quail. Additionally, there is no evidence of lambda-cyhalothrin accumulation in bird tissues or in eggs (EXTOXNET, 1996). Lambda-cyhalothrin has shown mixed toxicity to other non-target terrestrial organisms. It is extremely toxic to honey bees, with a contact LD<sub>50</sub> of 0.9 µg/bee and an oral LD<sub>50</sub> of 38 ng/bee (EXTOXNET, 1996), but has no adverse effect on earthworms (IPCS, 1990a).

#### ***Toxicity to Aquatic Organisms***

Like other synthetic pyrethroids, lambda-cyhalothrin has been shown to be quite toxic under laboratory conditions to both cold and warm water fish. Acute 96-hr LC<sub>50</sub> values range from 0.2 to 1.3 µg/L. It is also highly toxic to aquatic arthropods with 48-hr LC<sub>50</sub> ranging from 0.008 to 0.4 µg/L (IPCS, 1990a; WHO, 2003). In the field, however, these effects are not likely to occur under the recommended use scenarios (WHO, 2003). No serious adverse effects have been observed due to the low rates of application and the lack of persistence in

the environments (IPCS, 1990a). Accumulation studies have shown that although bioaccumulation is possible in fish, it is unlikely due to the rapid metabolism of lambda-cyhalothrin (EXTOXNET, 1996).

### **Chronic Exposure**

#### ***Toxicity to Non-Target Terrestrial Organisms***

No data were located on the chronic toxicity to non-target terrestrial organisms.

#### ***Toxicity to Aquatic Organisms***

No data for chronic duration exposures of aquatic organisms were located; however, a subchronic study in Sheepshead minnow embryos and larvae showed no effect on hatchability or larval survival when exposed to up to 0.25 µg/L through 28 days post hatching. A significant effect on larval weight was observed at 0.38 µg/L. In an additional subchronic exposure study, survival, growth, and reproduction of *Daphnia magna* were seen at 40 ng/L but not at 2.5 ng/L (IPCS, 1990a).

## **Profile for Malathion:**

CAS Registry Number 121-75-5

### ***Summary***

#### ***Chemical History***

Malathion is an organophosphate pesticide used in a wide variety of applications, including agricultural, veterinary, and public health uses. In pest eradication programs, malathion is used to eradicate mosquitoes, Mediterranean fruit flies, and boll weevil (ATSDR, 2003b). The primary target of malathion is the nervous system; it causes neurological effects by inhibiting cholinesterase in the blood and brain. Exposure to high levels can result in difficulty breathing, vomiting, blurred vision, increased salivation and perspiration, headaches, and dizziness (U.S. EPA, 2005c). Loss of consciousness and death may follow very high exposures to malathion (ATSDR, 2003b).

#### ***Description of Data Quality and Quantity***

Several comprehensive reviews on the toxicity of malathion have been prepared or updated in recent years:

- EPA risk assessment for the Reregistration Eligibility Decision (RED) document (U.S. EPA, 2005c)
- IRIS summary review (U.S. EPA, 2005d)
- *Toxicological Profile for Malathion* (ATSDR, 2003b)

- *Specifications and Evaluations for Public Health Pesticides for Malathion* (WHO, 2003).

EPA and ATSDR have developed quantitative human health benchmarks (EPA's acute and chronic oral RfDs, short-, intermediate-, and long-term dermal and inhalation benchmarks and ATSDR's acute inhalation and intermediate oral and inhalation MRLs).

## Summary Table

Duration	Route	Benchmark Value	Units	Endpoint	Reference
Acute, Intermediate, Chronic	Inhalation	0.026	mg/kg/day	Inhalation LOAEL for respiratory effects in rats of 25.8 mg/kg/day (0.1 mg/L) with UF of 100 and SF of 10 applied	U.S. EPA (2005c)
Acute	Oral	0.14	mg/kg/day	Acute RfD based on neurological effects in rats	U.S. EPA (2005c)
Intermediate	Oral	0.03	mg/kg/day	Adopt chronic oral RfD for intermediate duration	
Chronic	Oral	0.03	mg/kg/day	Oral RfD based on neurological effects in rats	U.S. EPA (2005c)
Acute, Intermediate, Chronic	Dermal	0.05 (child) 0.5 (adult)	mg/kg/day	Dermal NOAEL for neurological effects in rabbits with UF of 100 applied (for children, an additional SF of 10 was also applied)	U.S. EPA, 2005c

For inhalation exposure, a LOAEL of 0.1 mg/L (25.8 mg/kg/day, assuming absorption via inhalation route is equivalent to oral absorption) for histopathological lesions in the nasal cavity and larynx of rats was identified for malathion. Uncertainty factors of 10 each were applied to account for interspecies and intrahuman variability and a safety factor of 10 to account for the extrapolation from LOAEL to NOAEL and the severity of effect (U.S. EPA, 2005c). This value is appropriate for short- (1–30 days) and intermediate-term (1–6 months) inhalation exposures; this value was also adopted for chronic (long-term, >6 months) exposures.

For oral exposure, an acute oral RfD of 0.14 mg/kg/day was derived based on the inhibition of red blood cell (RBC) cholinesterase in rats and uncertainty factors of 10 each to account for interspecies and intrahuman variability (U.S. EPA, 2005d). A chronic oral RfD of 0.03 mg/kg/day was derived based on the RBC cholinesterase inhibition in rats and uncertainty factors of 10 each to account for interspecies and intrahuman variability (U.S. EPA, 2005c).

For dermal exposures, a NOAEL of 50 mg/kg/day for plasma, RBC, and brain cholinesterase inhibition in rabbits exposed dermally was identified for malathion. Uncertainty factors of 10 each to account for interspecies and intrahuman variability were applied; a safety factor of 10 to account for susceptibility of young was applied to be protective of children (U.S. EPA, 2005d). This value is appropriate for short- (1–30 days), intermediate- (1–6 months), and long-term (>6 months) dermal exposures.

### Background

CASRN: 121-75-7

Synonyms:	1, 2-Di (ethoxycarbonyl) ethyl, <i>O</i> , <i>O</i> -dimethyl, phosphorodithioate (ATSDR, 2003b), maldison, malathon, mercaptothion, mercaptotion, carbofos (WHO, 2003)
Chemical Group:	organophosphate
Registered Trade Names:	Cekumal, Fyfanon®, Malixol®, Maltox® (ATSDR, 2003b); Celthion, Cythion, Dielathion, El 4049, Emmaton, Exathios, Fyfanon and Hilthion, and Karbofos (EXTOXNET, 1996)

### *Usage*

Malathion is a nonsystemic, broad-spectrum organophosphate insecticide used to control sucking and chewing pests in agricultural and horticultural applications (WHO, 2003). It is also used to control household insects, fleas, ectoparasites in animals, and head and body lice in humans (EXTOXNET, 1996). A major public health use of malathion is to eradicate mosquitoes and Mediterranean fruit flies, with ground application and aerial spraying being the most common methods of application (ATSDR, 2003b).

### *Formulations and Concentrations*

There are several typical formulations for malathion, each formulation varying in the amount of active ingredient (ai) it contains. The typical formulations for malathion are (U.S. EPA, 2005c; ATSDR, 2003b)

- Technical grade (91–95 percent ai)
- Dust (1–10 percent ai)
- Emulsifiable concentrate (3–82 percent ai)
- Ready-to-use liquid (1.5–95 percent ai)
- Pressurized liquid (0.5–3 percent ai)
- Wettable powder (6–50 percent ai).

Malathion may also be used to formulate other pesticides (ATSDR, 2003b).

### *Degradation Products*

In the United States, technical grade malathion is >90 percent pure and contains less than 5 percent impurities (reaction byproducts and degradation products). As many as 14 different impurities have been identified in technical grade malathion (ATSDR, 2003b), some of which are toxic themselves and potentiate the toxicity of malathion. Because of their toxicological properties, relevant impurities include malaaxon (CASRN 1634-78-2), isomalathion (CASRN 3344-12-5), MeOOSPS-triester (CASRN 2953-29-9), MeOOOPS-triester (CASRN 152-18-1), MeOSSPO-triester (CASRN 22608-53-3), and MeOOSPO-triester (CASRN 152-20-5). Both isomalathion and malaaxon are more toxic than malathion, and isomalathion is a potentiator of malathion (WHO, 2003). Degradation products of malathion include dimethyl phosphate, dimethyldithiophosphate, dimethylthiophosphate,

isomalathion (a metabolite of malathion), malaaxon, and malathion dicarboxylic acid and are generally the result of impurities or exposure to extreme storage conditions (PAN, 2005).

In dustable powder form, malathion levels decrease when it is stored and it is converted into the more toxic metabolite isomalathion (WHO/FAO, nd). In the environment, malathion is usually broken down into other chemical compounds within a few weeks by water, sunlight and bacteria found in the soil and water (ATSDR, 2003b). At pH 5.0, malathion is reasonably stable to hydrolysis. It hydrolyzes rapidly at pH 7.0 and above or below pH 5.0 (WHO, 2003; ATSDR, 2003b). It is stable in an aqueous solution that is buffered at a pH of 5.26 (WHO/FAO, nd). In air, malathion is broken down by reacting with sunlight as well as other chemicals found naturally in the air (ATSDR, 2003b). Malathion is generally stable to photolysis (WHO, 2003).

#### *Shelf Life*

Malathion levels decline over time during storage. The extent of the decline depends on the type of formulation, as does the increase in isomalathion levels. Technical grade malathion stored at 20°C for 25–30 months lost 3–8 g/kg, while isomalathion levels increased 2.2–2.4 mg/kg. Levels of other impurities did not increase significantly. Malathion stored for 14 days at 54°C declined 2.6 percent as an emulsifiable concentrate, 2.8 percent as an emulsion (oil in water), and 5 percent as a dustable powder, while isomalathion levels increased 0.11 percent, 0.095 percent, and 1.35 percent, respectively (WHO, 2003).

#### *Environmental Behavior*

##### **Fate and Transport in Terrestrial Systems**

Malathion is released directly into the air during aerial application to target areas such as crops or residential areas. It may also be released via volatilization from crop and ground surfaces. Aerial applications may also release malathion into the soil by way of spray droplets that reach the surface of the soil. This may include spraying and fogging applications. Malathion may also be released into the soil as a consequence of wet deposition applications or when improperly disposed of (ATSDR, 2003b).

In air, malathion may be transported from the site of application to other areas by wind and precipitation. In soils, malathion is moderately to highly mobile, indicating a potential to readily move from soil into groundwater. However, because malathion degrades rapidly in the environment, movement from soil to groundwater is not a significant concern (ATSDR, 2003b).

Malathion degrades through atmospheric photo-oxidation, hydrolysis, and biodegradation. (ATSDR, 2003b). In the atmosphere, malathion breaks down rapidly in sunlight, with a half-life of 1.5 days. In soil, malathion is of low persistence with an average half-life of 6 days. It degrades rapidly depending on the degree of soil binding, which is generally moderate (EXTOXNET, 1996). Malathion degrades more quickly in moist soil (ATSDR, 2003b). The persistence of malathion in vegetation depends largely on the lipid content of the plant. The degradation process is increased with moisture content (EXTOXNET, 1996).

## **Fate and Transport in Aquatic Systems**

Malathion may be released into surface waters through direct applications, spills, runoff from sprayed areas, wet deposition from rain, manufacturing or processing facilities, and wastewater releases (ATSDR, 2003b). The water solubility of malathion is 148 mg/l at 25°C. At pH 5, it is reasonably stable to hydrolysis; however, as pH increases, malathion hydrolyzes more readily (WHO, 2003). Because it is highly soluble and binds moderately to soil, malathion may also pose a risk to groundwater or surface waters (EXTOXNET, 1996).

In water, malathion degrades relatively quickly due to the action of the water as well as bacteria in the water (ATSDR, 2003b). In water, malathion breaks down into mono- and dicarboxylic acids. However, degradation also depends on the temperature and pH of the water. In river water, malathion breaks down in 1 week, while it is stable in distilled water for 3 weeks. Degradation increases with water temperature, alkalinity, and salinity of the water. Because of its short half-life in water, malathion is not expected to bioaccumulate in aquatic organisms (EXTOXNET, 1996).

### *Human Health Effects*

#### **Acute Exposure**

##### *Effects/Symptoms*

Similar to other organophosphates, malathion is a cholinesterase inhibitor and interferes with the normal functioning of the nervous system. Malathion exhibits low acute toxicity via ingestion, dermal, and inhalation exposures (ATSDR, 2003b). Human volunteers fed very low doses of malathion for 6 weeks showed no significant effects on blood cholinesterase activity (ATSDR, 2003b). However, acute exposure to high concentrations can cause numbness, headaches, sweating, abdominal cramps, blurred vision, difficulty breathing, respiratory distress, loss of consciousness, and occasionally death. Acute exposure data for humans are limited and come from case reports of accidental poisonings (ATSDR, 2003b).

Several factors affect the toxicity of malathion, including the product purity, route of exposure, gender, and the amount of protein in the diet. Animal studies have shown that malathion is only slightly toxic following acute oral and dermal exposures, with reported LD<sub>50</sub> values in rats of 1,000–10,000 mg/kg and 400–4,000 mg/kg, respectively. Additionally, as protein levels in the diet decrease, malathion toxicity increases. Females have been shown to be more susceptible to malathion toxicity than males due to differences in metabolism, storage, and excretion (EXTOXNET, 1996). It is uncertain whether children are more susceptible to the toxic effects of malathion; however, animal studies have shown that very young animals are more susceptible to the effects of malathion than older ones when exposed to high levels (ATSDR, 2003b). Weanling male rats acutely exposed to malathion were twice as susceptible to malathion as adults (EXTOXNET, 1996).

## ***Treatment***

Exposure to malathion may be determined through laboratory tests of urine and blood that measure breakdown products of malathion in urine or cholinesterase levels in blood (ATSDR, 2003b).

Long-term deleterious effects may be avoided if people exposed to high amounts of malathion are given the appropriate treatment quickly after exposure (ATSDR, 2003b). Oral exposure to malathion should be treated with rapid gastric lavage unless the patient is vomiting. Dermal exposures should be treated by washing the affected area with soap and water. If the eyes have been exposed to malathion, flush them with saline or water. People exposed to malathion who exhibit respiratory inefficiency with peripheral symptoms should be treated via slow intravenous injection with 2–4 mg atropine sulfate and 1,000–2,000 mg pralidoxime chloride or 250 mg toxogonin (adult dose). Exposure to high levels of malathion that result in respiratory distress, convulsions, and unconsciousness should be treated with atropine and a reactivator. Morphine, barbiturates, phenothiazine, tranquilizers, and central stimulants are all contraindicated (WHO/FAO, nd).

## ***Chronic Exposure***

### **Noncancer Endpoints**

Most chronic human data come from studies of workers who are exposed to malathion via inhalation or dermally. Chronic exposure data in both humans and animals indicate that the main target of malathion toxicity is the nervous system (ATSDR, 2003b). A two-year rat study showed no adverse effects other than cholinesterase enzyme depression (EXTOXNET, 1996). Chronic animal studies have shown no reproductive or developmental toxicity at doses of malathion that are not maternally toxic. Malathion has been shown to be a contact sensitizer. Recent animal studies indicate that malathion can affect immunological parameters at doses that are lower than those that cause neurotoxicity (ATSDR, 2003b).

### **Cancer Endpoints**

EPA has classified malathion as “suggestive evidence of carcinogenicity” (U.S. EPA, 2005c). While some studies indicate an increased incidence of some forms of cancer in people who are regularly exposed to malathion, such as those exposed occupationally, there is no conclusive evidence that malathion causes cancer in humans. In one study, rodents fed very high doses of malathion in their diet had increased incidences of liver tumors (ATSDR, 2003b; U.S. EPA, 2005c).

## ***Toxicokinetics***

Malathion is absorbed via inhalation, the gastrointestinal tract, and dermally (WHO/FAO, 1997). Dermal absorption is dependent on the site and dose applied (ATSDR, 2003b). Malathion is broken down in the liver into metabolites. One of its metabolites is malaaxon, from which malathion exhibits its toxic effects via cholinesterase inhibition (ATSDR, 2003b; U.S. EPA, 2005c; WHO/FAO, 1997). Neither malathion nor its metabolites tend to

accumulate in the body and are mostly excreted within a few days (ATSDR, 2003b). Malathion is excreted mostly in the urine with a small amount being excreted in the feces. A very small amount may also be excreted in breastmilk. Metabolites excreted include the monoacid and diacid of malathion, demethyl malathion, dimethyl phosphate, and O,O-dimethylphosphorothioate. In feces, the majority of material excreted is malathion with a smaller amount being malaoxon (WHO/FAO, 1997)

### *Ecological Effects*

#### **Acute Exposure**

Malathion is not expected to pose a hazard to birds and mammals from acute dietary exposure. Malathion exhibits low to moderate toxicity to birds (U.S. EPA, 2005e). Acute oral LD<sub>50</sub> values in various bird species include blackbirds and starlings (over 100 mg/kg), pheasants (167 mg/kg), chickens (525 mg/kg), and mallards (1,485 mg/kg). Malathion is rapidly metabolized by birds, with 90 percent being excreted in the urine within 24 hours. The toxicity of malathion to reptiles has not been evaluated, but the avian toxicity thresholds have been used to estimate the hazard. Acute effects were reported in one study of the Carolina anole and another on developing snapping turtle embryos (U.S. EPA, 2005e). Malathion is extremely toxic to beneficial insects, including honeybees (U.S. EPA, 2005e; EXTTOXNET, 1996).

Malathion also has a wide range of toxicity to species in the aquatic environment, from being quite toxic to walleye with a 96 hr LC<sub>50</sub> of 0.06 mg/L to being slightly toxic in goldfish with a 96 hr LC<sub>50</sub> of 10.7 mg/L (EXTTOXNET, 1996). In invertebrates and amphibians in their aquatic stages, malathion is also found to be highly toxic. In aquatic invertebrates, EC<sub>50</sub> values range from 1 µg/L to 1 mg/L. However, since malathion has a very short half-life, there is little potential for bioconcentration in aquatic organisms (EXTTOXNET, 1996). Malathion is also highly toxic to the larvae of terrestrial, non-target insects that have aquatic early life stages (U.S. EPA, 2005e).

#### **Chronic Exposure**

Although not persistent in the environment, birds may be chronically exposed because current labels do not restrict consecutive applications, intervals, or avoidance of nesting birds. Sublethal effects to birds may include reduced nesting behavior, disorientation, and loss of motor coordination. Studies have shown that chronic malathion exposure in the diet of terrestrial avian species causes moderate toxicity. Bobwhite quail exposed to 350 ppm for 10 weeks exhibited regressed ovaries, enlarged or flaccid gizzards, and a reduction in number of eggs that hatched. At higher exposures, a reduction in the number of eggs produced, viability of embryo, and an increase in cracked eggs was observed, while studies in waterfowl showed low toxicity (U.S. EPA, 2005e).

# Profile for Pirimiphos-Methyl:

CAS Registry Number 29232-93-7

## *Summary of Insecticide*

### *Chemical History*

Pirimiphos-methyl is a fast-acting, broad spectrum, noncumulating organophosphate insecticide and acaricide used in agricultural, horticultural, and public health applications (WHO/FAO, 1983, 1974). In public health applications, it is used to control disease vector insects, including mosquitoes, ants, beetles, bed-bugs, cockroaches, fleas, flies, lice, and mites (WHO/FAO, 1983, 1974). Pirimiphos-methyl has both contact and fumigant action (WHO/FAO, 1974). It is applied as a liquid concentrate, ready to use formula, and as treated articles (ear tags) (U.S. EPA, 1999b). It can be applied by closed system containers, low- and high-pressure hand wands, backpack sprayers, tagging equipment, and foggers (U.S. EPA, 2001). Pirimiphos-methyl acts like other organophosphates by inhibiting cholinesterase activity (U.S. EPA, 1999d). It is of low mammalian toxicity (WHO/FAO, 1983). WHO/FAO (1992) has classified it as slightly hazardous. Early symptoms of pirimiphos-methyl exposure include excessive sweating, headache, weakness, giddiness, nausea, vomiting, stomach pains, blurred vision, slurred speech, and muscle twitching. Symptoms of more severe poisoning may advance to convulsions, coma, loss of reflexes, and loss of sphincter control (WHO/FAO, 1983).

### *Description of Data Quality and Quantity*

Comprehensive reviews on the toxicity of pirimiphos-methyl have been prepared:

- Interim Reregistration Eligibility Decision for Pirimiphos-methyl Case No. (2535) (U.S. EPA, 2001)
- IRIS summary review (U.S. EPA, 2006)
- Data Sheet on Pesticide No. 49 – Pirimiphos-methyl (WHO/FAO, 1983).

EPA has developed quantitative human health benchmarks that include an oral acute and chronic RfD and short- and intermediate-term inhalation and dermal benchmarks.

## Summary Table

Duration	Route	Benchmark Value	Units	Endpoint	Reference
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Duration	Route	Benchmark Value	Units	Endpoint	Reference
Acute	Inhalation	0.015	mg/kg/day	Oral LOAEL for neurological effects in rats with UF of 1000 applied; assume no portal of entry effects	U.S. EPA (2001)
Intermediate	Inhalation	0.0007	mg/kg/day	Oral LOAEL for neurological effects in rats with UF of 300 applied; assume no portal of entry effects	U.S. EPA (2001)
Chronic	Inhalation	0.0007	mg/kg/day	Adopt intermediate for chronic duration	U.S. EPA (2001)
Acute	Oral	0.015	mg/kg/day	Acute oral RfD based on a LOAEL of 15 mg/kg/day for neurological effects in rats and UF of 1,000 applied	U.S. EPA (2001)
Intermediate	Oral	0.0002	mg/kg/day	Adopt chronic RfD for intermediate duration	U.S. EPA (2001)
Chronic	Oral	0.0002	mg/kg/day	Chronic oral RfD based on a LOAEL of 0.2 mg/kg/day for neurological effects in rats and UF of 1,000 applied	U.S. EPA (2001)
Acute	Dermal	0.015	mg/kg/day	Oral LOAEL for neurological effects in rats with UF of 1,000 applied; assume no first pass effects and 100% oral absorption	U.S. EPA (2001)
Intermediate	Dermal	0.0007	mg/kg/day	Oral LOAEL for neurological effects in rats with UF of 300 applied; assume no first pass effects and 100% oral absorption	U.S. EPA (2001)
Chronic	Dermal	0.0007	mg/kg/day	Adopt intermediate for chronic duration	

For oral exposure, an acute RfD of 0.015 mg/kg/day was derived based on a LOAEL of 15 mg/kg/day for brain, red blood cell, and plasma cholinesterase inhibition in rats (EPA MRID# 43594101, citation not provided). An uncertainty factor of 1,000 was applied for the use of a LOAEL and the degree of cholinesterase inhibition (10), and intra- and inter-species variability (100) (U.S. EPA, 2001).

A chronic oral RfD of 0.0002 mg/kg/day was derived based on an LOAEL of 0.2 mg/kg/day for plasma cholinesterase inhibition in a subchronic rat study (EPA MRID# 43608201, citation not provided). An uncertainty factor of 1,000 was applied for the use of a LOAEL and data gaps for long-term studies (10), and intra- and inter-species variability (100) (U.S. EPA, 2001). The chronic RfD was used to represent intermediate exposures.

For inhalation and dermal exposure, the oral toxicity endpoints (i.e., LOAELs) were selected for use, and both assume 100 percent absorption and no first pass or portal-of-entry effects

(U.S. EPA, 2001). For acute inhalation and dermal benchmarks, an uncertainty factor of 1,000 was applied for the use of a LOAEL and the degree of cholinesterase inhibition (10), and intra- and inter-species variability (100). For intermediate inhalation and dermal benchmarks, an uncertainty factor of 300 was applied for the use of a LOAEL (3) and intra- and inter-species variability (100). The intermediate benchmark was used to represent chronic exposures.

### *Insecticide Background*

CASRN:	29232-93-7
Synonyms:	O-(2-Diethylamino)-6-methyl-4-pyrimidinyl O,O-dimethyl phosphorothioate, 2-diethylamino-6-methylpyrimidin-4-yl dimethyl phosphorothionate, pirimifosmethyl, methylpirimiphos, pyridimine phosphate, ENT 27699GC, PP511, CMS 1424 (U.S. EPA, 2001, 2006; WHO/FAO, 1983)
Chemical Group:	organophosphate (U.S. EPA, 2001; WHO/FAO, 1983)
Registered Trade Names:	Actellic 5E, Atelic, Atellic, Atellifog, Blex, Nu-Gro Insecticide, Nu-Gro 5E, Tomahawk Insecticide Ear Tags, LPM Insecticide Ear Tags, Silosan, Sybol (U.S. EPA, 2001, 2006; WHO/FAO, 1983)

### *Usage*

Pirimiphos-methyl is a fast-acting, broad spectrum organophosphate insecticide and acaricide used to control a wide variety of sucking and chewing pests in agricultural and horticultural applications. It is used in horticultural applications; to clean fruits and vegetables before harvest; to control pests on stored products; and to eradicate nuisance and disease vector insects, including mosquitoes, ants, beetles, bed-bugs, cockroaches, fleas, flies, lice, and mites (WHO/FAO, 1983, 1974). The intended uses of existing products include greenhouse applications, treatment of stored grain and seeds (corn and sorghum) intended for both human and animal consumption, and direct animal applications including incorporation into cattle eartags and sprays (U.S. EPA, 1999c, n.d.). Pirimiphos-methyl is used to control a large number of different insects including, but not limited to, cigarette beetles; confused flour beetles; corn sap beetles; flat grain beetles; hairy fungus beetles; red flour beetles; sawtoothed beetles; granary weevils; maize weevils; merchant grain beetles; rice weevils; lesser grain borers; and angoumois grain moths, Indian meal moths, and almond moths on corn (seed and whole-grain), rice (whole-grain), wheat (whole-grain), and grain sorghum (seed and whole-grain); mealy bugs; mites (iris bulbs) horn flies and face flies (U.S. EPA, 2001). For malaria control, typical use includes the application of 1 or 2 g pirimiphos-methyl/m<sup>3</sup> of a 2–5 percent suspension to indoor walls and ceilings every 3 months. Ultra-low-volume (ULV) sprays and thermal fogs are additional application methods. To control DDT resistant fleas, a 2 percent dust is applied in rodent burrows. Pirimiphos-methyl is not recommended for use directly on humans or on processed foods

(WHO/FAO, 1983; U.S. EPA, 1999c). Current registered uses in the United States include food and non-food uses. Food uses include use on sorghum, corn (grain and seed), nonlactating dairy cattle, beef/range/feeder cattle, and calves. Non-food uses include use on iris bulbs. No residential or public health uses are currently registered in the United States (U.S. EPA, 2001)

#### *Formulations and Concentrations*

There are several typical formulations for pirimiphos-methyl, each formulation varying in the amount of active ingredient (ai) it contains. The typical formulations for pirimiphos-methyl include (U.S. EPA, 1999c, 2001; WHO/FAO, 1983) the following:

- U.S. registered formulations: emulsifiable liquid concentrate (57 percent ai), treated ear tags (14 percent and 20 percent ai)
- For agricultural and horticultural uses: emulsifiable concentrate (250–500 g ai/L), ULV concentrate (500 g ai/L), encapsulated formulas (250–400 g ai/kg), dusts (10 and 20 g ai/kg), wettable powders (250 and 400 g ai/kg), fog (100 g ai/L), aerosol (20 g ai/L with pyrethroids), solvent free formulation (900 g ai/kg), smoke generator formulation
- For public health uses: emulsifiable concentrate (250 and 500 g ai/L), ULV concentrate (500 g ai/L), encapsulated formulation (200 g ai/L), dusts (10 and 20 g ai/kg), wettable powder (250 and 400 g ai/kg), fog (100 g ai/L), aerosol (20 g ai/L with pyrethroids), solvent-free formulation (900 g ai/kg), smoke generator formulation
- For household uses: emulsifiable concentrate (80 g ai/L), dusts and aerosols (with pyrethroids) for use in the home and garden.

#### *Degradation Products*

Stored pirimiphos-methyl products are broken down by hydrolysis of the phosphorus-ester side chain, which results primarily in the parent hydroxyl-pyrimidine (WHO/FAO, 1974). The main hydrolysis degradates at pH 5, 7, and 9 were 2 (diethylamino)-4-hydroxy-6-methyl pyrimidine and O-2-diethylamino-6-methylpyrimidin-4-yl o-methyl-phosphorothioate (U.S. EPA, 2001). In soil, the major metabolite is the parent hydroxypyrimidine (IV) together with smaller amounts of the related compounds (V) and (VI). Compound (IV) is the major degradation product in water with only trace quantities of the P=0 analogue (III) detected (WHO/FAO, 1974).

In humans, pirimiphos-methyl is broken down into the degradation products desethyl pirimiphos-methyl and pirimiphos-methyloxon, which are also active and have transient stability (WHO/FAO, 1983). When pirimiphos-methyl is broken down in rats and dogs, the major urinary metabolite (30 percent of administered dose) was 2-ethylamino-4-hydroxy-6-methylpyrimidine. Other metabolites included 4-O(2-diethylamino-6-methylpyrimidinyl)- $\beta$ -D-glucosiduronic acid (11 percent of dose in dogs), an unidentified phosphorus-containing product likely to be a dealkylated derivative of either pirimiphos-methyl or its oxygen analogue (12 percent of dose in rats), and 2-amino-4-hydroxy-6-methyl pyrimidine (8 percent of dose in rats and 5 percent of dose in dogs) (WHO/FAO, 1992).

### *Shelf Life*

Under normal storage conditions at room temperature, pirimiphos-methyl is stable for up to 6 months. However, it decomposes in sunlight (WHO/FAO, 1983).

### *Environmental Behavior*

#### **Fate and Transport in Terrestrial Systems**

Pirimiphos-methyl has limited mobility and persistence in soil (WHO/FAO, 1974). For a variety of soil types, pirimiphos-methyl has a half-life of less than one month (WHO/FAO, 1974). It hydrolyzes rapidly in acidic soils and is stable in neutral and alkaline environments with a half-life of 7.3 days at pH 5, 79 days at pH 7, and 54–62 days at pH 9 (U.S. EPA, 2001). Pirimiphos-methyl decomposes in sunlight (WHO/FAO, 1983).

#### **Fate and Transport in Aquatic Systems**

Pirimiphos-methyl is not expected to have a significant impact on water resources due to the lack of significant outdoor uses (U.S. EPA, 2001). It degrades in water mainly by hydrolysis, which is attenuated by sunlight. In sunlight, 50 percent degradation occurs within one day. Volatilization also occurs from still water; however, it is not as significant as hydrolysis (WHO/FAO, 1974).

### *Human Health Effects*

#### **Acute Exposure**

#### ***Effects/Symptoms***

Similar to other organophosphates, pirimiphos-methyl is a cholinesterase inhibitor and interferes with the normal functioning of the nervous system. It causes dose-related reversible decreases in plasma, red blood cell, and brain cholinesterase at very low doses by ingestion, dermal, and inhalation exposures. It is of relatively low acute oral, dermal, and inhalation toxicity (U.S. EPA, 1999b). In two human studies, volunteers were fed a dose of 0.25 mg/kg/day for up to 56 days. Marginal plasma cholinesterase depression was observed after both dosing periods (U.S. EPA, 1998b, 2006). However, these studies have many deficiencies and should be used as supplemental data. When compared to animal data, they provide some evidence that humans may be more sensitive than animals as is indicated by the lower effect level for cholinesterase inhibition in humans (U.S. EPA, 1999b). No human poisonings from mishaps with pirimiphos-methyl have been reported (WHO/FAO, 1983).

Animal studies have shown that pirimiphos-methyl is only slightly toxic following acute oral and dermal exposures, with reported LD<sub>50</sub> values in rats of >2,400 mg/kg (U.S. EPA, 1999a). Other reported oral LD<sub>50</sub>s are as follows: rabbit (male) 1,154–2,300 mg/kg, mouse (male) 1,020–1,360 mg/kg, guinea pig (female) 1,000–2,000 mg/kg, dog (male) > 1,500 mg/kg, and cat (female) 575–1,150 mg/kg. The reported dermal LD<sub>50</sub> is > 4,500 mg/kg in female rats (WHO/FAO, 1983), >4,050 mg/kg in female rabbits, and 2,200–4,050 mg/kg in male rabbits (U.S. EPA, 2001, 1999a, 1998a). The reported acute inhalation LC<sub>50</sub> is > 4.7 mg/L for rats (U.S. EPA, 2001, 1999a, 1998a). Among mammals, no one species appears to

be more susceptible. However, the hen appears to be highly susceptible with a reported LD<sub>50</sub> of 79–80 mg/kg (WHO/FAO, 1983). Clinical signs of exposure include neurotoxicity, excessive salivation, abnormal gait, ataxia, and leg paralysis. Dermal exposure also decreased plasma cholinesterase levels (WHO/FAO, 1983). Eye and skin irritation have been observed in rabbits (U.S. EPA 1999d, 1998b); however, pirimiphos-methyl has not been shown to be a dermal sensitizer in guinea pigs or rats (U.S. EPA, 1998b; WHO/FAO, 1983).

### ***Treatment***

Exposure to pirimiphos-methyl may be determined through laboratory tests of urine and blood that measure breakdown products of pirimiphos-methyl in urine or cholinesterase levels in blood. Blood levels of cholinesterase, especially in plasma, are the most useful in diagnosis of poisoning. However, neither urinary or blood tests are specific for pirimiphos-methyl exposure. Early symptoms of pirimiphos-methyl exposure include excessive sweating, headache, weakness, giddiness, nausea, vomiting, stomach pains, blurred vision, slurred speech, and muscle twitching. Symptoms of more severe poisoning may advance to convulsions, coma, loss of reflexes, and loss of sphincter control. Following dermal exposures, the person should stop working and any contaminated clothing should be removed. Exposed areas of skin should be washed with soap and water and flushed with large quantities of water. For oral exposures, vomiting should not be induced unless a potential lethal dose has been ingested and the person is conscious. Care should be taken as the vomitus may contain toxic amounts of the chemical. Once under medical care, potential lethal doses should be treated by rapid gastric lavage unless the patient is already vomiting. Any ocular exposure should be treated by washing with isotonic saline. If no respiratory insufficiency is noted, peripheral symptoms should be treated with 2–4 mg of atropine sulfate and 1,000–2,000 mg pralidoxime chloride or 250 mg toxogonin (adult dose) by slow intravenous injection. If severe respiratory difficulties, convulsions, and unconsciousness are present, atropine and a reactivator should be given immediately. The airway should be maintained. Morphine, barbiturates, phenothiazine, tranquilizers, and central nervous system stimulants are all contraindicated (WHO/FAO, 1983).

### ***Chronic Exposure***

#### **Noncancer Endpoints**

Workers in two WHO-supervised health spray program did not show any signs of pesticide poisoning; however, at the end of one of the programs, plasma cholinesterase activity was 70–75 percent of the mean of pre-exposure values. The people living in the spray areas exhibited no signs of poisoning and no effect on cholinesterase activity. Volunteers exposed to 0.25 mg/kg/day for up to 56 days exhibited no toxic effects on liver function or blood tests and an acceptable daily intake (ADI) of 0.01 mg/kg was established (WHO/FAO, 1983).

Chronic exposure data in animals indicates that a main target of pirimiphos-methyl toxicity is the nervous system. Rats repeatedly exposed to high doses of pirimiphos-methyl showed a

cumulative inhibitory effect on cholinesterase (WHO/FAO, 1983). In 90-day and 2-year dietary studies in rats, plasma cholinesterase and some erythrocyte and brain cholinesterase inhibition was reported. In a 2-year dog study and an 80-week mouse study, similar effects were observed (WHO/FAO, 1983).

In developmental and reproductive toxicity studies in rats and rabbits, maternal/parental NOELs were less than or the same as offspring NOELs. No increased sensitivity was noted in fetuses or pups. There is no evidence that pirimiphos-methyl is teratogenic in rat or rabbit feeding studies (U.S. EPA, 1998b, 2006; WHO/FAO, 1983). In several mammalian studies, no mutagenic potential was observed (U.S. EPA, 1998b; WHO/FAO, 1983).

### **Cancer Endpoints**

EPA determined that the carcinogenic potential of pirimiphos-methyl could not be determined because a reliable rat carcinogenicity study is lacking (U.S. EPA, 1998b). In an 80-week mouse feeding study, a 78-week mouse feeding study, a 80-week mouse oral study, a 2-year rat feeding study, a 78-week rat feeding study, and a 2-year oral dog study, no evidence of carcinogenic potential was identified (WHO/FAO, 1983; U.S. EPA, 1998b, 2006). Additionally, mammalian mutagenicity studies do not provide any evidence that supports a carcinogenic potential for pirimiphos-methyl (WHO/FAO, 1983).

### *Toxicokinetics*

Pirimiphos-methyl can be absorbed via the gastrointestinal tract, the skin, or, less commonly, by inhalation of fogs, smokes, or spray mists. It is rapidly metabolized and excreted. Pirimiphos-methyl is broken down into desethyl pirimiphos-methyl and pirimiphos-methyloxon, which are also active and have transient stability. In rats dosed with radiolabeled pirimiphos-methyl, 70 percent was excreted within 24 hours and 100 percent was excreted within 5–6 days. Excretion was mainly in the urine (85 percent) and to a lesser extent, feces (15 percent). Pirimiphos methyl and its metabolites do not accumulate in the liver, kidneys, or fatty tissues of rats and domestic animals following oral exposure (WHO/FAO, 1983).

### *Ecological Effects*

#### **Acute Exposure**

Pirimiphos-methyl is not expected to pose a hazard to birds and mammals from acute exposure, because of lack of exposure. In the laboratory, pirimiphos-methyl exhibits relatively high toxicity to birds (WHO/FAO, 1983). Acute oral LD<sub>50</sub> values in various bird species include chickens (79–80 mg/kg), Japanese quail (140 mg/kg), and green finches (200–400 mg/kg). Dietary LD<sub>50</sub>s of 630 mg/kg for mallard ducks and 206 mg/kg for bobwhite quail chicks were identified. No lasting adverse effect on hens; chicks; or egg production, quality, or hatchability was seen in studies of chickens fed 4–40 ppm in their diet (WHO/FAO, 1983).

When used for its registered purposes, pirimiphos-methyl is not expected to result in significant exposures of aquatic organisms (U.S. EPA, 2001). Additionally, any risk would be mitigated by its strong tendency to decompose in water and to undergo photo-oxidation (WHO/FAO, 1983). In static tests, the reported 48-hour LC<sub>50</sub> was 1.4 mg/L in carp and 0.25 mg/L in rainbow trout. The 24-hour LC<sub>50</sub> for carp was 1.6 mg/L. In flow-through tests, the reported 48-hour LC<sub>50</sub> was 4.1 mg/L in fathead minnow and 0.53 mg/L in rainbow trout, while the 24-hour LC<sub>50</sub> was 5.6 mg/L in fathead minnow and 0.78 mg/L in rainbow trout (WHO/FAO, 1983).

#### *Chronic Exposure*

Due to low risk of both terrestrial and aquatic acute ecological effects of pirimiphos-methyl, serious adverse effects are not anticipated from chronic exposures. Subchronic 90-day exposure of birds to oral doses of up to 10 mg/kg did not result in clinical or histopathological findings (WHO/FAO, 1983).

## **Profile for Propoxur:**

CAS Registry Number 114-26-1

#### ***Summary of Insecticide***

##### *Chemical History*

Propoxur is a broad spectrum, nonsystemic carbamate insecticide that was first introduced in 1959. It is used by homeowners and pest control operators in both agricultural and nonagricultural applications to kill a variety of chewing and sucking pests, mosquitoes, ants, flies, cockroaches, hornets, crickets, and lawn and turf insects (U.S. EPA, 1997a, 2000; EXTOXNET, 1996). Propoxur (Baygon) was first registered in the United States for pesticide use in 1963 and currently there are two registered technical products, several manufacturing use only products, and 173 registered products containing propoxur (U.S. EPA, 1997b).

Propoxur exhibits its toxic effects through reversible cholinesterase inhibition (U.S. EPA, 2000). It has moderate toxicity in mammals (WHO/FAO, 1976), high toxicity in birds, and moderate toxicity in fish (EXTOXNET, 1996; U.S. EPA, 1997b). Short-term exposures may cause effects on the nervous system, liver, and kidneys (IPCS, 1994). In humans, symptoms of acute oral poisoning include red blood cell cholinesterase inhibition with mild transient cholinergic symptoms including nausea, vomiting, sweating, blurred vision, and tachycardia. Long-term inhalation exposures in humans results in cholinesterase inhibition, headaches, nausea, and vomiting (U.S. EPA, 2000). Propoxur pesticides are available as emulsifiable concentrates, wettable powders, dusts and powders, baits, aerosols, fumigants, granular

baits, containerized baits, pest strips, shelf paper, pet flea collars, and oil sprays (EXTOXNET, 1996; U.S. EPA, 1997a). Applications methods include aerosol can and injection tube; concentrated liquid using a compressed air sprayer or hand or power sprayer; wettable powder using a ready-to-use sprayer liquid, a power or had pressurized sprayer, or a low pressure sprayer for oil soluble liquid (U.S. EPA, 1997b).

*Description of Data Quality and Quantity*

Extensive review data for propoxur are limited. Relevant resources include

- Propoxur: Registration Eligibility Decision (RED) Document (U.S. EPA, 1997b)
- IRIS summary review (U.S. EPA, 2006)
- Pesticide Information Profile for Propoxur (EXTOXNET, 1996)
- Data Sheet on Pesticides. No. 25: Propoxur (WHO/FAO, 1976)
- International Safety Cards: Propoxur (IPCS, 1994).

EPA has developed quantitative human health benchmarks (acute and chronic oral RfDs and short-, intermediate-, and long-term dermal and inhalation benchmarks) for propoxur.

## Summary Table

Duration	Route	Benchmark Value	Units	Endpoint	Reference
Acute, Intermediate, Chronic	Inhalation	0.004	mg/kg/day	Inhalation NOEL (2.2 mg/m <sup>3</sup> ) for neurological effects in rats, adjusted for intermittent exposure and UF of 100 applied	U.S. EPA (1997b)
Acute, Intermediate, Chronic	Oral	0.005	mg/kg/day	Chronic RfD based on LOEL in humans with UF of 30 applied	U.S. EPA (1997b)
Acute, Intermediate, Chronic	Dermal	10	mg/kg/day	Dermal NOAEL for toxicity in rabbits with UF of 100 applied	U.S. EPA (1997b)
Cancer	Inhalation, Oral, Dermal	0.0037	per mg/kg/day	Cancer slope factor based on male rat bladder tumors	U.S. EPA (1997b)

For inhalation exposure, a NOEL of 2.2 mg/m<sup>3</sup> (2.4 mg/kg/day)<sup>20</sup> was identified in rats exposed to propoxur (Pauluhn, 1992, 1994) via inhalation for 6.3 hours per day, 5 days per week for 2 years. Significant plasma, red blood cell, and brain cholinesterase inhibition were observed at higher concentrations (U.S. EPA, 1997b). The concentration was adjusted for intermittent exposure<sup>21</sup> (0.4 mg/kg/day) and an uncertainty factor of 100 was applied to account for interspecies and intrahuman variation, for an inhalation benchmark of 0.004 mg/kg/day. This value is appropriate for all exposure durations. However, the vapor pressure of propoxur is extremely low and significant human exposure via inhalation is not expected (U.S. EPA, 1997b).

For oral exposure, the chronic oral RfD of 0.005 mg/kg/day was calculated based on a LOEL of 0.15 mg/kg for a 40 percent red blood cell cholinesterase inhibition reported in a human exposure study (Vandekar et al., 1971) with an uncertainty factor of 30 applied to account for intrahuman variability (10) and the use of a LOEL (3) (U.S. EPA, 1997b). This value is appropriate for all exposure durations.

For dermal exposure, a NOEL of 1,000 mg/kg/day for lack of toxic effects in a subchronic rabbit study (Diesing and Flucke, 1989) is appropriate for all exposure durations (U.S. EPA, 1997b); an uncertainty factor of 100 was applied to account for interspecies and intrahuman variability. This value is appropriate for all exposure durations. However, studies indicate a very low absorption potential (<20 percent in humans) and/or hazard by the dermal exposure route (U.S. EPA, 1997b).

<sup>20</sup> Conversion between mg/m<sup>3</sup> and mg/kg/day assumes, for Wistar rats, an average body weight of 0.187 kg and inhalation rate of 0.2 m<sup>3</sup>/day (U.S. EPA, 1988).

<sup>21</sup> Adjustment for intermittent exposure is the product of air concentration and exposure of 6.3/24 hours/day and 5/7 days/week.

EPA classified propoxur as a Group B2 chemical, probable human carcinogen. EPA calculated a unit risk of  $3.7 \times 10^{-3}$  per mg/kg/day based on bladder tumors in male rats (U.S. EPA, 1997b).

### *Insecticide Background*

CAS #:	114-26-1
Synonyms:	o-isopropoxyphenyl methylcarbamate (IUPAC); 2-(1-methylethoxy) phenyl methylcarbamate (CA) (WHO, 2005; U.S. EPA 1997b) 2-Isopropoxyphenyl methylcarbamate Phenol, 2-(1-methylethoxy)-,methylcarbamate, Phenol, o-isopropoxy-, methylcarbamate, Propoxur [Phenol, 2-(1-methylethoxy) -, methylcarbamate 2-(1-Methylethoxy)phenyl methylcarbamate PHC (PAN, 2005; IPCS, 1994)
Chemical Group:	carbamate (EXTOXNET, 1996; U.S. EPA 1997b)
Registered Trade Names:	Trade and other names for propoxur include: Arprocarb, Bay, Bay 9010, Bay 5122, Bay 9010, Baygon, Bayer 39007, Bifex, Blattanex, Blattosep, Brifur, Bolfo, BO Q 5812315, Chemagro 9010, Compound 39007 , Dalf dust , DMS 33, ENT 25671, Invisi-Gard, OMS 33, PHC (JMAF), Pillargon, Prentox Carbamate, Propogon, Proprotox, Propyon, Rhoden, Sendra, Sendran, Suncide, Tendex, Tugon, Fliegenkugel, UN Carbamate, Unden, and Undene (WHO, 2005; PAN, 2005; EXTOXNET, 1996; IPCS, 1994; WHO/FAO, 1976; IPCS, 1973)

### *Usage*

Propoxur is a residual carbamate insecticide that has a variety of indoor uses, including the control of mosquitoes, ants, cockroaches, crickets, flies, bees, hornets, wasps, ticks, yellow jackets, bedbugs, fleas, woodlice, and spiders (U.S. EPA, 1997b; WHO, 2005; WHO/FAO, 1976). Indoor food applications include only crack and crevice treatment in food areas (U.S. EPA, 1997b). There are limited outdoor applications consisting mostly of perimeter and spot treatments of nests and lawn and turf insects (U.S. EPA, 1997b, 2000). Crop applications include sugar cane, cocoa, grapes, other fruit, maize, rice vegetables, cotton, lucerne, forestry, and ornamentals (WHO, 2005). Propoxur is used in the control of malaria and in pet flea collars (U.S. EPA, 2000). In public health and agricultural applications, propoxur is applied as a dust or by spraying (WHO, 2005). It is available in commercial products as a single active ingredient or combined with other pesticides (U.S. EPA, 1997b).

### *Formulations and Concentrations*

Common formulations of pesticides containing propoxur include technical grade propoxur, emulsifiable concentrates, wettable powders, baits, aerosols, fumigants, granules, and oil sprays (EXTOXNET, 1996). Typical formulations and percent propoxur content include ready-to-use liquid (0.5–1 percent), pressurized aerosol liquid (0.25–2 percent), oil-soluble liquid/liquid concentrate (8–19.6 percent propoxur), pastes (2 percent), wettable powders (70 percent), solid baits (0.25–2 percent), pet flea collars (impregnated plastic) (0.4–10 percent), impregnated shelf papers (1 percent), and insecticidal tapes (10 percent) (U.S. EPA, 1997b). Common formulations used for agricultural, horticultural, and forestry applications include wettable powders (50 percent), dusts (1–2 percent), granules, oils, emulsifiable concentrates (200 g/L; 20 percent w/w), pressurized sprays, smokes, baits (various concentrations) (WHO/FAO, 1976; IPCS, 1973).

WHO (2005) indicated that the propoxur content in various preparations should be declared and contain the following:

- Technical grade propoxur: not less than 980 g/kg
- Wettable Powder: 500 g/kg  $\pm$  5% of the declared content.

### *Shelf Life*

Propoxur is reported to be stable under normal storage and use conditions (IPCS, 1973) but unstable in highly alkaline media. The half-life propoxur is reported as 40 minutes at pH 10 at 20°C (WHO/FAO, 1976). WHO (2005) reported that following storage at  $54 \pm 2^\circ\text{C}$  for 14 days, 97 percent or greater of the active ingredient must be present in wettable powder formulations.

### *Degradation Products*

*In vivo*, propoxur is biotransformed by depropylation to 2-hydroxyphenol-N-methylcarbamate and by hydrolysis to the phenol. The glucuronides detected in urine are accounted for by ring hydroxylation and isopropoxy hydroxylation followed by conjugation. Major metabolites in rats include 5-hydroxy-2-isopropoxyphenyl n-methylcarbamate, 2-hydroxyphenyl n-methylcarbamate, o-isopropoxyphenol, o-isopropoxyphenyl, and n-hydroxymethylcarbamate. In mice, the major metabolites include o-isopropoxyphenyl n-hydroxymethylcarbamate. In bean plants, the major metabolites include 4-hydroxy-2-isopropoxyphenyl n-methylcarbamate, 2-hydroxyphenyl n-methylcarbamate, and o-isopropoxyphenyl n-hydroxymethylcarbamate (HSDB, 2005). Limited human data are available. Many propoxur metabolites were found in the urine of a person attempting suicide by ingestion of a large quantity of the emulsifiable concentrate formulation. These were present both as free compound or conjugated with glucuronide or sulfate. As in other species, biotransformation was from depropoxylation, hydrolysis of the ester bond and ring hydroxylation (IPCS, 1989).

## *Environmental Behavior*

### **Fate and Transport in Terrestrial Systems**

Propoxur is expected to be moderately to very highly mobile and moderately persistent in soil (HSDB, 2005; U.S. EPA, 1997a, 1997b; EXTTOXNET, 1996). With a  $K_{oc}$  ranging from <1 to 103, high to very high mobility is expected if propoxur is released in soil (HSDB, 2005); however, the mobility depends on the soil type and previous exposures to propoxur. Biodegradation in soil is more rapid in previously exposed soils. In many soil types, propoxur is highly mobile due to its low affinity for soil binding (EXTTOXNET, 1996; U.S. EPA, 1997a, 1997b). It evaporates from soil, with the amount increasing with the moisture content of the soil, and the half-life is 6–8 weeks, depending on the soil type (IPCS, 1973). Data from studies of the persistence of propoxur in several soil types suggest that it moves rapidly through all soil profiles below the 12 inch sampling depth. Its fate and transport characteristics are similar to those chemicals that are known to leach into groundwater (U.S. EPA, 1997b).

Hydrolysis appears to be the primary mode of degradation (U.S. EPA, 1997b). At neutral pH, propoxur is hydrologically stable but degrades rapidly at alkaline pH values (U.S. EPA, 1997b). Half-life values of a propoxur in aqueous solutions at 20°C are reported to range from 1 minute at pH 12.8 to 40 minutes at pH 10.8 (IPCS, 1973). Half-life values of 16 days at pH 8, 1.6 days at pH 9, and 0.17 days at pH 10 are reported (U.S. EPA, 1997b). Volatilization is not expected to be a major fate process from moist soil surfaces (HSDB, 2005). The major fate process in moist soils is biodegradation. Under aerobic conditions, biodegradation half-lives of 80 days in silt loam soil and 120 days in sandy loam soil are reported (HSDB, 2005). On inert surfaces, however, volatilization is the main fate process. On a glass surface, 50 percent of a propoxur residue was still present 1.8 hours after application (IPCS, 1973). Propoxur in soil shows no or little susceptibility to photolysis (U.S. EPA, 1997b; IPCS, 1973). Half-lives of several months were reported for the degradation of propoxur under aerobic and anaerobic conditions (U.S. EPA, 1997b).

### **Fate and Transport in Aquatic Systems**

Propoxur is highly soluble in water and there is a high likelihood of groundwater penetration because it does not adsorb strongly to soil particles (HSDB, 2005; EXTTOXNET, 1996; U.S. EPA, 1997a). It is relatively stable in water at pH 7 or less but hydrolyzes rapidly at pHs greater than 7 (IPCS, 1973). In a 1 percent aqueous solution at pH 7, propoxur hydrolyzes at a rate of 1.5 percent per day (EXTTOXNET, 1996). Reported field half-lives for propoxur are 14–50 days (EXTTOXNET, 1996). The hydrolysis half-life of propoxur is reported to be 1 year at pH 4, 93 days at pH 7, and 30 hours at pH 9 (HSDB, 2005). Volatilization from water is not expected to be a major fate process. However, propoxur is susceptible to photolysis in water (U.S. EPA, 1997b). The half-life of propoxur irradiated with light more than 290 nm is reported as 88 hours (HSDB, 2005). Because propoxur degrades rapidly in water, bioconcentration in fish is unlikely (HSDB, 2005).

## *Human Health Effects*

### **Acute Exposure**

#### *Effects/Symptoms*

Propoxur causes its toxic effects by reversible inhibition of cholinesterase. Short-term exposures may cause effects on the nervous system, liver, and kidneys (IPCS, 1994). In humans, symptoms of acute oral poisoning include red blood cell cholinesterase inhibition with mild transient cholinergic symptoms including nausea, vomiting, sweating, blurred vision, and tachycardia (U.S. EPA, 2000). Limited data exist on the human health effects of acute exposure to propoxur. In volunteers, a single oral dose was reported to cause stomach discomfort, sweating, and redness of the face. However transient erythrocyte cholinesterase activity inhibition (up to 27 percent) was observed at a higher level and was associated with vomiting, sweating, and blurred vision (WHO/FAO, 1976). When used to control for malaria, spray operators experienced occasional short-lasting symptoms including nausea, headache, sweating, and weakness from which they quickly recovered (WHO/FAO, 1976; EXTOWNET, 1996). Additionally, some mild reactions were reported by residents where it was applied (WHO/FAO, 1976).

In animals, propoxur is acutely toxic via the oral, inhalation, and dermal routes (U.S. EPA 1997b, 2000; EXTOWNET 1996). Acute inhalation and dermal exposures are moderate to highly toxic while oral exposures are highly to be extremely toxic (U.S. EPA, 1997a, 2000). Propoxur is highly toxic to animals via ingestion. In rats, the oral LD<sub>50</sub> for propoxur ranges from 68 mg/kg in females to 116 mg/kg in males (EXTOWNET, 1996; WHO/FAO, 1976; U.S. EPA, 1997b). In other species, reported oral LD<sub>50</sub> values include approximately 100 mg/kg in mice and 40 mg/kg in guinea pigs (EXTOWNET, 1996). Reported dietary levels causing no toxic effects in animals include 300mg/kg/day for mice, 10 mg/kg/day for rats, and 5 mg/kg/day for dogs (IPCS, 1989). Via the dermal route, the reported LD<sub>50</sub> values in various species include greater than 2,400 mg/kg in rats (EXTOWNET, 1996; WHO/FAO, 1976) and 500 mg/kg to > 2000 mg/kg in rabbits (EXTOWNET, 1996; U.S. EPA, 1997b). Via inhalation, the reported LC<sub>50</sub> values include a 4-hour LC<sub>50</sub> of >0.5 mg/L in rats (U.S. EPA, 1997b) and a 1-hour LC<sub>50</sub> of > 1.44 mg/L (EXTOWNET, 1996).

Similar to its effects in humans, acute exposure to propoxur in animals causes symptoms typical of cholinesterase inhibition (EXTOWNET, 1996; U.S. EPA, 1997b). Cholinesterase depression, muscle spasms, and salivation have been reported within 10 minutes of oral administration in rats (U.S. EPA, 1997b). In rats fed propoxur in their diet for 16 weeks, whole blood cholinesterase was inhibited at dietary levels over 500 ppm while plasma, whole blood, and brain cholinesterase were inhibited at dietary levels greater than 1,000 ppm at study termination. Signs of cholinesterase inhibition were also observed in both rats and mice within 15 minutes of exposure to different concentrations of propoxur aerosol (WHO/FAO, 1976). Brain pattern and learning ability changes can occur at lower concentrations than those that cause cholinesterase inhibition and/or organ weight changes (EXTOWNET, 1996).

Although propoxur is a mild eye irritant in rabbits, it is not a skin irritant in rabbits or a dermal sensitizer in guinea pigs (U.S. EPA, 1997b). Acute exposure to propoxur is not considered to be teratogenic in rats (WHO/FAO, 1976).

### **Treatment**

Exposure to propoxur may be determined through laboratory tests that determine cholinesterase levels in blood with erythrocyte cholinesterase being a more informative indicator than either plasma or whole blood. However, the enzyme will only be inhibited for a few hours following exposure. Additionally, phenol metabolites may be determined in urine (WHO/FAO, 1976; U.S. EPA, 2000). However, neither of these tests are reliable indicators of total exposure because they are not specific for propoxur (U.S. EPA, 2000).

Propoxur poisoning should be treated by first removing any contaminated clothing, and washing affected skin with soap and water and flushing the area with large amounts of water (WHO/FAO, 1976; IPCS, 1994). If propoxur gets in the eyes, they should be rinsed immediately with isotonic saline or water. Contact lenses should be removed, if possible. Oral exposure to propoxur should be treated by administration of activated charcoal (HSDB, 2005; IPCS, 1994). Rapid gastric lavage with 5 percent sodium bicarbonate is indicated if the patient is not already vomiting. Medical attention should be sought (WHO/FAO, 1976; HSDB, 2005). Inhalation exposures should be treated by removal to fresh air, placing in a half-upright position, monitoring for respiratory distress, and seeking medical attention (HSDB, 2005; IPCS, 1994). Because propoxur is quickly metabolized and symptoms are of a short duration, atropine treatment is not usually necessary by the time the patient reaches medical help (WHO/FAO, 1976). However, adults showing signs of propoxur toxicity should be treated with 1–2 mg atropine sulfate given intramuscularly or intravenously as needed. Oxygen may be necessary for unconscious patients or those in respiratory distress. Pralidoxime is usually not necessary unless the poisoning is severe. Barbiturate and central stimulants are contraindicated (HSDB, 2005; WHO/FAO, 1976).

### *Chronic Exposure*

#### **Noncancer Endpoints**

Limited data are available on the effects of chronic exposure to propoxur in humans. Chronic effects are expected to be similar to acute effects (EXTOXNET, 1996). Cholinesterase inhibition, headaches, vomiting, and nausea were reported in humans following chronic inhalation exposure (U.S. EPA, 2000). When used to control for malaria, spray operators experienced occasional short lasting symptoms including nausea, headache, seating, and weakness from which they quickly recovered (WHO/FAO, 1976). No data are available on human reproductive or developmental effects (U.S. EPA, 2000).

In animals, propoxur is quickly detoxified and does not accumulate in body tissues over time. Daily doses approximating the LD<sub>50</sub> have been tolerated by rats for long periods of time when the dose was given over the course of the day (EXTOXNET, 1996; WHO/FAO, 1976). Chronic oral exposure to propoxur in animals has been reported to cause

cholinesterase inhibition, decreased body weight, liver and bladder effects, and a small increase in neuropathy (U.S. EPA, 1997b, 2000; WHO/FAO, 1976). Significant plasma, red blood cell, and brain cholinesterase inhibition was observed in male and female rats exposed to propoxur in air over a 2-year period (U.S. EPA, 1997b).

The nervous system and liver are the main organs affected by propoxur in both humans and animals (EXTOXNET, 1996). Increased liver weights were observed in rats fed propoxur in feed for 2 years (WHO/FAO, 1976). Reproductive and developmental effects have not been reported in rabbits orally exposed to propoxur. However, some fetotoxicity, decreased litter size, central nervous system impairment in offspring, and decreased fetal weights have been reported in rats orally exposed to propoxur (U.S. EPA, 1997b, 2000; WHO/FAO 1976). The data indicate that reproductive effects in humans are not expected at typical exposure levels and teratogenic effects will occur only at high levels (EXTOXNET, 1996). The available data indicate that propoxur is not mutagenic (EXTOXNET, 1996; U.S. EPA, 1997a).

### **Cancer Endpoints**

EPA's OPP has classified propoxur as Group B2, probable human carcinogen, with a unit risk of  $3.7 \times 10^{-3}$  per mg/kg/day (U.S. EPA, 1997a, 1997b). No information is available on the carcinogenicity of propoxur in humans (U.S. EPA, 2000). A significant increase in bladder papillomas and/or carcinomas was reported in male rats while a significant increase in hepatocellular adenomas and combined adenoma/carcinoma was reported in male mice (U.S. EPA, 1997b, 2000). High dose exposure to propoxur is also associated with an increase in tumors of the uterus (U.S. EPA, 2000).

### *Toxicokinetics*

Like most carbamates, propoxur can be absorbed through the oral, inhalation, and dermal pathways (HSDB, 2005; IPCS, 1994; WHO/FAO, 1976). It is readily absorbed by the lungs (HSDB, 2005) and gastrointestinal tract (IPCS, 1994) but to a lesser extent through the skin (WHO/FAO, 1976). Dermal rat studies indicate that absorption decreases with dose in a nonlinear way. Absorption of a dermal dose of  $6.91 \mu\text{g}/\text{cm}^2$  was 7.88, 10.2, 17.9, 23.2 and 32.5 percent for durations of 0.5, 1, 2, 4, 8, and 32 hours, respectively, which was a higher rate of absorption than in human studies of 8 and 24 hour exposures. Human studies indicate that the rate of 19.6 percent absorption most closely approximates the rate expected in the field (U.S. EPA, 1997b). Approximately 16 percent of the dose of radiolabeled propoxur applied to the forearms of volunteers was available for percutaneous absorption (HSDB, 2005). Additionally, the rate of dermal absorption is affected by the solvent used (U.S. EPA, 1997b).

Propoxur and its metabolites are distributed by the lymph system. Metabolism studies in rats exposed to radiolabeled propoxur have shown radioactivity in all organs (especially the intestines) except bones at 1 hour. High concentrations of radioactivity were still present in the gastrointestinal tract, bladder, and mucous membranes of the pharyngeal system after 24 hours. Some radioactivity was still present in the liver, kidneys, and mucous membranes of the pharyngeal region at 48 and 72 hours (U.S. EPA, 1997b). Peak concentrations were seen

in the blood (at 15 minutes), brain (1 hour), liver (4 hours), and kidneys (6 hours) after oral exposure to 50 mg/kg propoxur, with the highest concentrations seen in the kidneys and the lowest concentration in the brain (HSDB, 2005). Ingested propoxur is rapidly absorbed, broken down, and excreted in the urine (EXTOXNET, 1996; U.S. EPA 1997b). The major routes of metabolism in rats are depropylation to 2-hydroxyphenyl-N-Methylcarbamate and hydrolysis to isopropoxyl phenyl. Peak circulating and tissue concentrations of isopropoxyl phenol were achieved 30–60 minutes after a single oral dose in rats (HSDB, 2005). Because of its rapid metabolism and excretion, propoxur does not accumulate in mammalian tissues (EXTOXNET, 1996). The main route of excretion for propoxur is probably the urine (WHO/FAO, 1976) accounting for 60–95 percent of the dose (HSDB, 2005). In humans, 38 percent of a single oral dose of Baygon was excreted in the urine within the first 24 hours. Of that, most was excreted by the first 8–10 hours (EXTOXNET, 1996). In dermal studies in humans, total excretion was 19.6 percent of the total dermal dose (U.S. EPA, 1997b). Lesser amounts of propoxur are excreted as carbon dioxide (20–26 percent) and in feces (4 percent) (HSDB, 2005).

### *Ecological Effects*

#### **Acute Exposure**

Acute exposure to technical grade propoxur is very highly toxic to many bird species (EXTOXNET, 1996; U.S. EPA, 1997b). Remarkable variation in the results of dietary studies of the toxicity of propoxur has been reported. Oral LD<sub>50</sub> values for 97 percent ai in a 2 percent bait product range from 4.2 mg ai/kg body weight in mourning doves to 120 mg ai/kg body weight in sharp-tailed grouse (U.S. EPA, 1997b; EXTOXNET, 1996). An unexplained phenomenon where, in some instances, birds of a given species are able to metabolize propoxur has been reported. U.S. EPA (1997b) indicated more confidences in the LD<sub>50</sub> values for Mallard ducks (9.44 mg ai/kg) and Bobwhite quail (1,005 mg ai/kg formulated product). In the diet, subacute 5-day LC<sub>50</sub> values range from 206 ppm in Northern bobwhite quail exposed to an unknown concentration to greater than 5,000 ppm in Mallard ducks exposed to 98.8 percent ai and Japanese quail exposed to an unknown concentration (U.S. EPA, 1997b). The reported oral LD<sub>50</sub> in mule deer is 100–350 mg/kg (EXTOXNET, 1996). Additionally, propoxur has been found to be highly toxic to honeybees (EXTOXNET, 1996).

Propoxur is expected to pose a minimal risk to aquatic organisms because of its limited outdoor bait use (U.S. EPA, 1997b). However, when exposures occur, they pose a slight to moderate acute risks to fish and other aquatic species (EXTOXNET, 1996). In freshwater fish, propoxur is moderately toxic with LC<sub>50</sub> values ranging from >1–10 ppm (U.S. EPA, 1997b). The reported 96-hour LC<sub>50</sub> values range from 3.7 ppm in rainbow trout exposed to 98.8 percent ai to 25 ppm in fathead minnow exposed to 88 percent ai (U.S. EPA, 1997b; EXTOXNET, 1996). The 96-hour LC<sub>50</sub> for bluegill sunfish was reported as of 6.6 mg/L (EXTOXNET, 1996).

Propoxur is more toxic in freshwater and estuarine invertebrates. Acute exposure to technical grade propoxur is very highly toxic to freshwater and estuarine invertebrates with EC/LC<sub>50</sub> values of 0.011 ppm in daphnids, 0.034 ppm in amphipods, 0.18 ppm in stonefly, and 0.041 ppm in pink shrimp (U.S. EPA, 1997b). An oral LD<sub>50</sub> of 595 mg/kg was reported for propoxur in bullfrogs (EXTOXNET, 1996).

#### *Chronic Exposure*

Very little data exist for chronic exposure to propoxur in non-target terrestrial organisms. In birds, no reproductive effects were seen in Northern bobwhite quail fed diets containing greater than 320 ppm (98 percent ai) of propoxur for a number of weeks. No effects on brain cholinesterase were seen at concentrations up to 80 ppm. In Mallard ducks, no reproductive or brain cholinesterase effects were seen in birds fed diets containing 80 ppm (98 percent ai) for 23 weeks. However, reduced egg production and embryo survival were noted at 320 ppm (U.S. EPA, 1997b). Little or no data exist for chronic exposure to propoxur in marine/estuarine organisms. However, no significant accumulation of propoxur is expected in aquatic organisms (EXTOXNET, 1996).