Malaria Indoor Residual Spraying (IRS)

Supplemental Environmental Assessment for President's Malaria Initiative—Indoor Residual Spraying (IRS) for Malaria Control in Liberia using either Lambda-Cyhalothrin, Deltamethrin Bifenthrin, Cyfluthrin, Alpha-cypermethrin or Etofenprox.

January 2009

This publication was produced for review by the United States Agency for International Development. It was prepared by RTI International.

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Contract GH-I-00-06-00002-00

Prepared for
Global Health Bureau
United States Agency for International Development

Prepared by
Tito Kodiaga
RTI International
3040 Cornwallis Road
Post Office Box 12194
Research Triangle Park, NC 27709-2194

SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT FOR PRESIDENT'S MALARIA INITIAVE- INDOOR RESIDUAL SPRAYING (IRS) FOR MALARIA CONTROL IN Liberia

PROGRAM/ACTIVITY DATA:

Program/Activity Number: GH-I-00-06-00002-00
Country/Region: Africa/Liberia
Program/Activity Title: IRS for Malaria Control in Liberia

Sub-activity:

Funding Begin: **Funding End: 2009** **LOP Amount: $1,275,651**

SEA Prepared By: Tito Kodiaga
Current Date: **February, 2009**

IEE Amendment (Y/N): Y
Filename & date of original IEE: xxxxxxxxxxxxxx

ENVIRONMENTAL ACTION RECOMMENDED: (Place X where applicable)

Categorical Exclusion: ____ Negative Determination: _X__
Positive Determination: ____ Deferral: ____

ADDITIONAL ELEMENTS: (Place X where applicable)

CONDITIONS: _X__ PVO/NGO: ____

Other Relevant Environmental Compliance Documentation:
USAID Liberia SO3 Health Portfolio IEE, 2008

SUMMARY OF FINDINGS:

Liberia has been selected as one of the eight new countries to receive funding during the third year of the President's Malaria Initiative (PMI). The objective of this Initiative is to assist African countries, in collaboration with other partners, to rapidly scale up coverage of vulnerable groups with four highly effective interventions: artemisinin-based combination therapy (ACT), intermittent preventive treatment for malaria in pregnancy (IPTp), insecticide-treated mosquito nets (ITNs), and indoor spraying (IRS) with residual insecticides.

Malaria is the leading cause of morbidity and mortality in Liberia. It accounts for over 40% of all outpatient consultations, 18% of inpatient deaths, and is reported to cause approximately 21,000 deaths among children under five years of age. Liberia has 15 counties, all of which have year-long, stable, malaria transmission. The entire population of approximately 3.6 million is at risk of malaria, including the estimated 565,000 children under-five and 188,500 pregnant women.

According to the most recent Malaria Indicator Survey (MIS), conducted in 2005, only 3.2% of children under-5 with fever received first-line treatment for malaria within 24 hours, and only about 4% of pregnant women received any kind of treatment during their pregnancy. Approximately 18% of households owned a net (not necessarily an ITN), and only 2.6% of children under-five had slept under an ITN the previous night. Indoor residual spraying was conducted from 2004-2006 by MENTOR in internally displaced persons (IDP) camps, covering a population of approximately 150,000. No up-to-date information exists on national or county coverage with ACTs or IPTp.

As part of PMI, the United States Agency for International Development (USAID) proposes to implement a pilot Indoor Residual Spraying (IRS) program in Liberia for malaria vector control during the 2009 spray season. USAID is obligated to comply with the Code of Federal Regulations Title 22 Section 216 (22 CFR 216). 22 CFR 216 mandates that detailed pesticide procedures are addressed prior to direct or indirect support of pesticide use. This document fulfills this legal obligation. Additionally, this document seeks to fulfill the Environmental Impact Assessment requirements of the government of Liberia.

The pesticide of choice for use in the planned 2009 IRS activities has not been selected yet but it can be confirmed that it will be a pyrethroid because the Government of Liberia (GOL) through the IRS Task Force has settled on the use of pyrethroids as the preferred chemical for the 2009 spray cycle targeted to begin in March. This Supplementary Environmental Assessment (SEA) thus includes all the WHO approved pyrethroid class of pesticides which are namely; Lambda-cyhalothrin, Bifenthrin, Alpha-cypermethrin, Deltamethrin, Cyfluthrin and Etofenprox.

Engagement with the Environment Protection Agency (EPA) Liberia has been a major part in the preparation review and approval of this report in order to get national regulatory environmental government approval. Thus a similar report has been submitted to EPA for review and approval.

This document relies upon USAID's *Integrated Vector Management for Malaria Vector Control: Programmatic Environmental Assessment* (PEA), the primary resource for providing guidance for IRS implementation that maximizes the safety of workers and beneficiaries and minimizes environmental contamination.

The potential adverse health and environmental impacts of the intervention that could possibly occur during this IRS implementation include transitory, acute health impacts on beneficiaries and spray operators as a result of unintentional pesticide exposure. The adverse impacts will potentially affect the health of the sprayers and the target residents while at the same time affecting the general environment including water, soils, vegetation etc.

Environmental impacts are expected to be minimal but, if they occur, would most likely include negative impacts on fish, aquatic invertebrates, and bees. The Safer Use Action Plan (SUAP) section details the mitigation requirements for the pilot program to minimize these risks to human health and the environment; and assigns roles and responsibilities for these risks reduction actions. Mitigation measures include substantial training for all individuals involved in implementation, community education, utilization of personal protective equipment, and best practices for re-use/disposal of contaminated water from operations.

In this IRS project the potential adverse environmental impacts are expected to be minimal in most of the areas and insignificant in terms of scope, extent, magnitude and nature. Most of the anticipated adverse impacts that could occur will be reversible in nature and temporary in duration.

Anticipated adverse impacts through exposure to the environment or human health including livestock will be avoided, minimized, mitigated, or compensated and corrected if possible before cumulative effects are experienced using the Environmental Monitoring and Mitigation Plan found in this report.

A **negative determination with conditions** is recommended for this project. The conditions are that USAID, USAID contractors, and the MOH&SW implement the risk reduction actions outlined in SUAP. USAID will discuss the compulsory nature of SUAP implementation with the Ministry of Health and Social Welfare (MOH&SW).

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

Expected negative impacts include possible contamination of the natural environment from accidental spills of the insecticide, as well as human health exposure owing to poor handling, negligence or accidents.

APPROVAL OF ENVIRONMENTAL ACTION RECOMMENDED:

CLEARANCE:
Mission Director, USAID/Liberia: _____ Date: 3/09/09
Pamela White

CONCURRENCE:
Environmental Officer, Bureau of Global Health: _____ Date: _____
Teresa Bernhard

ADDITIONAL CLEARANCES:

Mission Environmental Officer
USAID/Liberia: By email Date:3/09/09
Phakatip Chungbhivat

PMI Advisor: By email Date: 3/09/09
Kassahun Belay

Health Team Leader: By email Date: 3/09/09
Christopher McDermott

Regional Environmental
Advisor, USAID/West Africa: By email Date: 3/03/09
Ronald Ruybal

Environmental Officer
Africa Bureau: _____ Date: 3/09/09
Brian Hirsch

SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT FOR INDOOR RESIDUAL SPRAYING (IRS) FOR MALARIA CONTROL IN LIBERIA

by

Tito Kodiaga, RTI International

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EXECUTIVE SUMMARY

Introduction and Study Objectives

This executive summary provides an overview of the Supplementary Environmental Assessment (SEA) for the proposed Indoor Residual Spraying (IRS) intervention to combat Malaria spread in Liberia specifically in Margibi County, Mambah-Kaba district where the spray operations will focus upon.

The National Malaria Control Program (NMCP) in Liberia with funding from the President's Malaria Initiative (PMI) would like to undertake IRS program in Mambah-Kaba District of Margibi County as a PMI funded pilot public health intervention for Malaria control.

Malaria is holoendemic (perennial intense transmission with considerable immunity outside of childhood) in Liberia and a leading cause of morbidity and mortality. Malaria is the leading cause of out-patient department (OPD) attendance (40-45%), and the number one cause of inpatient deaths.

Hospital records suggest that at least 17.8% of inpatient deaths are attributable to malaria, and child mortality rates in Liberia are among the worst in the world (235/1000). An estimated 120,000 children <5 years of age die each year in Liberia based on these figures, putting conservative estimates of malaria-attributable childhood deaths at 21,300 each year. This number may well be underestimated because of a weak surveillance system and poor reporting. Also each year, approximately 167,000 children are born. During pregnancy, both the unborn child and their mothers are highly vulnerable to malaria. The maternal mortality ratio is one of the highest in the world at 760/100,000. Since pregnant women constitute around 5% of the population (approx. 3.6 million), at any given time in a year, approximately 180,000 pregnant women are at risk of malaria each year.

Indoor Residual Spraying (IRS) is one of the interventions selected by the NMCP in Liberia for combating the spread of Malaria in Mambah-Kaba district, Margibi County.

Indoor Residual Spraying is the organized, timely spraying of an insecticide on the inside walls of houses or dwellings. It is designed to interrupt malaria transmission by killing adult female mosquitoes when they enter houses and rest on the walls after feeding, but before they can transmit the infection to another person. IRS has been used for decades and has helped eliminate malaria from many areas of the world, particularly where the mosquitoes are indoor-resting and where malaria is seasonally transmitted.

IRS is a commonly-used malaria vector control method that is particularly effective in preventing malaria epidemics. It is implemented by the application of residual insecticides, to which Anopheles female mosquitoes have been demonstrated to be susceptible, to the interior walls of houses and other structures. Several formulations of insecticides are available for this purpose; those that may be used for this project include both pesticides that can be classified as pyrethroids, cabarmates, organochlorines or organophospates. The Liberia PMI funded project is proposing the use of an insecticide from the pyrethroid class of pesticides.

The objective of IRS programs is to reduce the mean life-span of the female mosquito population in Mambah-Kaba district below the duration required for development of the parasite life phases that occur in the mosquito and, thereby, to substantially reduce the population's ability to sustain malaria transmission. IRS is most effective in areas with seasonal malaria transmission and is typically implemented by teams of

spray operators who spray houses in at-risk localities prior to the rainy season, as heavy rains prompt increases in the *Anopheles* vector population. To be effective, IRS must attain coverage rates of at least 85% of the houses in a target area.

Mambah-Kabah district in Margibi County is the area that has been selected for the implementation of the IRS program in Liberia. The selection of this district was done by NMCP in collaboration with Centres for Disease Control (CDC), USAID and Research Triangle International (RTI). The reason for its selection was because of the high seasonal transmission of malaria that it experiences and being a rural community, lack of resources (funds) due to poverty to procure drugs or ITNs increases their vulnerability.

Research Triangle Institute International (RTI), a USAID contractor, is responsible for providing substantial technical assistance to the National Malaria Control Program (NMCP) Liberia to plan and implement the pilot PMI IRS program. Major components of program implementation that will be supported by PMI through RTI include:

- Purchase of insecticide, spraying equipment, and adequate amounts of personal protective clothing and equipment for staff;
- Financial support for trainers and spray teams;
- Technical advisors to plan the program, train field staff, and supervise field operations;
- Information, Education and Communication (IEC) campaigns to inform beneficiaries, raise public awareness, promote behavior change and promote cooperation;
- Financial support for renting a storage facility for the insecticide, empty sachets, spray and cleaning equipment; and
- Additional human health and environmental safety components as described in the Safer Use Action Plan (SUAP).

Adverse Impacts

The potential negative health and environmental impacts of the intervention that could possibly occur during this IRS implementation include transitory, acute health impacts on beneficiaries and spray operators as a result of unintentional pesticide exposure. The adverse impacts will potentially affect the health of the sprayers and the target residents while at the same time affecting the general environment including water, soils, vegetation etc.

Environmental impacts are expected to be minimal but, if they occur, would most likely include negative impacts on fish, aquatic invertebrates, and bees. The SUAP section details the mitigation requirements for the pilot program to minimize these risks to human health and the environment. Mitigation measures include substantial training for all individuals involved in implementation, community education, utilization of personal protective equipment, and best practices for re-use/disposal of contaminated water from operations.

In this IRS project the potential adverse environmental impacts are expected to be minimal in most of the areas and insignificant in terms of scope, extent, magnitude and nature. Most of the anticipated adverse impacts that could occur will be reversible in nature and temporary in duration.

Expected negative impacts include possible contamination of the natural environment from accidental spills of the insecticide, as well as human health exposure owing to poor handling, negligence or accidents.

Mitigation Measures

Anticipated adverse impacts through exposure to the environment or human health including livestock will be avoided, minimized, mitigated, or compensated and corrected if possible before cumulative effects are experienced. Mechanisms to mitigate adverse impacts include;

- Provision of Personal Protective Equipment (PPE) of standards recommended by WHO for IRS activities to all the spray teams;
- Training of all the spray teams and drivers on good spraying techniques and how to respond in cases of emergency;
- Awareness creating and sensitization of all the targeted residents in the districts on the do's and don't before the spraying and after the spraying to reduce exposure incidents;
- Undertake pregnancy testing for all the female spray candidates and general physical testing for all the spray teams;
- Training of all the surrounding health care facility personnel on emergency response due to acute pesticide poisoning;
- Equipping all the health facilities with the recommended anti-dotes for pesticide poisoning;
- Locating the storage facilities in environmentally sound sites;
- Ensuring that the storage facilities are secure to avoid incidences of pilferage;
- Ensuring sound disposal of after spray pesticide residue; and ensuring that all the empty pesticide sachets and un-used pesticides are locked securely as recommended by WHO until such a time that an appropriate disposal mechanism will be arrived at and this could include shipping the sachets back to the manufacturer.

Compliance with measures described in the SUAP will be monitored on a regular basis by NMCP, Ministry of Agriculture and Environmental protection Authority (EPA). RTI International will also conduct an internal compliance inspection and submit a compliance report to major program stakeholders. Finally, USAID health and environment staff will visit the program site periodically to determine the progress of the IRS campaign as well as to assess compliance with this SEA.

Section L of this report particularly describes the monitoring measures and plans put into place to ensure that compliance is achieved and tracked throughout of the process. It highlights the issues that will be monitored and the responsible parties.

Development of Mitigation Measures in the Environmental Mitigation and Monitoring Plan

An Environmental Mitigation and Monitoring Plan (EMMP) has been designed to implement the measures required manage the environmental impacts of the proposed project. The EMMP is presented in Chapter 8.

Implementation of the EMMP

Ministry of Agriculture

In implementing the EMMP the Ministry of Agriculture at the district level will provide assistance and support in the project to ensure that there is adequate monitoring geared towards ensuring that the pesticides used for IRS do not get diverted into the local market through pilferage. They will use their

inspectors to undertake regular monitoring and inspections. The district agricultural officers will work with RTI to educate the local farmers and see to it that farmers stick to the pesticides they have been using.

Environmental Protection Act

EPA will continue playing its oversight role of ensuring that compliance is achieved in environmental management by undertaking regulatory control measures in pesticide application using its district environmental officers.

Ministry of Health and Social Welfare

This is the main client of the project through the NMCP. This institution as the collaborating partner will ensure that all the aspects of safe application of IRS are followed in accordance with the WHO requirements of the IRS program. NMCP will provide support in training and awareness, mobilization and day to day monitoring of the spray activities.

Recommendations and Conclusion

Well-designed and managed IRS activities such as the proposed program in Liberia have minimal adverse impacts on the environment. RTI has a proven track history in implementing IRS activities in sub Saharan Africa and will employ the best practice elements that it has utilized in other countries to ensure sound environmental protection.

The pesticide class selected for use in Liberia (pyrethroids) 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, pyrethroids are 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, in coordination of movements, paralysis or other disrupted motor functions. These effects are generally reversible because pyrethroids beak down rapidly in the body (IPCS, 1990a; EXTOXNET, 1996). EPA has not classified synthetic pyrethroids as endocrine disruptors.

Pyrethroids are not expected to be prevalent in surface or groundwater because it has extremely low water solubility and binds tightly to soil. In the environment, pyrethroids degrade through biological and photochemical reactions (IPCS, 1990a). Biological reactions are thought to be more important. Pyrethroids will degrade rapidly in soils, remain relatively stable in water, and is usually not found in air due to its low vapor pressure.

The appendix section of this report contains a complete toxicological profile of all the pyrethroid based insecticides that have been approved for use in IRS by WHO for further reference.

In general significant adverse impacts are not foreseen through out the project phase of the IRS project Liberia for as long as the EMMP is followed strictly and any adverse impacts are identified and corrected immediately. However there will be potential short term impacts during the pre-spray phase, spraying phase and post spraying phase. None of the impacts are expected to be long term in nature were they to occur and neither would they be irreversible nor permanent.

ACRONYMS

ACT	Artemisinin-based combination therapy
ADS	Automated Directives System (ADS)
ANC	Antenatal care
BCC	Behavior Change Communication
BMP	Best Management Practise
CDC	Centres for Disease Control
DDT	
DEC	District Environmental Committees
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMMP	Environmental Monitoring and Mitigation Plan
EPA	Environmental Protection Agency Act
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GFATM	Global Fund on Aids Tuberculosis and Malaria
GOL	Government of Liberia
IEC	Information, Education and Communication
IKS	Indigenous Knowledge Systems
INGOs	International Non-Governmental Organizations
IPTp	Intermittent Preventive Treatment for malaria in pregnancy
IRS	Indoor Residual Spraying
ITN	Insecticide-treated Nets
IVM	Integrated Vector Management.
LLINs	Long Lasting Insecticide Treated Nets
MIS	Malaria Indicator Survey
MOH&SW	Ministry of Health and Social Welfare
NMCP	National Malaria Control Program
OPD	Out-Patient Department
PEA	Programmatic Environmental Assessment
PMI	Presidential Malaria Initiative
PPE	Personal Protective Equipment
RTI	Research Triangle Institute
SEA	Supplemental Environmental Assessment
SUAP	Safer Use Action Plan
UNCBD	United Nations Convention of Biological Diversity
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFAO	United Nations Food and Agriculture Organization
UNICEF	United Nations Children Fund
USA	United States of America
USAID	United States Agency for International Development
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme
WP	Wettable Powder

BACKGROUND AND PURPOSE

The Government of Liberia through the Ministry of Health and Social Welfare (MOH&SW) with funding from United States Agency for International Development (USAID) through the President's Malaria Initiative (PMI) and with facilitation by Research Triangle Institute (RTI International) is proposing to undertake Indoor Residual Spraying (IRS) in the rural district of Mambah-Kaba in Margibi County to combat malaria spread and prevalence by applying a chemical (synthetic pyrethroid) on the inner walls of the houses before the onset of the rainy season that generally brings with it increased transmission of malaria by the female anopheles mosquito.

Malaria Burden in Liberia

Malaria is the primary cause of morbidity and mortality in Liberia and will remain so, until effective malaria control is sufficiently scaled up to cover these highly vulnerable communities. The disease is responsible for nearly 50% of all cases seen at health facilities. Data from the nation-wide household malaria survey show that 65% of children under five years have parasites in their blood, 80% of which have clinical signs/symptoms of malaria.

Malaria is endemic in Liberia and is one of the leading public health problems. It accounts for more than 38% of all outpatient consultations and is reported to be the cause of at least 42.3% of in-patient deaths of all ages. Deaths due to malaria in children under five years of age constitute 46.4% of all in-patient deaths and 42.4 % in pregnant women (LMIS, 2005).

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.

1.1 Project Objectives

Liberia covers 43,000 square miles in West Africa and is bounded by nearly 350 mile (greatest length) of Atlantic Ocean coastline off the southwest and by the neighboring countries of Sierra Leone (Northwest), Guinea (North) and Cote d'Ivoire (East and South east). Its greatest width is 150 miles. Liberia is administratively divided into 15 counties and 95 political districts. The country is grouped among the least developed countries in the world ranking 174 out of 175 countries in the UNDP's Human Development Index for 19991. The population in the 2006 World Health Report was 3.58 million.

Liberia has been in a state of intermittent civil war for more than a decade. The latest conflict ended in 2003, and humanitarian assistance groups have been providing much of the services to the Liberian population over the last 2-3 years, including almost all health services. Few health or other indicators were collected over the period of the conflict, but as the country begins to transition from an emergency to a development phase, data has become available and is being collected by a number of organizations. Life

expectancy for females and males is 44 and 41, respectively. The expenditure on health is approximately 5.6% of the GDP. Infant, under-five, and maternal mortality rates are high at 157 (2005), 235 (2005), and 770 (2000), respectively (WHO World Health Statistics). A DHS conducted in the beginning of 2007 reported an HIV prevalence of 1.5%.

Malaria is holoendemic (perennial intense transmission with considerable immunity outside of childhood) in Liberia and a leading cause of morbidity and mortality. The entire population is at risk of acquiring malaria. The major vectors for transmission are *Anopheles gambiae s.s*, *An. funestus*, *An. melas* and the major parasite species are *Plasmodium falciparum* (>90%), *P. ovale*, and *P. malariae*. Malaria is the leading cause of out-patient department (OPD) attendance (40-45%), and the number one cause of inpatient deaths.

Hospital records suggest that at least 17.8% of inpatient deaths are attributable to malaria, and child mortality rates in Liberia are among the worst in the world (235/1000). An estimated 120,000 children <5 years of age die each year in Liberia based on these figures, putting conservative estimates of malaria-attributable childhood deaths at 21,300 each year. This number may well be underestimated because of a weak surveillance system and poor reporting. Also each year, approximately 167,000 children are born. During pregnancy, both the unborn child and their mothers are highly vulnerable to malaria. The maternal mortality ratio is one of the highest in the world at 760/100,000. Since pregnant women constitute around 5% of the population (approx. 3.6 million), at any given time in a year, approximately 180,000 pregnant women are at risk of malaria each year.

Figure 1. Map of Liberia

The 2005 malaria indicator survey (MIS) – the results of which have only recently been finalized -- demonstrated low coverage of treatment and prevention measures for malaria control. These numbers have very likely improved with the work that has been accomplished in the last two years, although with almost 60% of the population without access to health facilities, much remains to be accomplished.

The 2005 MIS showed weak case management practices for malaria in children under-five. Only 5.3% of children with fever were seen within 48 hours (3.5% the same day and 1.8% the next day). Of those treated for fever, only 3.2% received an artemisinin-based combination therapy (ACT), which was the national first-line treatment at the time, while 45.7% received chloroquine (CQ). Other antimalarial drugs used included SP (0.5%) and quinine (QN) (2.5%), while > 38% of children with fever were not given any antimalarial drug.

The purpose for this project is to implement Indoor Residual Spraying in Mambah-Kaba district as a key intervention to reduce malaria transmission using a pyrethroid based insecticide. Indoor Residual Spraying is the organized, timely spraying of an insecticide on the inside walls of houses or dwellings. It is designed to interrupt malaria transmission by killing adult female mosquitoes when they enter houses and rest on the walls after feeding, but before they can transmit the infection to another person. IRS has been used for

decades and has helped eliminate malaria from many areas of the world, particularly where the mosquitoes are indoor-resting and where malaria is seasonally transmitted.

IRS is an effective intervention to the control of malaria spread especially in areas that are categorized as epidemic prone areas because through the use of IRS the vector population is reduced dramatically by killing of the vectors hence reducing incidences of infections.

IRS other than reducing the population density of the female anopheles mosquitoes is also an effective intervention compared to ITNs because most of the malaria spreading vectors are endophilic, i.e. rests indoors and hence by spraying the resting places of these vectors, their population is reduced massively.

1.2 History of Malaria Control in Liberia and Intervention

Indoor Residual Spraying;-The National Malaria Control Program (NMCP) has used IRS sparingly in Liberia. IRS has been recently used primarily for emergency response such as in Internally Displaced Persons (IDP) camps during and post conflict. For 2004-2008 the NMCP has a target of 100% of all IDPs, refugee camps, and temporary shelters to be sprayed with IRS by 2008. Along with the NMCP, MENTOR and CONCERN have implemented IRS in a few counties. A small cadre of expertise exists in country with recent IRS utilization. MENTOR trained approximately 800 individuals as sprayer operators for IRS in the IDP camps; however, they currently have only 20 functional sprayers, no dedicated transport and limited insecticide stock (Alpha-cypermethrin). From September 2004-July 2006 MENTOR sprayed 26,872 shelters covering a population of approximately 148,000. There has been no quality control conducted on the insecticide used, and the original source and expiration date for the Alpha-cypermethrin are unknown. It is unknown and cannot be determined if any IRS activities were being conducted by private companies, e.g., Firestone Rubber Plantation. Neither a pre-IRS environmental assessment nor recent insecticide resistance monitoring of anopheline vector mosquitoes has been conducted. There is no tax/tariff relief on insecticides currently.

Insecticide-treated nets: The 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 also 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. In year one, to support this target, PMI will procure 480,000 LLINs for free distribution through ANCs, and 150,000 for free distribution in Bomi County through a door-to-door campaign. 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 will work 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.

Prevention: Malaria in Pregnancy (MIP); The burden of malaria during pregnancy in Liberia is substantial, yet coverage of prevention measures is inadequate. The 2005 Liberia MIS reported that in the health facilities surveyed, 30.6% of pregnant women coming for outpatient services had malaria. The 2006 Liberia Human Development Report states that malaria is the main cause of severe anemia in pregnant women and a major contributor to maternal mortality. Nonetheless, the 2005 MIS reported that only 6.9% of pregnant women received IPT1 and that only 4.3% of pregnant women received two doses of SP, while

67.6% reported that they had taken some medicine to prevent malaria. Furthermore, 31% of women reported sleeping under a bed net, although not necessarily an ITN. According to the recent DHS, approximately 75-80% of reproductive-aged women had antenatal care from a health professional, but only about 37% delivered in a health facility. A reported 83% of mothers took an antimalarial drug for prevention during pregnancy for their last birth in the five years preceding the survey.

Environmental Management /Larviciding

Environmental management or larviciding has not been used as a vector control mechanism in Liberia before or after the conflict.

Status of IRS implementation

The National Malaria Control Program (NMCP) has used IRS sparingly in Liberia. IRS has been recently used primarily for emergency response such as in Internally Displaced Persons (IDP) camps during and post conflict. For 2004-2008 the NMCP has a target of 100% of all IDPs, refugee camps, and temporary shelters to be sprayed with IRS by 2008. Along with the NMCP, MENTOR and CONCERN have implemented IRS in a few counties. A small cadre of expertise exists in country with recent IRS utilization. MENTOR trained approximately 800 individuals as sprayer operators for IRS in the IDP camps; however, they currently have only 20 functional sprayers, no dedicated transport and limited insecticide stock (Fendona, or alpha-cypermethrin). From September 2004-July 2006 MENTOR sprayed 26,872 shelters covering a population of approximately 148,000. There has been no quality control conducted on the insecticide used, and the original source and expiration date for the Fendona are unknown. We were unable to determine if any IRS activities were being conducted by private companies, e.g., Firestone Rubber Plantation. Neither a pre-IRS environmental assessment nor recent insecticide resistance monitoring of anopheline vector mosquitoes has been conducted. There is no tax/tariff relief on insecticides currently.

The NMCP has very limited malaria vector surveillance or control capacity. There is no laboratory or equipment available for mosquito collection, identification or for determining the resistance status of malaria vectors. Only two individuals on the NMCP staff have IRS experience, and only two of the four sprayers available are functional.

A malaria eradication project was sponsored by UNICEF and WHO, from 1958-61, to ascertain whether transmission could be interrupted with IRS. The project covered the central province of Liberia, an area of ~14,000 km2, using DDT at 2 gm/m2 with one application per year. Entomological investigations showed an apparent disappearance of vectors immediately after spraying; control persisted for up to 26 months. 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.

1.3 Need for Action and the Preferred Alternative

1.3.1 Preferred Alternative

The preferred alternative to combating the malaria spread in Mambah-Kaba is using Indoor Residual Spraying (IRS) to target the malaria spreading vector by applying pyrethroid based pesticides on the walls of houses or structures in Mambah-Kaba district.

IRS is the organized, timely spraying of an insecticide on the inside walls of houses or dwellings. It is designed to interrupt malaria transmission by killing adult female mosquitoes when they enter houses and rest on the walls after feeding, but before they can transmit the infection to another person. IRS has been used for decades and has helped eliminate malaria from many areas of the world, particularly where the mosquitoes are indoor-resting and where malaria is seasonally transmitted.

The objective of IRS is to reduce the mean life-span of the female mosquito population below the duration required for development of the parasite life phases that occur in the mosquito and, thereby, to substantially reduce the population's ability to sustain malaria transmission.

IRS is most effective in areas with seasonal malaria transmission and for this reason, the NMCP has, based on entomological data selected Mambah-Kaba district in Margibi County as the areas where the IRS program will be undertaken as a pilot under the PMI program. The malaria transmission season in Mambah-Kaba district begins in April and for this reason, the IRS activity is expected to commence in March just before the transmission season in order to reduce the population's ability to sustain malaria transmission.

1.3.2 Insecticide Choice

The preferred insecticide of choice is a pyrethroid which is one of the main classes of insecticides that are approved by WHO Pesticide Evaluation Scheme (WHOPES) for use in IRS. The pyrethroid pesticide that will be selected from the class of pyrethroids will be applied in the recommended concentration and dose as recommended and approved by WHOPES.

There are other classes of WHOPES approved pesticides in IRS that can be used and were considered in the alternative pesticide section of this report (See section 2). These classes are organochlorines, organophosphates, and carbamates.

1.3.3 Application Methodology

The insecticide of choice will be purchased by RTI using international practices in procurement through competitive bidding and following the criteria for selection of the best bids and outlined in the bid documents. Once a supplier is selected based on the bid selection criteria, the insecticides will be freighted to Monrovia airport and thereafter transported in closed containerized trucks and secured in the Liberia's Medical stores owned by the MOH&SW.

Inventory of the insecticides will occur at all points of the freight beginning with the first stop which is at the airport where RTI's logistics team will verify that the quantities supplied tallies with the request made as indicated in the airway bill.

From the Liberia's Bio-Medical Research Institute's stores in Monrovia, the insecticides will be transported to RTI's rented warehouse in Mambah-Kaba district where the spray operations will concentrate on. This warehouse rented by RTI will be refurbished to ensure that it meets United Nations Food and Agriculture Organization (UNFAO) requirements for pesticide storage and will be managed by RTI's logisticians and manager. All the insecticides transported to the RTI's warehouse will be inventoried and recorded by the logistics manager.

Every day in the morning before the spray operations begin, the spray operators will be handed between 8-10 sachets by the store manager and must sign out all pesticide received daily and return empty sachets or unused pesticides at the end of the day.

RTI has developed standard requisition, tracking and monitoring forms that have been used to inventory, record and track all the insecticides given out and returned. These forms will be used in Liberia's program and the store managers will receive training on how to use these forms. The steps below highlight the insecticide distribution process including recording and tracking methods.

- At reception at central 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 provincial warehouse where distribution takes place and 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 district office, all sachets are counted and stamped with the relevant district stamp and registered on a stock card.
- Only enough can refills for the day's work are issued to each spray operator, with their code written on the sachet. These sachets are signed for by the spray operator in a log book.
- At the end of the day, empty and full sachets are returned and number checked against what was signed for. Returned empty and full sachets are signed in by the store keeper or supervisor into the log book.
- Supervisor examines spray operator performance by comparing number of structures sprayed to can refills used to see if there is an over or under application.
- Store keeper must submit on a daily basis (1) insecticide stock balances, (2) sign-in/sign-out results and (3) structures sprayed per spray operator to central RTI office for data entry.
- The next day all previously signed but unused sachets are re-issued and again signed for by the relevant spray operator.
- At the end of each day and at the end of the spray round, stock remaining = stock at start - number of sachets distributed. Number of sachets distributed should be equal to number can refills used.

1.3.4 Training of Spray Operators

The individuals recruited for IRS campaigns will receive intensive training on the use, operation, calibration and repair of the sprayer and practical exercises during a 21-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).

Potential spray operators must also pass written and practical tests at the end of training. In this way, spray operators will be prepared to conduct appropriate application of the insecticide.

Spray operators will initially be chosen based on their completion of primary school. Their ability to read, write and make calculations, as well as a medical exam to determine fitness for implementation of the activity. Pregnancy tests will be conducted as part of the medical exam to ensure that pregnant women are not included on the spray teams. This training will be conducted by RTI's staff in conjunction with MOH&SW.

1.3.5 Residential Awareness

In all IRS operations, the risk of residential exposure is also present and cannot be overlooked. District authorities and program staff will work with relevant boards, committees, and non-governmental organizations to carry out an IEC campaign to sensitize residents to IRS activities, in accordance with WHO guidelines. The IEC campaign (as well as IRS Program team leaders and supervisors who will also instruct residents on best practices prior to spraying) will focus on the following elements of residential safety during the 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 if possible
- stay outside the home during spraying and for four hours after spraying
- move and keep all animals outside the home during spraying, and for four 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.

1.3.6 Household Selection

All the structures/households in Mambah-Kaba district will be targeted for the spray operations and none will be omitted from the spray operations. As mentioned earlier, IRS operations only become effective if coverage of over 85% is achieved. Therefore all the structures that are used for sleeping or relaxing at night will be targeted during the spray operations. Prior to the spray operations, the communities will be informed about the operations using different communication and education methods in advance so that they are well prepared. The overall objective of IRS is to spray all the resting surfaces of the vector and therefore when a lower percentage of house coverage is achieved, what this means is that the vectors will be residing in the unsprayed houses and hence completing their transmission cycle.

1.3.7 Equipment Decontamination

Water used to rinse out sprayers 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 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, and so on; the seventh container is empty).

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 (the uncommon situations where more insecticide returns is where the distance to the new site makes it difficult for the team to reach to empty their sprayers. Even then, the amount coming back will be less than a full drum or 220 litres). 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.

Soak Pit. The site for the soak pit may be selected by the environmental authority (soak pits are usually sited at the highest point at the IRS depot/storage site and away from the natural path of run-off water). Depending on the size of the operation, you can construct a small or large pit. Usually an area of three meters by three meters (or nine square meters) is excavated to a depth of one meter. The bottom of the pit is packed with hard coal or charcoal. This is followed by saw dust (where this is feasible) and stone aggregates. The area is then fenced off to keep domestic animals and children out of the soak pit area. Because there is no loose soil, it serves as a nice area where washing of overalls can be done. The soak pit is also good for drying overalls, laying them either on top of the stones or over the fencing. The entire soak pit area is fenced complete with a lockable access door to prevent unauthorized entry by children, or animals.

2.0 Alternatives Including the Proposed Action

2.1 Alternative IRS Pesticides or Chemical

2.1.1 Pyrethroids-Preferred IRS Chemical

The pesticide of choice for the 2009 spray cycle according to a decision made by the IRS Task Force in Liberia will be from the pyrethroid class of pesticides and will either be Lambda-cyhalothrin, Cyfluthrin, Deltamethrin, Alpha-cypermethrin, Bifenthrin or Etofenprox. These are all WHO approved pesticides as reflected in the WHOPES. At this time the actual pesticide has not been selected and can only be known when the bidding process is complete. However, pyrethroids exhibit similar characteristics and therefore the only point that would lead to selection of a given pesticide is the cost implication, and the time it will take the suppliers to deliver the pesticide of choice.

The points below outline the criteria used in this PMI program to select a pesticide. This criteria is based partly on WHOPES requirements, host country requirements and USAID regulations.

2.1.2 Insecticide Selection criteria

The selection of a pesticide for use in IRS is the sole prerogative of the host country however, the process is guided by the by the following threshold criteria that must be met in making decisions on pesticides used in malaria vector control:

- Must be a World Health Organization Pesticide Evaluation Scheme (WHOPES) approved pesticide and should be preferred based on their safety as described in USAID's Programmatic Environmental Assessment for Integrated Vector Management.
- Must be registered for use in the country in IRS by Ministry of Agriculture, Health or any other recognized entity.
- Must be a pesticide accepted by the National Malaria Control Program (NMCP)
- Should have a residual effect of more than 4 months (effective on the types of walls for a period longer than, or at least equal to the average duration of the malaria transmission season in the area)
- Malaria vectors in the region must be susceptible to the insecticide and demonstrate a low toxicity to human and external environment
- Must demonstrate low risk to the environment, livestock and agriculture in terms of toxicity
- Pesticide must be appropriate for use in the wall surfaces of the selected location
- Cost of the insecticide should be competitive against others.
- Host country must demonstrate capacity to prevent pilferage

As mentioned above and shown in the table 1 below pyrethroids are WHOPES approved, have a residual effect of more than 4 months and more importantly the vectors in the area are susceptible to this class of pesticides as demonstrated by entomological studies undertaken by Liverpool Associates for Tropical Health (LATH).

Further more, pyrethroids have been accepted by NMCP and the IRS Task Force as demonstrated in the IRS Task Force meeting held in (See annex 1). Pyrethroids have a low toxicity to livestock and the

environment compared to other class of pesticides, and pyrethroids are known to be effective on all forms of wall surfaces.

It should be noted that Liberia has not institution responsible for registration of pesticides so this criteria was not applied. The other reason why pyrethroids were selected was because the country coming out of war does not have adequate institutional structures for controlling pilferage. Therefore selecting for example DDT which was the second best preferred alternative would bring with it the absolute predicament of containing pilferage.

2.2 Other Alternative Insecticides

World Health Organization Pesticide Evaluation Scheme (WHOPES) has approved the following insecticides in the table 1 below for use in IRS. This section describes why these other classes of pesticides were considered but rejected.

Table 1.

WHO recommended insecticides for indoor residual spraying against malaria vectors

Insecticide compounds and formulations (1)	*Class group (2)*	*Dosage (g a.i./m²)*	*Mode of action*	*Duration of effective action (months)*
DDT WP	OC	1-2	contact	>6
Malathion WP	OP	2	contact	2-3
Fenitrothion WP	OP	2	contact & airborne	3-6
Pirimiphos-methyl WP & EC	OP	1-2	contact & airborne	2-3
Bendiocarb WP	C	0.1-0.4	contact & airborne	2-6
Propoxur WP	C	1-2	contact & airborne	3-6
Alpha-cypermethrin WP & SC	P	0.02-0.03	contact	4-6
Bifenthrin	P	0.025-0.05	contact	3-6
Cyfluthrin WP	P	0.02-0.05	contact	3-6
Deltamethrin WP, WG	P	0.02-0.025	contact	3-6
Etofenprox WP	P	0.1-0.3	contact	3-6
Lambda-cyhalothrin WP, CS	P	0.02-0.03	contact	3-6

(1) CS: capsule suspension; EC = emulsifiable concentrate; WP = wettable powder.
(2) OC= Organochlorines; OP= Organophosphates; C= Carbamates; P= Pyrethroids.

Note: WHO recommendations on the use of pesticides in public health are valid ONLY if linked to WHO specifications for their quality control. WHO specifications for public health pesticides are available on the WHO homepage on the Internet at http://www.who.int/whopes/quality/en/.

2.2.1 Organochlorine Alternative (DDT)

The Stockholm Convention seeks the elimination of twelve chemicals or classes of chemicals, one of which is 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane, or DDT1. DDT is still used in indoor spraying primarily for control of vectors of malaria and visceral leishmaniasis. In negotiations that led to the treaty, there has been concern that a sudden ban on DDT use could adversely affect the malaria burden. Thus, DDT was permitted to be produced and used for the purpose of controlling disease vectors in accordance with WHO recommendations and guidelines and when locally safe, effective, and affordable alternatives are not available.

DDT was the only other alternative chemical that was strongly considered and recommended for use in 2009 by NMCP but was rejected on a temporary basis with a possibility of future use pending detailed environmental impact analysis of its use. The use of DDT was rejected owing to the following reasons;

1. Environmental effects

As a persistent molecule, DDT has low to very low rates of metabolism and disposition, depending on ambient temperatures. In tropical environments with high temperatures and solar radiation, DDT is less persistent than in temperate environments. It is degraded slowly into its main metabolic products DDE and DDD, which have similar physico-chemical properties but differ in biological activity. DDT is emitted through volatilization and runoff. It is more volatile in warmer than in colder parts of the world which, through long-range atmospheric transport, results in a net deposition and thus gradual accumulation at high latitudes and altitudes.

Loss through runoff is low because DDT has a strong affinity for organic matter in soils and aquatic sediment, but is virtually insoluble in water. Half-lives of DDT have been reported in the range of 3-7 months in tropical soils65, 66 and up to 15 years in temperate soils. The half-life of each of its metabolic products is similar or longer. DDT readily binds with fatty tissue in any living organism and, due to its stability, bio-concentrates and bio-magnifies with increasing trophic level in food chains. The half-life of DDT in humans is more than 4 years; the half-life for DDE is probably longer. DDT is highly toxic to insects, shrimps and fish, and adversely affects the reproduction of wild birds through thinning of egg shells.

Most of the DDT and its metabolic products present in the global environment originate from its large-scale use in agriculture and domestic hygiene in the past. Current use under the Stockholm Convention is allowed only for indoor spraying for disease vector control. Thus, use is much smaller than in the past. Nevertheless, DDT that is sprayed indoors may end up in the environment, even if it is sprayed on walls according to best practice. Little attention has been paid to this issue. A simple modelling study predicted that 60-82% of DDT was physically removed from house walls within six months after spraying, but verification through empirical study is needed. Data from Brazil, India, Mexico and South Africa suggested that higher levels of DDT are found in water or soil samples in areas with DDT residual spraying than in areas without spraying, but these results need further verification.

Conclusion: DDT used for indoor spraying could have adverse environmental effects, an aspect that requires close monitoring and investigation and because Liberia lacks adequate institutional and technical capacity for close monitoring environmental effects its immediate use was rejected. However, the government is seriously contemplating DDT use in the next spray cycle and would like a detailed analysis on the implication before doing so.

2. Inadequate Legislation

Liberia already as indicated and explained in (background section) previously used DDT in IRS and yet it does not have adequate legislation or capacity to implement or enforce regulations on pesticide management especially DDT as required by the Stockholm Convention. As a matter of fact Liberia does not have any legislation in relation to DDT or even legislation for the management of chemical pesticides including DDT.

An additional problem which has been reported is the suspicion of illegal trafficking and use of DDT in sectors other than health, particularly in the agricultural and domestic environment in Liberia. Enforcement of pesticide regulation is insufficient in Liberia to avoid misuse or leakage outside the health sector, particularly in Liberia where there are long, porous borders.

Conclusion: DDT used for indoor spraying could have adverse environmental effects owing to the lack of legislative capacity in Liberia to prevent pilferage or export to neighboring countries hence its use was rejected for this reason.

3. Exposure levels

High levels of human exposure to DDT among those living in sprayed houses, most of who are living under conditions of poverty and often with high levels of immune impairment, have been found in recent studies in South Africa and Mexico, but contemporary data from India, the largest consumer of DDT, are lacking. The simultaneous presence of, and possible interaction between, DDT, DDE and pyrethroids in human tissue is another area of concern.

Exposure of the foetus and young child occurs through the placenta and through lactation, and exposure of children and adults occurs through direct contact with DDT in the environment, indoor soil and household dust, and through the food chain. DDT accumulates in fatty tissue and is slowly released. Populations in adjacent regions and temperate regions may be indirectly affected by indoor spraying of DDT through long-range atmospheric transport. A monitoring system is needed for the assessment of trends in exposure to DDT, and allowing for the attribution of effects to IRS locally; in this regard, human milk is considered an important media to be monitored.

Conclusion: Indoor spraying with DDT is increasing the exposure intensity. DDT may still be needed for malaria control in the short term but, as the evidence base on some of the more serious and chronic disease outcomes is mounting, the adverse health effects of those at risk needs to be urgently revisited. It is for this reason that DDT was rejected.

4. Monitoring and evaluation

In the context of the Stockholm Convention, a process of reporting by each Party that uses and/or produces DDT is in place. A Register has been established for this purpose. By means of a questionnaire, Parties are asked to report every three years on their production, storage, use, conditions of use, regulations, control, resistance monitoring, safety, capacity, and alternatives in relation to DDT. However, the response rate has been poor. Parties that use DDT need trained personnel and a proper infrastructure to monitor the use, export and import of DDT. Donors and funding agencies aiding in the purchase of DDT should be obligated to provide adequate financial assistance to ensure that proper regulations are in place and should be required to provide a situation report to WHO or UNEP annually.

Conclusion: DDT used for indoor spraying could have adverse environmental effects owing to the lack of legislative capacity in Liberia to prevent pilferage or export to neighboring countries hence its use was rejected for this reason.

Therefore cognizant of the potential adverse impacts of using DDT as specified above, an IRS task force was formed comprising representatives from EPA, Ministry of Health, NMCP, Ministry of Lands Mining and Energy, USAID and MENTOR Initiative. The responsibility of this task force was to determine the implication of using DDT for IRS in 2009 bearing in mind the regulatory requirements related to procurement of DDT, environmental approvals and the time frame.

The Task Force deliberated on this matter and on the 2nd of December 2008, the committee concluded that while DDT has been recommended as one of the better insecticides for IRS in Liberia, the time frame for which to obtain environmental approval to purchase, import and utilize this insecticide is significantly longer than for pyrethroids. This is more so due to the several control measures required by the US Government before any support related to the use of DDT is accepted. For this reason, DDT was rejected for use in 2009 but will be considered for use in 2010 subject to the fulfillment of all the environmental requirements by EPA and US Government.

2.2.2 Carbamate Alternative

Carbamates, or urethanes, are a group of organic compounds sharing a common functional group with the general structure -NH(CO)O-. Carbamates are esters of carbamic acid, NH2COOH, an unstable compound. Since carbamic acid contains a nitrogen attached to a carboxyl group, it is also an amide. Therefore, carbamate esters may have alkyl or aryl groups substituted on the nitrogen, or the amide function. For example, ethyl carbamate (trivial name "urethane"), is unsubstituted, whereas ethyl N–methylcarbamate has a methyl group attached to the nitrogen (see methyl isocyanate for formation of N-methylcarbamates). Insecticides approved by WHOPES for use under the class of carbamates are 2 namely Bendiocarb and Propoxur. These 2 insecticides Bendiocarb and Propoxur were considered and rejected because of the following reasons;

1. Toxicity to Non Target Organisms

Compared to insecticides from the pyrethroid class which is the preferred chemical of choice, in terms of toxicity to non target organisms, carbamates exhibit a stronger degree of toxicity than pyrethroids as shown in the table xx below.

2. Residual Effect

Liberia has one annual transmission season and for this reason, the pesticide of choice for use in IRS should be one that can last for over at least over 6 months on the wall to sustain the residual effectiveness. Carbamates do not have this long residual effect as compared to pyrethroids or DDT which are the preferred chemicals. Pyrethroids have a residual effect of 3-6 months whilst carbamates range from between 2-6 months. Hence this being a critical requirement the use of carbamates was rejected.

3. Residential / Occupational Exposure

Like other carbamates, it reversibly inhibits acetylcholinesterase, an enzyme required for normal transmission of nerve impulses. Bendiocarb and Propoxur bind to the active site of this enzyme leading to an accumulation of acetylcholine, which is required for the transmission of nerve impulses, at nerve muscle sites. The fact that carbamates inhibit cholinesterase raises key concerns on exposure impacts and effects as compared to pyrethroids that do not have these characteristics. Furthermore as compared to pyrethroids, carbamates demonstrate a higher risk through occupational exposure as compared to pyrethroids that show a low risk as shown in table 2. This factor caused the rejection of carbamates as a pesticide of choice.

4. Ground Water Contamination

The spray area is surrounded by water bodies that are considered as ecologically sensitive in nature and hence the risk from contamination is elevated. According to the table below, carbamates demonstrate a high risk in terms of ground water contamination as compared to pyrethroids.

Table 2. Risk Results for Groundwater Contamination[1]

Risk Below Level of Concern	Low Risk	Moderate Risk	High Risk
DDT		Alpha-cypermethrin	Bendiocarb
		Bifenthrin	Etofenprox
		Cyfluthrin	Fenitrothion
		Deltamethrin	Malathion
		Permethrin	Methoprene
			Pirimiphos-methyl
			Propoxur

This table reflects exposure to pesticides from dermal contact and ingestion of groundwater contaminated with pesticides that have been buried.

Key	
Risk Below Level of Concern	HQ < 1
Low Risk	HQ 1 to <10
Moderate Risk	HQ 10 to < 100
High Risk	HQ ≥ 100

Source IVM PEA.

2.2.3 Organophosphate Alternative

There are only 3 types of organophosphates that have been approved by WHOPES for use in IRS and they include Malathion, Fenitrothion and Primiphos-methyl. This class of insecticide was considered as a possible alternative chemical to pyrethroids but rejected due to the following reasons;

1. Residual Effect

Organophosphates lack a long residual effect on the wall required to complete a single annual transmission season as experienced in Liberia. The above pesticides last on the wall for between 2-3 months or 3-6 months. As a matter of fact only Fenitrothion exhibits a residual effect of between 3-6 months as compared to pyrethroids where all the pesticides in that class can sustain up to 6 months residual effect. A pesticide that lasts longer is required and for this reason organophosphates were rejected.

2. Residential/Occupational Exposure

Compared to pyrethroids, organophosphates demonstrate a high risk in terms of exposure to residential and occupational exposure as shown in table 4. This factor leads to a high preference to pyrethoids than to organophosphates.

3. Toxicity to Non Target Organisms

Compared to insecticides from the pyrethroid class which is the preferred chemical of choice, in terms of toxicity to non target organisms, carbamates exhibit a stronger degree of toxicity than pyrethroids as shown in the table 3 below.

Table 3.

IRS Insecticide	Mammal	Bird	Fish	Other Aquatic	Bee	Persistence	Bioaccumulate1
Alpha-cypermethrin							
Bendiocarb							
Bifenthrin							
Cyfluthrin							
DDT		2					
Deltamethrin							
Etofenprox							
Fenitrothion							
Lambda-cyhalothrin							
Malathion							
Pirimiphos-methyl							
Propoxur							

Bioaccumulation in the environment, not in mammalian bodies (mammalian detoxification produces different results).
[2] Low toxicity, but high chronic or bioaccumulation affect on raptors, pelicans.

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

Table 4.

Occupational Exposure				Residential Exposure			
Risk Below Level of Concern	Low Risk	Moderate Risk	High Risk	Risk Below Level of Concern	Low Risk	Moderate Risk	High Risk
Alpha-cypermethrin	Bendiocarb	Propoxur	DDT	Alpha-cypermethrin		Malathion	DDT
Bifenthrin	Cyfluthrin		Fenitrothion	Bifenthrin			Fenitrothion
Etofenprox	Lambda-cyhalothrin		Pirimiphos-methyl	Bendiocarb			Pirimiphos-methyl

Deltamethrin	Malathion			Cyfluthrin			
				Deltamethrin			
				Etofenprox			
				Lambda-cyhalothrin			
				Propoxur			

Source; IVM PEA

2.3 Alternative Spray Site

2.3.1 Selection Criteria of IRS Site

The choice of an IRS spray site is largely driven by the type of mosquito species, the malaria prevalence or transmission rate in the area including whether it is an endemic or epidemic prone area. Therefore IRS normally is targeted to areas where there is evidence of high transmission or prevalence, or malaria endemism or possibility of epidemics are known or suspected. In most cases in a given country many areas will have the above mentioned characteristics and hence the overall decision on a site is determined or decided upon by the host country i.e. Ministry of Health. In the case of Liberia, the decision to choose the preferred site was based on the above specifics and eventually decided upon by the IRS Task Force comprising of Ministry of Health and Social Welfare, EPA, NMCP, Ministry of Agriculture with technical advice from USAID, CDC and RTI. (See annex 1 for minutes of the meeting leading to the choice of site)

2.3.2 Preferred Location-Mambah-Kaba

Mambah-Kaba district in Margibi County was chosen because of the above reasons and more importantly because it is in a rural setting where severe malaria and malaria mortality is generally of greater percentage and thus an IRS campaign in a rural setting would provide a greater impact. This does not mean that Mambah-Kaba region is the only area that exhibits a high prevalence of malaria cases.

Mambah-Kaba is one of the rural districts in Margibi County and is about 20kms from Monrovia the capital of Liberia. More background information of the project location is found in section 3 of this report.

2.3.3 Alternative Locations-Red Hill, Crabe Hole, Logan and Clara Town

The above urban settings, Red Hill, Crabe Hole, Logan and Clara Town were initially considered as possible IRS spray locations by the IRS Task Force. Generally the urban settings of Red Hill, Crabe Hole, Logan Town and Clara Town have been the preferred choice for implementation based on a needs report prepared by the IRS Task Force in December 2, 2008 and presented to the Minister of Health.

However, several issues of efficiency and effectiveness arose in regard to these urban settings, hence favoring a rural setting of Mambah-Kaba for the initial campaign. Specifically, the following points raised by

the IRS Task Force necessitated the rejection of the urban setting as spray sites and led to the selection of the rural Mambah-Kaba area.

- *Anopheles melas* have been observed in the mentioned urban areas above but not the rural areas- IRS is not particularly effective where this breed of mosquito is present due to their feeding habits

- In the urban setting there is greater population movement and access to multiple drug stores and clinic which confounds data, and therefore is not ideal for initial campaigns where significant monitoring is paramount to the success of the rest of the community.

2.4 Alternative IRS Solid Waste Disposal

2.4.1 Preferred Disposal Method-Incineration

The preferred disposal method of IRS pesticide solid waste that is cost effective and environmentally sound is incineration using specialized incinerators that must meet certain specifications and standards.

The empty insecticide sachets and other contaminated IRS solid wastes including gloves, masks and covering sheets require disposal in an environmentally and internationally accepted manner as prescribed by FAO/WHO with regards to disposal of pesticide wastes. The IRS wastes will be disposed using an incinerator that will be identified in Monrovia.

Incineration is highly recommended by the United Nations Environment Program (UNEP) WHO/FAO in relation to pesticide waste disposal, especially for primary and secondary packaging materials and contaminated single use clothing.

WHO and FAO jointly note that in relation to the disposal of pesticides, *Pyrethroids can be incinerated without major limitations in an appropriate high temperature incinerator with emission control equipment or in an appropriate cement kiln. . . .*[1] and that, *High temperature incineration is currently the most widely established and economical disposal option*,[2] compared to alternative options such as base catalyzed dechlorination, gas phase chemical reduction, or use of plasma arc.

Generally, according to WHO/FAO, incinerators recommended for this kind of waste disposal must meet the following key requirements, among others:

- The recommended combustion temperature is between 1,100°C and 1,300°C.

[1] World Health Organization (1990). *Cyhalothrin and Lambda-cyhalothrin Health and Safety Guide No. 38.* International Program on Chemical Safety. Geneva: WHO. Accessed June 6, 2008, http://www.inchem.org/documents/hsg/hsg/hsg038.htm.

[2] 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.

- 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.

Therefore at this point it is anticipated that the project will use an incinerator in Liberia that meets the above mentioned specifications in the disposal of the IRS solid wastes. There is a possibility that this type of incinerator might not be available in Liberia especially recognizing the fact that this is a country that has just emerged from conflict and hence existing infrastructure is inadequate. If this is the scenario arrived at during the assessment and identification process, the project will consider the following 2 options;

2.4.1 Use of Cement kilns/Furnaces

The use of cement kilns or furnaces are considered ideal for the disposal of pyrethroid solid waste, and we will also assess these facilities, where they exist, as possible alternatives.

2.4.2 Shipment to neighboring countries

The project will also explore the possibility of exporting the waste to neighboring countries especially Ivory Coast a neighboring country where there is an existing incinerator capable of disposing pesticide wastes. Export to a different country will require the fulfillment of inter-governmental requirements for the transportation of hazardous wastes as per the Stockholm Convention and RTI will facilitate this process of this is the resorted alternative.

2.5 Alternatives Disposal Methods Considered and Rejected

The following IRS waste disposal mechanism were considered but rejected mainly because of the high technological advancement of these methods and the absence of these types of infrastructure in Liberia. They include;

2.5.1 Autoclaving

Autoclaving is an efficient wet thermal disinfection process. Typically, autoclaves are used in hospitals for the sterilization of reusable medical equipment. They allow for the treatment of only limited quantities of waste and are therefore commonly used only for highly infectious waste, such as microbial cultures or sharps. It is recommended that all general hospitals, even those with limited resources, be equipped with autoclaves.

The advantages and disadvantages of autoclaving wastes are the same as for other wet thermal processes discussed in the subsequent sections below. The physical requirements for effective steam autoclave treatment are normally different from those required for sterilizing medical supplies. Minimum contact times and temperatures will depend on several factors such as the moisture content of the waste and ease of penetration of the steam.

Research has shown that effective inactivation of all vegetative micro-organisms and most bacterial spores in a small amount of waste (about 5–8kg) requires a 60-minute cycle at 121°C (minimum) and 1 bar (100kPa); this allows for full steam penetration of the waste material. Figure 4 shows an on-site steam autoclave for health-care waste treatment.

2.5.2 Base Catalyzed Dechlorination

The BCD process involves the addition of an alkali or alkaline earth metal carbonate, bicarbonate or hydroxide to the contaminated medium containing one or more halogenated or non-halogenated organic contaminant compounds. The BCD patent indicates that the alkaline chemical may be added to the contaminated medium in an aqueous solution, or in a high boiling point solvent. If the chemical is added in the form of a solid dispersion or suspension in water, the water assists in distributing the metal compound homogeneously throughout the contaminated medium. If the chemical is added with a high boiling point solvent, the solvent must have a boiling point of at least 200oC, and preferably be in the range from 200oC to about 500oC. Otherwise, it will distil from the mixture during treatment.

Alkali is added to the contaminated medium in proportions ranging from 1 to about 20 percent by weight. The amount of alkali required is dependent on the concentration of the halogenated or non-halogenated organic contaminant contained in the medium.

A hydrogen donor compound is added to the mixture to provide hydrogen ions for reaction with the halogenated and non-halogenated contaminants, if these ions are not already present in the contaminated material. The hydrogen donor compound may comprise the high boiling point solvent in which the alkali or alkaline earth metal compound is added, or it may include fatty acids, aliphatic alcohols or hydrocarbons, amines or other similar compounds. In order to activate these compounds to produce hydrogen ions a source of carbon must be added, either in solution or in suspension. An inexpensive carbon source which is water soluble and suitable for use, is a carbohydrate such as sucrose.

The mixture is heated at a temperature and for a time sufficient to totally dehydrate the medium. This may be performed at atmospheric or at reduced or elevated pressure. The water which is included in the aqueous solution allows homogeneous distribution of the alkali throughout the mixture and acts as a wetting agent and penetrant. When the water is removed from the medium during the dehydration step, the alkali is concentrated to a reactive state.

After dehydration, the medium is further heated at a temperature between 200oC and 400oC for a time sufficient to effect reductive decomposition of the halogenated and non-halogenated organic contaminant compounds, typically 0.5 to 2 hours. At this temperature the carbon source (eg the carbohydrate) acts as a catalyst for the formation of a reactive hydrogen ion from the hydrogen donor compound.

This method was rejected because the type of technology is unavailable in Liberia and the cost implication is enormous.

2.5.3 Encapsulation

Disposal of pesticide wastes in municipal landfills is less advisable if it is untreated than if it is pre-treated. One option for pre-treatment is encapsulation, which involves filling containers with waste, adding an immobilizing material, and sealing the containers. The process uses either cubic boxes made of high-density polyethylene or metallic drums, which are three-quarters filled with sharps and chemical or pharmaceutical residues. The containers or boxes are then filled up with a medium such as plastic foam, bituminous sand, cement mortar, or clay material.

After the medium has dried, the containers are sealed and disposed of in landfill sites. This process is relatively cheap, safe, and particularly appropriate for establishments that practice minimal programs for the

disposal of sharps and chemical or pharmaceutical residues. This technology is viable but was rejected due to the cost of this type of investment.

2.5.4 Gas Phase Chemical Reduction

GPCR is a non-incineration technology that uses hydrogen to reduce the contaminants down to their basic components. In the case of chlorinated hydrocarbons (such as PCBs), the basic components are methane and hydrochloric acid. Because hydrogen is used, rather than oxygen (as in incineration processes), there is no risk of forming dioxins and furans during the GPCR reactions. Contaminants are conveyed to the GPCR reactor, which has a hydrogen atmosphere, and is heated to a temperature of about 875°C. The combination of heat, hydrogen and steam breaks down the contaminants into *methane* and *hydrochloric acid*. The *hydrochloric acid* is neutralized with a caustic solution (sodium hydroxide), which creates slightly salty water. This water is held and tested to ensure it is clean, before it is reused in the plant as cooling water, or disposed of. This technology was rejected because it is expensive and unavailable in Liberia.

2.6 No Project Alternative

Indoor Residual Spraying is a critical intervention among the other interventions in the control of the spread of malaria. This is more so due to the fact that IRS is targeted at attacking the malaria vector and preventing or reducing transmission hence minimizing cases of incidences that would then be mitigated through curative approach. IRS is a preventive approach to reduce the incidence of succumbing to the malaria parasite because it reduces the vector population drastically hence bringing down the incidences and cases of malaria. As described in the paragraph below, a no project scenario/alternative will mean that the status quo is maintained and the malaria situation will remain the same. In effect the 25,000 households targeted under the IRS program will not have the benefit of IRS as an intervention. This way the no action alternative does not meet the overall goal of the President's Malaria Initiative which is to reduce the cases of malaria transmission, malaria related mortality in Africa and seeks to reduce malaria mortality by 50% in up to 15 countries (total population: 175 million) in sub-Saharan Africa in five years.

Hospital records suggest that at least 17.8% of inpatient deaths are attributable to malaria, and child mortality rates in Liberia are among the worst in the world (235/1000). An estimated 120,000 children <5 years of age die each year in Liberia based on these figures, putting conservative estimates of malaria-attributable childhood deaths at 21,300 each year. This number may well be underestimated because of a weak surveillance system and poor reporting. Also each year, approximately 167,000 children are born. During pregnancy, both the unborn child and their mothers are highly vulnerable to malaria. The maternal mortality ratio is one of the highest in the world at 760/100,000. Since pregnant women constitute around 5% of the population (approx. 3.6 million), at any given time in a year, approximately 180,000 pregnant women are at risk of malaria each year.

The 2005 malaria indicator survey (MIS) – the results of which have only recently been finalized -- demonstrated low coverage of treatment and prevention measures for malaria control. These numbers have very likely improved with the work that has been accomplished in the last two years, although with almost 60% of the population without access to health facilities, much remains to be accomplished.

USAID's direct support of IRS activities to the Ministry of Health and Social Welfare in Mambah-Kaba district will result in protection through IRS against malaria for approximately 25,000 households.

Targeted intervention to combat malaria in this district is expected to lead into reduced incidence of adult morbidity, miscarriages, low birth-weight, and adverse effects on fetal neurodevelopment. It will also reduce incidence of malaria-related childhood anemia, complications, organ failure, and death.

The no-project scenario will mean the status quo of the area remains and no occurrence of adverse impacts as well as positive impacts posed by the project implementation. The no project option will have the forgone costs and benefits highlighted above. The table 5 below describes the alternatives in a summary form.

Table 5. Alternatives Considered and Preferred		
	IRS Campaign using Registered insecticides, including: Lambda-cyhalothrin Deltamethrin Bifenthrin Alpha-cypermethrin Cyfluthrin Etofenprox	USAID support would include the following components: • Purchase of insecticide, spraying equipment, and adequate amounts of personal protective clothing and equipment for staff; • Financial support for trainers and spray teams; • Technical advisors to plan the program, train field staff, and supervise field operations; • IEC to inform beneficiaries, raise public awareness, promote behavior change and promote cooperation; • Financial support for renting storage facilities for insecticide, spraying equipment, personal protective clothing and empty insecticide sachets • Financial support and technical assistance for additional human health and environmental safety components, including updating infrastructure for responsible disposal of contaminated wash-water (e.g. soak pit) at Mambah-Kaba. • Financial and technical support for empty sachet disposal as needed according to the requirement of the Pesticide Board and international guidelines
Alternatives Considered but not Selected		
	ITN/LLIN Program	The 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 also 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. In year one, to support this target, PMI will procure 480,000 LLINs for free distribution through ANCs, and 150,000 for free distribution in Bomi County through a door-to-door campaign. 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 will work 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.
Alternatives Considered and Rejected		
	Alternative IRS Chemicals	Organophosphates (Fentrothion, Malathion, Primo,; Carbamates(Bendiocarb, Propoxur), Organochlorines (DDT)

	Larviciding and Environmental Management	Larviciding and environmental management are strategies not currently listed in the National Malaria Strategic Plan.
	Alternative Locations	Red Hill, Crabe Hole, Logan and Clara Town
	No Project Alternative	Status quo is maintained and PMI does not support IRS Program in Mamba-Kaba.

3.0 AFFECTED ENVIRONMENT

3.1 Overview County/District

Position and Size

Margibi is a county on the north to central coast of the West African nation of Liberia just about 45 minutes' drive from Monrovia. 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."

One of 15 counties that comprise the first-level of administrative division in the nation, it has four districts. Kakata serves as the capital with the area of the county measuring 2,616 square kilometres (1,010 sq mi). As of the 2008 Census, it had a population of 199,689, making it the sixth most populous county in Liberia.

The county is bordered by Montserrado County to the west, Grand Bassa County to the east, and Bong County on the north. The southern part of Margibi lies on the Atlantic Ocean.

Administrative and Political Units

Districts of Margibi County include;

- Firestone District (57,251)
- Gibi District (13,232)
- Kakata District (88,130)
- Mambah-Kaba District (41,076)

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.

3.2 Physical Environment

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."

Figure 2. Topography of Margibi County

Rainfall

The country has two seasons: rainy and dry seasons. The rainy season is from May to October, and the dry season runs from November to April. Average annual rainfall along the coastal belt is over 4000 mm and declines to 1300 mm at the forest-savannah boundary in the north (Bongers and others 1999). The months of heaviest rainfall vary from one part of the country to another, but are normally June, July and September 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 till 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.

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.

Observations concerning the diurnal distribution of rainfall prove that two-thirds of the rain along the coast, particularly in Monrovia and its environs, falls during the night between 18.00 and 07.00 hours. Most of the rest of the rain usually falls during the morning while only a minimum of rain is recorded between mid-day and early afternoon. This is one of the reasons why the rainy season in Liberia is not as inconvenient and disturbing as in other parts of West Africa. Data on Liberia's isokeraunic (thunderstorm) condition is not available, but 150 thunderstorms days per annum have been recorded at Roberts International Airport (Schulze 1975).

Humidity

Relative humidity is generally high throughout the country. Along the coastal belt it does not drop below 80 per cent and on average is above 90 per cent. There is a wider variation in the interior, where it may fall to below 20 per cent during the harmattan period. A relative air humidity of 90-100 per cent is common during the rainy season.

In Monrovia, the relative humidity shows a relationship with the existing air temperature and its variation depends on the prevailing season and the hour of the day. During the dry season it decreases to 80-85 per cent. In March and February the driest period of the year, relative air humidity may be as low as 65 per cent. Regardless of the season, the relative humidity at night and in the early morning is usually in the range of 90-100 per cent. Data from other weather stations such as Bomi Hills, Harbel and Greenville show similar results.

Only the zone, north of the Inter-Tropical Front, where the continental air masses prevail from mid-December to end of January show arid conditions. At times due to the extreme dryness of the harmattan, the humidity may drop to below 50 per cent (Schulze, W. 1975).

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 and Soils

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."

3.3 Biological Environment

Vegetation

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

3.4 Socioeconomic Environment

The county is ideally situated along the Atlantic Ocean in 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, to name but two.

Margibi County is famous for its numerous rubber plantations, paramount among them being the Firestone and Salala plantations. These institutions have been instrumental in providing jobs and other basic services including schools, shelter, and health care for thousands of inhabitants of the County. 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. "

The constraints to agricultural growth are many, as shown in the below table. Chief among them is a lack of capital for purchase of the various inputs that are missing. Because the population does not have access to credit and savings products, there is little possibility for communities to increase production to match their potential.

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. With the renegotiated concessions agreements, this situation should change. Participants in the CDA consultations called for the establishment of a rubber processing plant to transform raw materials into finished products, and thereby keep these value-adding jobs in Liberia. For smallholder producers, the CDA participants called for the Rubber Development Fund to support the Margibi Rubber Planters Association (approximately 1,500 farmers) to increase yields and strengthen linkages with larger rubber companies to give smallholders access to international markets.

Figure 3. Plantation Farming in Margibi

Firestone

While replanting its trees, Firestone is also rebuilding homes, schools, hospitals and infrastructure, thus contributing to improve the quality of life for employees and local communities. With the re-negotiated concession agreement with Firestone, the opportunity for growth and job creation stems from the following actions of the Company:"

- Hire only Liberian citizens for unskilled positions
- Give preference to qualified Liberian citizens at all skilled and management job levels, with at least 30% of senior management positions to be held by Liberian citizens within 5 years, and at least 50% within 10 years.
- Provide on-the-job and vocational training for Liberian citizens
- Provide $115,000 through 2015, and thereafter $150,000 annually in scholarships for Liberian citizens, with a 25% to be reserved for Margibi County students
- Provide $50,000 annually to the University Of Liberia's College of Agriculture
- Give preference in procurement to goods produced in Liberia by Liberian citizens and services provided by Liberian citizens who are resident in Liberia
- Require its affiliates and major sub-contractors to also give preference to such goods and services
- Provide 700,000 rubber stumps per year of the same quality it uses for its own replanting to qualified Liberian Rubbers farmers, free of charge
- Sell at its own cost farm supplies to qualified Liberian rubber Farmers
- Contribute $50.000 to the independent study to be commissioned by the Ministry of Agriculture on ways to" support and enhance the rehabilitation of natural rubber industry in Liberia and to assist smallholders
- Support government efforts to amend the law governing the Rubber Development Fund, financed on export fees on rubber and government appropriations, to be independently and transparently managed to support

Figure 4. Firestone Plant in Margibi

Fisheries

There has been a global trend in recent years towards more fish and fish products being sold in fresh chilled or frozen form, as opposed to the traditional forms of preservation in developing countries of salting or drying. This is partly the result of greater availability of ice and cold storage facilities in developing countries, but also due to the increased demand for frozen/fresh imports in developed countries. Given the location of Liberia and current and planned flight connections, the EU and USA are likely to provide the main overseas markets for high value fresh/chilled products in the future. Of course, strong demand for traditionally processed products still remains in the region."

Figure 5. Fisheries in Margibi

Buyers and regulators in developed country markets have become increasingly stringent about the quality, health and hygiene standards, and traceability/labeling of products sourced from overseas. Concerns over these issues have resulted in a wide range of legislation governing trade in fish products with which exporters must comply, along with various assurances about supplies of product now required by buyers in overseas markets.

Regulations have increasingly shifted the burden of responsibility for controlling the quality of exports to exporting countries." 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.”

At the time of writing, BNF data show just 230 tonnes of transshipped/exported product for 2007 to date. However, given the complete lack of any form of MCS in Liberian waters, it is likely that illegal and unreported exports from transshipments are very significant." Fish imports are recorded as being 4,738 tons in 2004, 11,072 tonnes in 2005, and 2,562 tons for the first half of 2007. Due to a large discrepancy between the fee charged on locally-caught and landed product ($25/ton) and the duty charged on imports ($2/tonne), it is very likely that a proportion of ‘imports’ is in fact product caught in Liberian waters, frozen at sea, and then brought in as imports by reefer vessels having been transshipped at sea from fishing vessels."


Figure 6. Artisinal fisherfolk in Margibi

Artisinal fish landings were estimated to be 7,700mt in 2004 (CAAS-Lib, 2007), while BNF data on industrial catches (all made under individual vessel licensing arrangements rather than any bilateral agreements) show an average annual reported catch over the period 1997 to 2006 inclusive of 7,682 tons.

Such figures are likely to be a significant under estimate. Tuna catches are primarily caught by purse seine vessels, and destined for tuna canneries. ICCAT data suggest that there are good levels of tuna catches in the West African region in and just outside the Liberian EEZ, and that catches of yellowfin, skipjack and bigeye tuna taken in the Liberian EEZ averaged around 5,000 tons over the period 1990 to 2002.

Table 6. Species Biomass Estimate

Species	Biomass Estimate
Pelagic	
S. aurita	31000
S. maderensis	17000
Carangis, scombrids, baraccuda, haritail	16000
Sardinellas and ancovies	37000
Dermasals	
Sparids	7800
Haemulids	190
Scianedis	4600
Lutjanids	710
Serranids	0
B. auritus	8400
Sharks	1070
Rays	1950
Cephalopods	680
Total	**126400**

Source NBF.

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. The citizens have called for a commitment from Firestone to invest $10 million in a rubber wood facility to produce sawn timber, kiln dried lumber and veneers, with an expected start date for the main plant of mid-2008. 500 persons would be expected to be employed, initially increasing to 1,000.

Du River in Margibi County

Courtesy of UNDP Energy and Environment Programme

Figure 7. Timber products

Demography

Population

Pending the results of the ongoing national census, there is no definitive population figure for Margibi County. Since the last population census in 1984, there have been attempts on the part of several institutions to conduct a census, but they were carried out in a manner that suited the institutions' own scope of operation. Thus, what has been gathered over the years cannot be regarded as comprehensive.

Table 7. County Population Projections

Population (census 1984)	151792
1997 Population Projection	205,465(LISGIS)
2006 Population Projection	211,733(LISGIS)
2006 Household Population	35,288.82 (LISGIS)
Population	240,996 (NRC 2006)

The Ministry of Rural Development in collaboration with UNICEF conducted a village profile assessment between September 2004 and January 2005. Findings from that assessment are presented below.

Table 8. Population Per Electoral District

County	District	Population
Margibi	Firestone	16664
	Gibi	8217
	Kakata	66921
	Mambah-Kaba	
Total		

The below population table is extracted from the Norwegian Refugee Council Needs Assessment report, "Returnees Monitoring Program", published in 2007.

Table 9. Population Estimates by Districts

Margibi								
District	Total	Population by Status				Population by status-percentage		
		Local	Returness	IDPs	Refugees	Local	Returness Ref. & IDPs	IDPs
Firestone	41681	39286	2393	2	0	94.25%	5.74%	0%
Gibi	24184	24135	34	15	0	99.80%	0.14%	0%
Kakata	101903	100208	1382	313	0	98.34%	1.36%	0%
Mambah-Kaba	73223	55389	17571	266	2	75.64%	23.99%	0%
Total	240996	219018	21380	596	2	90.88%	8.87%	0%

Source; Norwegian Refugee Council January 2007.

Water, Energy 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."

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 among the 290 recorded by the Norwegian Refugee Council 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.

Health

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. Both facilities badly need ambulances, renovation and supplies for full operation. 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 International Non Governmental Organizations (INGOs). Firestone Liberia actively participates to vaccination campaigns for the eradication of childhood diseases.

4.0 Complementary and Conflicting Policies, Plans or Controls for the Areas under Consideration

Liberia is just emerging from conflict and therefore does not have adequate legislations or policies that guide the procurement and use of pesticides. However the single most significant legislation that has a greater degree of bearing to this project is the Environmental Protection Agency (EPA) Act. This Act supersedes other legislations and is the overarching document that ensures the protection of water resources, fisheries, biodiversity and others. The Agriculture Act and Environmental Protection Agency Act are the only two legislations that can be referenced as bearing significance to the project and for which the project team must be aware about.

4.1 Environmental Protection Agency Act, 2008

This is an Act that was formed to establish a monitoring, coordinating and supervisory authority for the sustainable management of the environment in partnership with regulated Ministries and organizations and in a close and responsive relationship with the people of Liberia; and to provide high quality information and advice on the state of the environment and for matters connected therewith.

The Agency shall be the principal authority in Liberia for the management of the environment and shall co-ordinate, monitor, supervise and consult with relevant stakeholders on all activities in the protection of the environment and sustainable use of natural resources.

Section 32
Right and Responsibility to a Clean and Healthy Environment
1) Every person in Liberia has the right to a clean and healthy environment and a duty to take all appropriate measures to protect and enhance it through the Agency, the judicial process, the Environmental Court established under this Act and any appropriate organizations established for the purpose in accordance with this Act and any other written law;

Section 37
Environmental Impact Assessment
1) The Agency shall require that an environment impact assessment be undertaken on all projects, policies, programs and activities specified by the Agency in consultation with relevant ministries and agencies and published by notice;

2) A developer, or project proponent, shall not commence, carry out, execute, implement or conduct a project or activity for which an environmental impact assessment is required unless an environmental impact assessment has been concluded and an environmental regulations made there under;

3) A licensing or permitting agency or authority under any law in force in Liberia shall not issue a license for any project for which an environmental impact assessment is required under the Act, unless the applicant produces to the licensing agency or authority an environmental impact assessment license or permit issued under this Act and the regulations made there under; and

4) The Agency shall establish all rules, regulations and procedures relating to the implementation of the environmental impact assessment requirement under this Act, and which shall be reviewed five years after implementation date to assure their effectiveness.

This Act is vital in the implementation of this IRS program in the following ways;

The program must prepare an Environmental Impact Assessment (EIA) Report prior to the commencement of the IRS operations for review by EPA and approval. This EIA report contains an EMMP which is a document that the project commits to follow in order to ensure best practice.

Failure to adhere to this law and follow the best practice could lead to cancellation of the EIA license which would put a stop to the project implementation. Therefore the project team needs to be thoroughly familiar with the contents of the EMMP and must observe best practice through monitoring and supervision.

A permit will be issued by EPA which is an EIA license given by the authority after review of the EIA report. This permit is the single document that shows EPA's satisfaction with the EIA report.

4.2 Agriculture Act.

The Ministry of Agriculture was established on 11th May 1972 by an Act of Legislature, repealing the former Act establishing the Department of Agriculture. It has the mandate to work for the development of agriculture in the nation, and the improvement of the economic well-being and general welfare of the Liberian farmers.

This Ministry Agriculture of the Republic of Liberia is responsible for the development of the agriculture sector. It does so by ensuring that an effective organizational structure is put in place and is manned by staff capable of planning, coordinating, and implementing, monitoring and evaluating agricultural development programs from time to time. It also ensures that the staff and farmers are trained to cope with the challenges of the agricultural activities. The Ministry also ensures that the agricultural problems that impede production are investigated and solutions found, and the farmers are provided the supportive services and the enabling environment.

The Ministry of Agriculture does not have a department responsible for registration of pesticides. As a matter of fact, Liberia lacks effective institutions for controlling import and use of pesticides hence a major weakness and challenge when dealing with pesticides. It has a division of Quarantine that is supposed list all the companies that are involved in pesticide importation but this division is under staffed and does not execute its services well.

Table 10. Summary of Legislative Requirements

Legislation	Significance	License/Permit	Responsibility	Action
EPA Act	Require EIA report before approval for commencement of project.	Issues EIA license after which project can commence	RTI is responsible for preparing and submitting the EIA report.	EIA report should be prepared and submitted before operations begin.
	Environmental Audit required at the end of spray operations to ascertain level of compliance and correct negative actions.	No license issued but acknowledgment of audit report provided. Failure to submit audit report could lead to a halt in spray operations	RTI is responsible for preparing and submitting the EA report at the end of the operations	EA report should be prepared and submitted at the end of the operations.
Agriculture Act	All pesticides to be procured must be reviewed by the	No Permit is given	RTI will present the list of pesticides it	

	Quarantine Division in the Ministry of Agriculture. There is no pesticide registration body in Liberia.		intends to procure to the division for information.	

4.3 International Conventions

Liberia is a signatory to the following United Nations conventions that have a direct bearing on the IRS program. These are the international conventions that Liberia must respect when undertaking the IRS operations.

4.3.1 Ramsar Convention on Wetlands of International Importance

The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. There are presently 158 Contracting Parties to the Convention, with 1831 wetland sites, totaling 170 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance. The project area has wetlands and is close to the Atlantic Ocean hence the need to ensure that no form of activities of the IRS program could jeopardize the tenets of this convention especially through contamination of these resources through pesticide spills.

4.3.2 Basel Convention Prohibiting the Transboundary Movement of Chemicals

The Basel Convention (verbose: Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal) is an international treaty that was designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries (LDCs). It does not, however, address the movement of radioactive waste. The Convention is also intended to minimize the amount and toxicity of wastes generated, to ensure their environmentally sound management as closely as possible to the source of generation, and to assist LDCs in environmentally sound management of the hazardous and other wastes they generate. This convention is relevant to the program should the option of disposing the IRS solid waste in another country be considered as the most viable option. The project will have to ensure that the waste is shipped in accordance with this convention.

4.3.3 Stockholm Convention on Persistent Organic Pollutants

The Stockholm Convention on Persistent Organic Pollutants aims to protect human health and the environment by banning the production and use of some of the most toxic chemicals known to humankind. The Convention became international law in May 2004, was ratified by New Zealand in September 2004 and entered into force for New Zealand on 23 December 2004. Persistent organic pollutants (POPs) are chemical substances that persist in the environment, bioaccumulate through the food chain, and pose a risk of causing adverse effects to human health and the environment. Liberia is a signatory to the Stockholm convention which among others is aims at reducing the presence of the following chemicals in the environment;

- Nine pesticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, hexachlorobenzene, and toxaphene)
- PCBs (polychlorinated biphenyls)
- Dioxins and furans (polychlorinated dibenzo-p-dioxins or PCDDs, and polychlorinated dibenzofurans or PCDFs).

The disposal of the IRS solid waste through incineration is likely to lead to emission of Dioxins and Furans listed above and therefore the project must ensure that this does not happen in order to comply with this convention.

4.3.4 Convention on Biological Diversity

Signed by 150 government leaders at the 1992 Rio Earth Summit, the Convention on Biological Diversity is dedicated to promoting sustainable development. Conceived as a practical tool for translating the principles of Agenda 21 into reality, the Convention recognizes that biological diversity is about more than plants, animals and micro organisms and their ecosystems – it is about people and our need for food security, medicines, fresh air and water, shelter, and a clean and healthy environment in which to live. The project area has numerous diverse biological resources that must be protected in order to achieve the objectives and principles of the convention.

Table 11. Summary of Legislative Requirements

Legislation	Significance	Responsibility	Action
Ramsar Convention	This convention is concerned with the protection and conservation of wetlands of critical importance. The convention calls for the utmost protection of these resources of international importance and implementation of activities that would contravene this convention could lead to a series of international condemnation.	RTI must ensure that its activities do not contravene the tenets of the Ramsar convention.	Strict implementation of the EMMP by RTI to avoid destroying or adversely impacting such sites.
Stockholm/Basel Convention	These conventions are concerned with ensuring that the transportation and disposal of hazardous wastes occur in accordance with the requirements of this convention. IRS waste is categorized as hazardous by this convention and must be disposed in the required manner.	If RTI opts to transport the wastes to a neighboring country a license will be required from the secretariat and cooperating government. Any facility picked to dispose the waste will have to meet the Stockholm convention requirements.	RTI will facilitate the process of acquiring this license if this option is decided upon.
Convention on Biological Diversity	This convention governs the conservation and protection of biological resources. The spray area has a variety of diverse biological resources that must be conserved and protected according to this convention.	All activities implemented by RTI during the IRS program must not threaten biological resources in the area including pollution.	

5.0 ENVIRONMENTAL CONSEQUENCES

This section addresses the potential direct and indirect impacts of the proposed project. In this report, environmental impacts are defined in totality to mean, socio-economic, cultural, physical as well as biological. The chapter is structure into two parts one describing positive impacts of the development and the second part addressing the adverse impacts of the project on the environment.

The project impacts are classified as positive to mean beneficial or adverse to mean negative.

5.1 Positive Effects

The project positive effects include providing of protection against malaria to approximately 25,000 of the targeted households as a result of indoor spraying of structures with a chemical capable of reducing the transmission capacity of the malaria vector. This protection is expected to reduce the incidence of adult morbidity as a result of malaria, miscarriages caused by malaria during pregnancies, low birth-weight among children, and adverse effects on fetal neuron-development. It will also reduce incidence of malaria-related childhood anemia, complications, organ failure, and death.

5.1.1 Indirect Effects

Indirect effects can be considered equivalent to "irreversible commitments of resources," in that support of malaria vector control interventions may result in procurement of pesticides, equipment, storage facilities, vehicles, or other commodities that can be used for purposes other than those intended or that adhere to best practices.

Through this action, USAID will be providing the District Health Office with backpack compression sprayers, unused chemicals, used boots. Upon completion of this program, USAID will no longer supervise the use of this capital which will be handed over to NMCP. The IRS program will also indirectly contribute in the spurring of the local economy in the following ways albeit indirectly; The spray operators, washers, supervisors will all receive a daily payment for their work, vehicles will be hired at a cost for transporting the spray teams all that could be attributed as economic effect. There will be capacity building in form of training of the spray operators and clinicians and this form of capacity building can be termed as an indirect positive effect.

5.2 Potential Adverse Impacts

Adverse impacts of project are those unintended effects of the project that are negative to sustainable development and the environment. This study has delineated the potential adverse impacts in accordance to the different phases of the project. In effect, the possible adverse impacts have been presented beginning from the Pre-spray (Construction Phase); The Spray (Operation Phase) and Post Spray (Decommission) stage.

5.2.1 Physical Environment Exposure Risk

1. **Contamination of surface water courses**

All pyrethroids considered are toxic to fish and other aquatic organisms. Thus the primary concern in pyrethroid use for IRS would be the following the possible release of the pyrethroids into the existing water bodies as described in section 4 above. Accidental spills during the transportation of the pesticides or during application can cause surface water contamination hence adversely impacting on the water and aquatic resources.

Part of the villages to be sprayed in Mambda-Kaba district lie along the shores of the Atlantic ocean and along the Du River which is found in Margibi and thus provides a probable situation where this water mass can be possibly contaminated by accidental pesticide release during the spraying process. This ecosystem is critical and any form of contamination from the use of pesticide during spraying could interfere with the integrity and ecology of this ecosystem that supports vast biodiversity and livelihoods.

2. Impacts on Aquaculture

The aquatic resources in the Atlantic Ocean and the existing rivers could be at risk especially if accidental spills during transport and IRS operations occur. However any negative impact on aquatic resources and water mass itself should be transitory and exceptionally limited given the type and quantities of pesticides involved and any impact would be spread out over the larger fishing population. During the operations, bearing in mind that the local fisher folk use nets as a form of artisinal fishing, adverse impacts on fisheries could occur if the fishing nets that are mostly hung in the houses are not removed during the preparation of the houses. This could potentially contaminate the fishing nets and end up polluting not only the water bodies used for fishing but could kill the aquatic resources.

3. Underground Water Contamination

During the disposal of used rinse water after the daily spraying in the soak pits or accidental spills could highly impact on the underground water resources in the project area especially if the rinse water is disposed anyhow in the environment.

4. Soil Contamination

Any accidental release of the pesticide in large quantities during the transportation, storage and application of the chemical is likely cause soil contamination at the point of spill and considering the fact that the soil type is loamy in nature the impacts could be adverse. This impact is highly unlikely however steps have been put in place to ensure that accidental spills are mitigated as quickly as possible.

5. Livestock and Non Target Organism Exposure

Pyrethroids are generally considered the safest insecticides that can be used in IRS, although individual pyrethroids impacts on mammals range from low to high toxicity. Pyrethroids as indicated in the table below shows a high toxicity to large mammal. As a general precaution, all livestock must exit the house for four hours after spraying. After re-entering the home, dead insects from home should be collected and thrown into a pit latrine to prevent pets and livestock (particularly chickens and guinea-fowl) from eating them.

Pesticide residue is also known to remain on the wall surfaces and sometimes drip on the ground after the spray activity and in effect could end up causing harm to livestock including chicken, goats, and cows if they get in contact with surfaces that have been sprayed immediately after the spraying. Further more if chicken or other fowls including ducks feed on dead insects not targeted by the IRS they could be at risk through poisoning. The residents of the district all keep livestock and include cows, goats, ducks, chicken, sheep among others. ."One percent of households surveyed in Margibi County own goats, another 6% owned pigs, 6% owned ducks and 39% owned chickens. "

This impact can be avoided if the mitigation measures proposed are pursued. However, in terms of significance and magnitude, it could lead to loss of life by livestock if poisoning were to occur.

Table 12. Toxicity of IRS Insecticides to Non Target Organisms)

IRS Insecticide	Mammal	Bird	Fish	Other Aquatic	Bee	Persistence	Bioaccumulate1
Alpha-cypermethrin							
Bendiocarb							
Bifenthrin							
Cyfluthrin							
DDT		2					
Deltamethrin							
Etofenprox							
Fenitrothion							
Lambda-cyhalothrin							
Malathion							
Pirimiphos-methyl							
Propoxur							

Source IVM PEA.

Bioaccumulation in the environment, not in mammalian bodies (mammalian detoxification produces different results).
[2] Low toxicity, but high chronic or bioaccumulation affect on raptors, pelicans.

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

5.2.2 Human Exposure Risks/Impacts

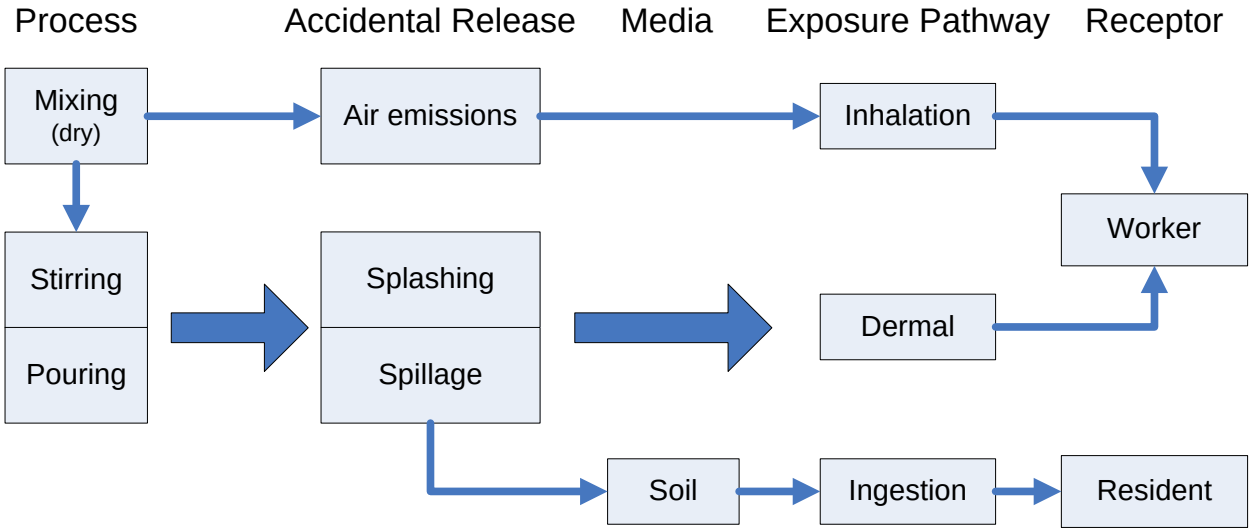
1. Worker Exposure and Resident Exposure

Through out the IRS spraying process, the spray team is at risk of exposure to the adverse effects of the chemical and this can arise from unintentional or deliberate exposure through accidents or poor and improper handling of the spray chemical altogether during the spraying. Worker exposure to the chemical could arise during the pre-spraying, spraying and after spraying phase of the IRS operations in the district.

2. Pre Spraying Exposure

Preparing pesticide solutions during the IRS will involve pouring the pesticide in the spray can 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 floors. Figure 8 below shows the possible modes of exposure during preparation of pesticides for IRS.

Figure 8. Conceptual Model for Possible Exposure Pathways from Preparation of Pesticide



3. Exposure during Spraying

Inhalation of aerosol vapors during spraying is the main process for worker exposure during IRS. 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. The figure below shows the possible modes of exposure during preparation of pesticides for IRS use by the sprayers in Mambah-Kaba.

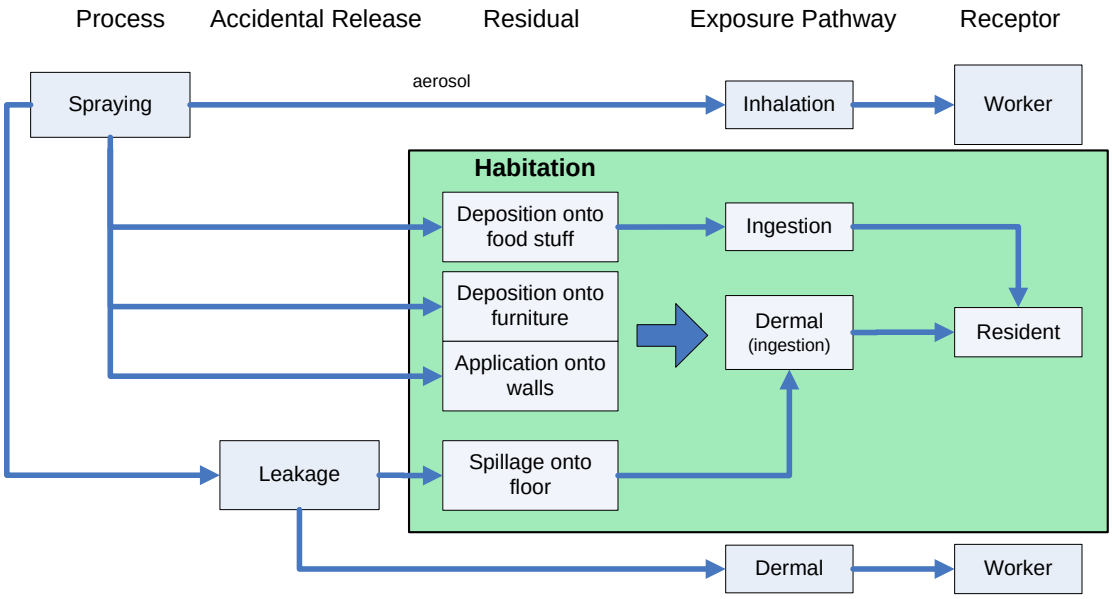


Figure 9. Conceptual Model for Possible Exposure Pathways from IRS

Exposure of the worker and the residents to the insecticide can be greatly reduced if the worker and residents follow best practices. Even if best practices are followed, workers should be closely monitored for acute symptoms, because there will always be some level of exposure. In addition, work-day duration should be monitored to limit exposure as required by safety recommendations (Najera and Zaim, 2002).

4. 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.

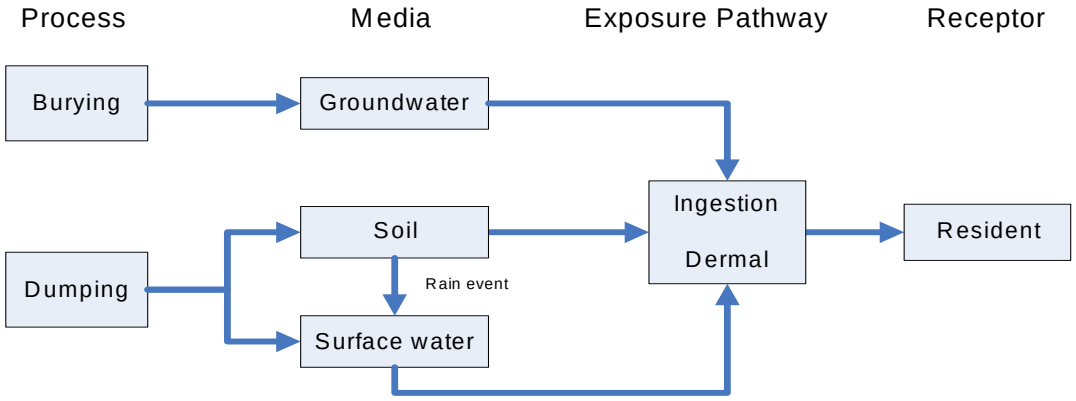
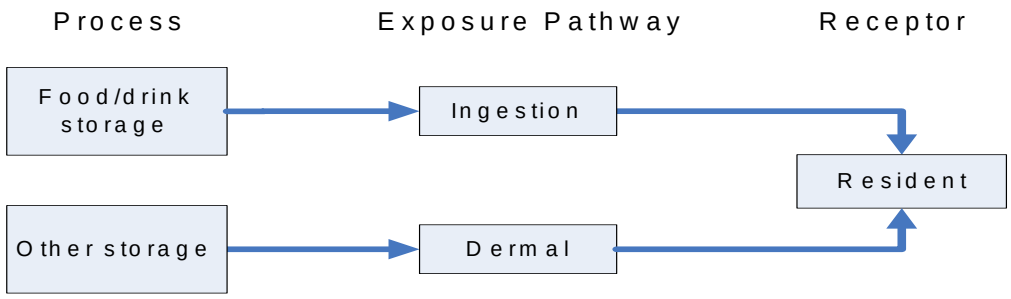


Figure 10. Conceptual Model for Possible Exposure Pathways from Disposal of Excess Pesticide Formulation

5. Reuse of Pesticide Containers

Reuse of pesticide containers occurs when best practices for disposal are not followed. Pesticides, especially those bought in bulk amounts, come in large, screw-on top containers that are made of extremely durable materials (i.e., plastics and metals); as a result, the desire to reuse is strong.

Secondly during the daily end of spray rinsing buckets and basins are used for washing and rinsing respectively. These containers if re-used can cause exposure to the person(s) and hence adverse effects.
A conceptual model for reuse of pesticide containers is presented in Figure 11 below. Sturdy pesticide containers might be improperly reused to store water or dry food, such as mill or flour, leading to ingestion exposures from drinking water and dermal exposures to the water or food.



5.3 Other possible Impacts through Exposure

1. **Foetal Exposure Impacts**

Female spray operators are at great risk of fetal exposure from the pesticide especially if they get involved in the spray activities when they are already expectant. Exposure of expectant female sprayers to pesticides during spraying has been documented to lead to serious implications of the condition and health of not only the mother but also the fetus.

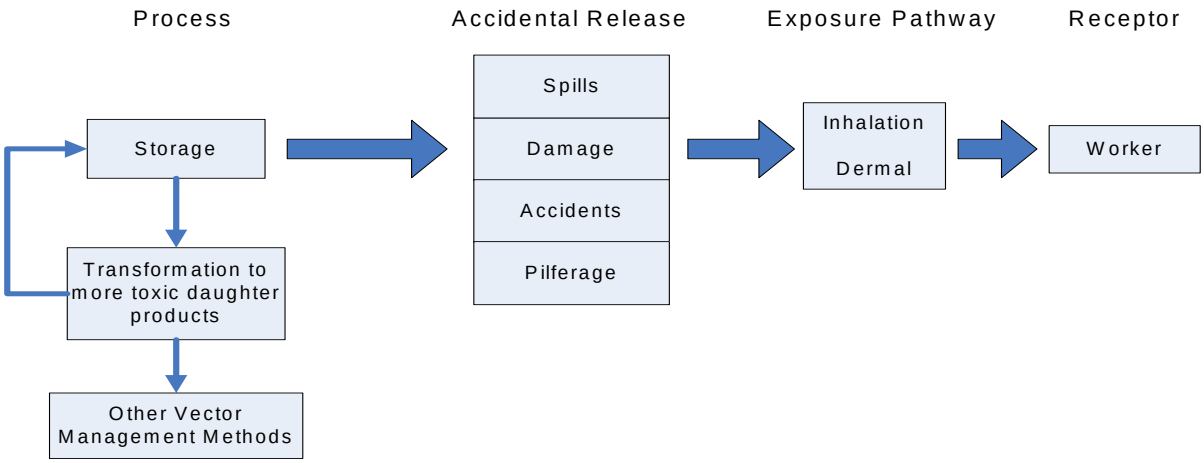
2. **Pilferage of Pesticides**

Proper storage of pesticides is just as important as the recommended use concentrations. Like any potentially harmful chemical, precautions must be taken to minimize any harm or contamination of the environment from the pesticide. United Nations Food and Agriculture Organization's Pesticide Storage and Stock Control Manual provides guidelines for the construction and maintenance of large storehouses, and the major principles in these guidelines should guide the location, construction, and management of temporary local storage facilities.

Pesticides used for IRS remain a temptation to persons who could pilfer these products for re-sale in the market for agricultural use. Pyrethroid based insecticides have a variety of indoor and outdoor uses, including the control of mosquitoes, household and ornamental plant pests, and fire ants. Pilfering can occur in the warehouses (storage facilities) if they are not well secured or during the spraying process if the sprayers pilfer the daily provided pesticides.

Pilfering could lead to the pesticides getting into the market and being used for the wrong reasons altogether and could eventually cause exposure to the residents and even contamination to the environment.

Figure 12 Conceptual Model for Possible Exposure Pathways from Storage of Pesticides



Note that pesticides stored beyond their expiration date may produce daughter products that can be introduced into other vector management methods. Pesticides and daughter products can be released to the environment during storage due to damage to the containers or accidents leading to spills. Workers at the storage facility can be dermally exposed through contact with damaged containers or the contaminated surfaces. In addition, workers may inhale vapors and particulate material released from spills.

3. Warehouse Fire Outbreaks

Fire incidents and out breaks in the storage facilities is a possible impact that could occur and thus steps must be taken to ensure that such occurrences are minimized because they could cause injury or loss of life. Liquid pesticides as is the case with ICON present major fire hazards because the solvents used in their formulation (oil and petroleum distillates) have low flashpoints and maybe readily vaporized at normal temperatures.

4. Warehouse Accidents

The bulk pesticides can be a likely cause of accident to the workers and storekeepers if they are stacked high up the ceiling. These chemicals could easily topple over and crash on the workers thereby causing fatal injury.

5.4 Mitigation Measures

This section outlines the various measures proposed to mitigate against any of the potential adverse impacts likely to occur and outline above. The mitigation measures include a mix of Information Education and Communication (IEC) approaches targeting the residents and spray operators and team, measures also include provision of Personal Protective Equipment (PPE) to the spray operators while also emphasizing on effective Training, as well as thorough supervision and monitoring.

- **Mitigation Measures for Residential Exposure.**

The steps to mitigate, to the fullest extent possible, occupational exposure to the pesticide are mentioned in the preceding section below in bullet form. District authorities and RTI program staff will work with relevant boards, committees, and non-governmental organizations to carry out an IEC campaign to sensitize residents to IRS activities, in accordance with WHO guidelines. The IEC campaign (as well as IRS

Program 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 if possible
- Stay outside the home during spraying and for four hours after spraying
- Move and keep all animals outside the home during spraying, and for four 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.

- **Measures to ensure Safe Pesticide Transport.**

Prior to long-distance transport of the insecticide from the customs warehouse/central storage facility to the district, 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 from the distributorship to the district storage facilities will include the following information:

- For what use the insecticide is intended
- Toxicity of the insecticide
- Understanding security issues, implications of the insecticide getting into the public
- Handling 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

Because vehicles will be rented for the program, it is important to ensure that pesticide contamination in the vehicle does not have negative impacts when the vehicle is subsequently used for another purpose (e.g. food transport). To prevent pesticide runoff from vehicle washing, drivers will also be responsible for wiping the vehicle bed with a damp cloth prior to washing the exterior of the vehicle. Finally, 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 to wear for cleaning the vehicle. All cloths used in wiping down the interior and bed of the vehicle should be washed with spray operator overalls.

- **Mitigating Foetal Exposure-Pregnancy Testing**

All the potential female spray candidates will be tested for pregnancy before being recruited into the spray operations. Female persons found to be pregnant should be re-assigned to other non risky chores in the IRS. The same applies to breastfeeding spray candidates.

- **Provision of Personal Protective Equipment**

Each spray operator will be provided with the following safety equipment, in accordance with WHO and FAO specifications: These PPEs will be replaced frequently whenever wear and tear is identified or reported. However, the respirators will be replaced everyday.

- Broad-rimmed hat/helmet
- Face shield or goggles (face shield preferable)
- Dust mask or filtered mask
- 2 or 3 cotton overalls per spray operator
- Nitrile rubber, neoprene, PVC or butyl rubber gloves, without inside lining, long enough to cover forearm
- Rubber boots

- **Training and Capacity Building**

The individuals recruited for IRS campaigns will receive intensive training on the use, operation, calibration and repair of the sprayer and practical exercises during a 21-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 will be conducted in accordance with WHO's "Manual for Indoor Residual Spraying" (WHO 2002). Potential spray operators must also pass written and practical tests at the end of training. In this way, spray operators will be prepared to conduct appropriate application of the insecticide.

- **Warehouse/Store Keeping Training**

All the store keepers and managers will be trained on sound store keeping practices and procedures in order to ensure that all the stock coming in and out of the storage facilities can be traced accordingly. This is a mechanism aimed at preventing pilferage of pesticides.

- **Training on Emergency Treatment Procedure**

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 comprise of drills to test knowledge of the operators.

- **Pesticide Exposure and Treatment**.

The following drugs are recommended for use in case of exposure to pyrethroids. The project will ensure that all the health facilities around the spray sites are stocked up with these recommended drugs and that all the staff responsible receives training on emergency treatment to pyrethroid exposure.

Table 13. Drugs Recommended for Treatment of pyrethroid exposure

Name of drug	Active ingredients
Promethazine	Promethazine Hydrocloride
Panadol	Paracetamol
Diazepam	Benzodiazapine/Diazapam
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

- **Supervision**

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 the preparation, spray technique, and sprayer and PPE cleanup during the IRS campaign, as well as compile all data collected by their respective teams.

Supervisors and additional district and national malaria program personnel will receive a 5-day "training of trainers course" according to WHO best professional practices, and will also receive additional training on personnel management, environmental aspects, entomological monitoring, geographical reconnaissance, and data recording and analysis. After each day's spray activities, supervisors will collect sachet packing material to track the amount of insecticide used, and ensure that spray operators practice proper personal hygiene to avoid prolonged insecticide exposure.

Scrupulous attention to personal hygiene is an essential component of the safe use of pesticides. For spray operators, safety precautions will depend largely on personal hygiene, including washing and changing 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 must be washed regularly.
- Particular attention will be given to washing gloves, as wearing contaminated gloves can be more dangerous than not wearing gloves at all.
- Spray operators must wash before eating.
- Eating, drinking and smoking during work will be strictly forbidden.
- A drop-cloth and overalls wash-person will be hired and provided with his/her own protective gear.
- Wash persons will wash overalls at a central location in tubs used exclusively for overall washing. Spray operators must also wash themselves (at least face/neck, and hands) after each day's operations using wash basins specifically procured for that purpose or in a shower or bathing area.
- Spray operators will never wash themselves, their overalls, or their PPE in any water bodies.
- All wash-water will be disposed of in a soak pit, and construction of infrastructure for proper disposal of contaminated water will be financed by USAID.

- **Mitigation Measures against Warehouse/Storage Exposure**

In order to ensure that there is no form of exposure that could arise due to pesticide storage the following key points will serve as key mitigation steps.

- All pesticide storage facilities will be double-padlocked and guarded on a 24 hour basis
- All the storage facilities will be located away from nearby water courses, domestic wells, markets, schools, hospitals etc
- All the storage facilities will have thermometers installed for temperature recording
- Soap and clean water 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 2 or more than 3 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 are will be placed in the outside of the store in the local language(s) with a skull and crossbones sign to caution against unauthorized entry
- All pesticides will be used and any remnants will be stored under lock and key until the next rounds of spraying.

- **Mitigation Measure for disposal of used spray water**

Water used to rinse out sprayers 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 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, and so on; the seventh container is empty).

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 (the uncommon situations where more insecticide returns is where the distance to the new site makes it difficult for the team to reach to empty their sprayers. Even then, the amount coming back will be less than a full drum or 220 litres). 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.

Soak Pit. The site for the soak pit may be selected by the environmental authority (soak pits are usually sited at the highest point at the IRS depot/storage site and away from the natural path of run-off water). Depending on the size of the operation, you can construct a small or large pit. Usually an area of three meters by three meters (or nine square meters) is excavated to a depth of one meter. The bottom of the pit is packed with hard coal or charcoal. This is followed by saw dust (where this is feasible) and stone aggregates. The area is then fenced off to keep domestic animals and children out of the soak pit area. Because there is no loose soil, it serves as a nice area where washing of overalls can be done. The soak pit is also good for drying overalls, laying them either on top of the stones or over the fencing. The figure below shows a soak pit with partially-constructed fencing (the bottom piece of mesh was still being fitted for attachment in this picture).

Figure 13. Soak Pit Surrounded by Wooden and Mesh Fencing.

- **Mitigating Exposure Impacts through Container Re-use**

Best practices emphasize that no matter how many times a container is cleaned; it should never be used to carry anything other than pesticides. Any container once used to contain potentially harmful chemicals should never be used to hold household items or food stuffs, especially water. The containers that will be used to ship the chemical in the country will not be allowed to get out of the warehouse. They will remain in the warehouse until such a time that they can be shipped back to the manufacturer. Accordingly, the buckets used for daily washing will be given to the NMCP while labeled and will be kept under lock and key for any future spray rounds.

6.0 Public Disclosure and Consultation

The public was engaged in a dialogue concerning the project early on in the SEA preparation process.

- **United States Agency for International Development**

USAID is the main development partner in this project and provides all the funds that will be used for IRS. The staff of USAID involved those from the Health Program as well as from the Environment section. There concern was mainly to ensure that the SEA addresses the significant concerns of pesticide exposure to human health and environment.

- **Environment Protection Agency**

EPA officers at the national level as well as the provincial and district levels were consulted during the SEA process. At the national level the EPA staff reiterated on the need to focus on the disposal of the pesticide in accordance with the international acceptable standards.

- **Civil Society**

Non Governmental Organizations including MENTOR Initiative, and CONCERN operating in the area and undertaking IRS activities were also consulted during the field visit. The major concern from these organizations was the re-introduction of DDT as an IRS chemical. They have previously implemented IRS and do not find it a problem to deal with pyrethroids but have reservations on the use of DDT based on the known adverse environmental impacts.

- **Target Residents**

Owing to time constraints, the local residents were not exhaustively consulted during the field visit. However, there are plans to engage the target residents at length during the Information Education and Communication campaign that will occur 4 weeks prior to the commencement of the spray operations. This engagement process will be documented and included in this report as an amendment.

- **IRS Task Force**

An IRS task force was set up comprising of EPA, Ministry of Lands, Mines and Energy, NMCP, MOHSW, USAID, CHS-EDC, BRD-MPW, RTI and MENTOR Initiative. This task force was consulted during the stakeholder consultation process and the concern of this committee was on the steps that RTI would put into place to minimize adverse impacts. The IRS Task Force had reservations on the use of DDT during this years spray round and should only be used after an exhaustive environmental impact assessment. Annex 1 section of this report shows copies and minutes of the IRS Task Force meetings.

7.0 ENVIRONMENTAL MITIGATION AND MONITORING PLAN

This Environmental Monitoring and Mitigation 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 that will be pulled out and provided to the Liberia IRS management team and will be used as the tool for ensuring mitigation and monitoring practices are adhered to.

7.1 Scope of the EMMP

The EMMP consists of a series of components defined by project phase. These are:

- Detailed pre-spray issues,
- Spray Issues
- Post Spray

7.2 Environmental Management Program

The EMMP presents a program by which RTI 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.

ENVIRONMENTAL MANAGEMENT PLAN

PRE Spraying Phase

Table 14.

Impact	Mitigation Measure	Monitoring Indicator	Responsibility
Accidental Spills of Insecticides during Road Transportation to warehouse and spray sites **(Human Health and Environmental impacts**	Ensure that the drivers identified to haul the insecticide to the spray sites are well trained on the FAO standards and guidelines for the storage, transport and stock control for pesticides	Number of Road Accidents and spills reported Records showing Drivers Training	RTI –Team responsible for IEC Ministry of Agriculture EPA
Possible environmental contamination caused by warehouse exposure due to poor siting of warehouses, Pilferage and vermin attack of the stored pesticides before spraying	Ensure the selected warehouse is sited away from a flood plain area, water course, wells, schools, markets	Storage facility located outside of floodplain, away from nearby schools, hospitals, water courses	RTI – Ministry of Agriculture EPA
	Secure the selected warehouse and apply all the guidelines for Storage and Stock Control manual by FAO.	Storage facilities secured as per the FAO Storage and Stock Control Manual	RTI – Ministry of Agriculture EPA
Accidental Fires and injuries in the Warehouses	All warehouses must be equipped with a fire extinguisher, thermometer, exit doors and warning signs, and proper stacking position and height as stipulated in the FAO Storage and Stock Control Manual.	Presence of fire fighting equipment, thermometers, warning signs and at least 3 exits access in the warehouse	RTI – Ministry of Agriculture EPA
	All the workers handling pesticides or other products and equipment in the storage facilities must all have PPE including goggles, gloves, boots, overall, dust masks etc.	Availability of PPE to all the workers.	RTI –Team responsible for IEC
	All spray operators and store managers must be trained on how to operate the fire extinguishers and what to do in case of fire outbreaks. Develop an Emergency Response Plan	Training in fire prevention and fighting Develop an Emergency Response Plan	RTI –Team responsible for IEC

Spraying Phase

Table 14.

Impact	Mitigation Measure	Monitoring Indicator	Responsibility
Foetal Exposure	Pregnancy tests to ensure pregnant women are not on the spray teams; prohibition of breastfeeding women on spray teams; Education of women regarding risk and presentation of consent forms	**Percentage female spray operators who took pregnancy tests** **Tests for pregnancy repeated every 30 days after the initial test during the spray operations**	RTI NMCP Ministry of Agriculture EPA
		Percentage female spray operators who indicated they were not breastfeeding	
		Percentage female spray operators who have signed consent forms	
	Reassign women spray operators who become pregnant during the campaign to tasks that minimize occupational exposure to insecticides	Number of females reassigned	RTI NMCP Ministry of Agriculture EPA
Spray Operators, Drivers and storekeepers Exposure due to negligence or lack of PPEs, or un-intentional exposure caused by accidents	Training of spray operators, team leaders and supervisors according to WHO and EA guidelines; training of storekeepers, drivers and health workers Provide PPEs to all the workers, supervisors, team leaders and store managers. Train the team leaders, sprayers, supervisors and store keepers on emergency procedures to take if exposure occurs accidentally i.e. dermal, eye or ingestion emergencies.	● All outlines for training exercises include components described in the text of this EA, as well as the EMP ● **Lack of vehicle accidents** ● **Lack of major spill during insecticide transport** ● **Health workers trained** ● **Storekeepers trained** ● **Drivers trained** (see guidelines in Pesticide Procedures E) Spray Operators conduct the following activities during spraying: ● **Frequently agitate spray can** ● **Hold pump such that compression gauge can be seen** ● **Stands parallel to wall being sprayed**	RTI NMCP Ministry of Agriculture EPA
	Ensure that each Team Leader and Supervisors effectively monitor the spray operations diligently and take		

	Procurement of sprayers manufactured according to WHO specifications; procurement and proper use of PPE by spray operators, team leaders and supervisors (cotton overalls, face shield, dust mask, broad-rimmed hat, rubber gloves, gum boots) procurement of PPE for wash persons.	● **Stands 45 cm from wall** ● **1m/2.5 sec spray rate** ● **75 cm swatch width and 5 cm overlap** ● **Nozzle not dripping** ● **All house wall surfaces sprayed** ● No eating, drinking or smoking witnessed during operations (previously mentioned)	
	Prohibition of eating, drinking and smoking during work; prohibition of eating before washing		
Residential Exposure	IEC Campaign, instruct residents to: Clear homes of mats or rugs, furniture, cooking implements and foodstuffs prior to spraying	Households cleared and well prepared before the spraying	RTI NMCP Ministry of Agriculture EPA
	Move all furniture out of the house and for immovable ones, take to the centre of the house and cover accordingly	Furniture covered and or moved to the centre of the houses	RTI NMCP Ministry of Agriculture EPA
	Advise residents to stay outside the home during spraying and for two to four hours after spraying	Residents stay outside of the hours until the recommended time lapse	
	Move and keep all animals outside the home during spraying, and for four 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	Animals kept away from the houses until the recommended time after spraying	
	Advise not to re-plaster or paint over the sprayed walls after spraying and keep using bed nets for protection against malaria	Number of houses not plastered or painted after the spraying period	

	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	Cases of reported exposures to the health facilities	
Acute Effects of Pesticide Go Untreated	Ensuring treatment medicines for insecticide exposure listed in EA mitigation section are available at the District level. Ensure first Aid kits are available in the storage facilities and the transport vehicles	**Percentage of treatment medicines available at health facilities** Availability of first aid kits in storage facilities and hired vehicles	RTI NMCP Ministry of Agriculture EPA
Aquaculture Contamination	IEC Campaign, informing fisher folk involved in aquaculture in the target areas of Mambah-Kaba district to clean any aquaculture equipment stored in their home before use in Atlantic Ocean and to ensure disposal of floor residue and dead insects as a result of IRS in pit latrines or a hole especially dug for the purpose of disposal	● Number of post-spraying complaints from fisher folk involved in aquaculture in target area	RTI NMCP Ministry of Agriculture EPA
Community Exposure, Foetal Exposure	Prohibition of spraying in homes where sick persons or pregnant women are living and cannot move outside the home *and* stay outside the home during and 4 hours after spraying Prohibition of spraying in homes where food, utensils and flooring have not been removed from the house, and where furniture has not been removed outside *or* moved to the middle of the room and covered with a cloth by the spray operator	Residents outside house during spraying (previously mentioned) Residents stay outside for four hours after spraying (previously mentioned) Occurrence of skin/eye/throat irritation (previously mentioned Food and goods outside house during spraying (previously mentioned	RTI Supervisors, Team Leaders Ministry of Agriculture EPA
Pilferage and Community Exposure, Environmental Contamination	Daily tracking of insecticide sachets used, spray-operator sign-out of sachets, return of empty sachets to supervisors, etc. (Indicators are equivalent to procedures listed in Pesticide Procedures) Ensure that the storage facilities meet all the security criteria listed in the FAO Storage and	At reception at 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 provincial warehouse where	Storekeepers, Team Leaders, Supervisors, RTI, Ministry of Agriculture EPA

	Stock Control Manual	distribution takes place and signed for, based on sachet numbers (if provincial warehouse present) On reception at district office, all sachets are counted and stamped with the relevant district stamp and registered on stock card.	
Potential Exposure without Impact on Vector	Collection of insecticide samples and lab-testing of insecticide to ensure quality control	● Moisture content ● 75% active ingredient present	RTI
Potential Exposure without Impact on Vector	Entomological monitoring	● Monitoring results presented in end-of-round report and monitoring reports submitted after end-of-round report	RTI

Post Spraying Phase

Table 16.

Impact	Mitigation Measure	Monitoring Indicator	Responsibility
Accidental Spills of Insecticides during Road Transportation to from spray sites to warehouse **(Human Health and Environmental impacts**	Ensure that the drivers identified to haul the insecticide to the spray sites are well trained on the FAO standards and guidelines for the storage, transport and stock control for pesticides	Number of Road Accidents Records showing Drivers Training	RTI –Team responsible for IEC, Ministry of Agriculture EPA
Pilferage and Community Exposure, Environmental Contamination	Keep storage facilities up to standards described in Pesticide Procedures J; Storage of all insecticides, empty packaging, barrels and tubs in storage facilities, reducing use of contaminated goods domestically	Presence of a dedicated and trained storekeeper ● Insecticide stored separately from food and medicine (previously mentioned) ● Stock records up-to-date (previously mentioned) **● Facility double-padlocked and guarded** **● Facility physically secure** ● 5-6 can refills/day are issued to each spray operator, with their code written on the sachet. These sachets are signed out buy the spray operator ● At the end of the day, empty and full sachets are returned and number checked against what was signed for ● The next day all previously signed but unused sachets are re-issued and again signed for by the relevant spray operator **● Spray operator performance, number of structures sprayed versus can refills used is calculated to see if there is an over or under application**	RTI- NMCP, Ministry of Agriculture EPA

		● At the end of the spray round, [stock remaining] = [stock at start] - [no of sachets distributed]. No. sachets distributed should be equal Stock records up-to-date (previously mentioned)	
Accidental Fires and injuries in the Warehouses	All warehouses must be equipped with a fire extinguisher, thermometer, exit doors and warning signs, and proper stacking position and height as stipulated in the FAO Storage and Stock Control Manual.	Presence of fire fighting equipment, thermometers, warning signs and at least 3 exits access in the warehouse	RTI – NMCP, Ministry of Agriculture EPA
	All the workers handling pesticides or other products and equipment in the storage facilities must all have PPE including goggles, gloves, boots, overall, dust masks etc.	Availability of PPE to all the workers.	RTI – NMCP, Ministry of Agriculture EPA
	All spray operators and store managers must be trained on how to operate the fire extinguishers and what to do in case of fire outbreaks. Develop an Emergency Response Plan	Training in fire prevention and fighting Develop an Emergency Response Plan	RTI – NMCP, Ministry of Agriculture EPA
Community Exposure	End-of-program cleaning/decontamination of interior and exterior of vehicles	● Interiors and exteriors of vehicles cleaned	Drivers/Rental company
Environmental Contamination and Resident Exposure from post spray disposal activities	Daily sprayer maintenance, sprayer progressive rinse, spray operator bathing, washing of overalls, PPE and cloths used to cover furniture, latrine disposal of laundry wash-water Ensure that a soak pit is constructed for disposing residual water after clean up Storage of empty sachets until manufacturer recapture or disposal option selected by the country. Procurement and distribution of barrels for	Evidence of progressive rinsing during all post spray clean ups Evidence of soak pits in all the return sites for clean up designed and constructed in the acceptable format Evidence of empty sachets stored in sealed barrels awaiting recapture by manufacture Availability of wash barrels and tubs with	RTI- NMCP, Ministry of Agriculture EPA

	progressive rinse, and wash-tubs for personal hygiene; inscription of program barrels and tubs as District Health Office property to deter sale and domestic use in event of pilferage	program inscription	
Spray Operator and Community Exposure, Environmental Contamination continue unnoticed	Train district and/or national environmental compliance inspectors in Training of Trainers (TOT) and spray operator training course	● EPA Environmental Compliance Inspectors trained on IRS	RTI, EPA
Spray operator exposure due to lack of washing after spraying	Ensure all spray sites have washrooms with adequate water and soap for washing	Soap and clean water available at all times (previously mentioned) ● Adequate numbers of shower/bathing facilities available for spray operators (designated wash basins at a minimum) (previously mentioned)	RTI- NMCP, Ministry of Agriculture EPA
Spray Operator Exposure due to sprayer negligence during progressive rinse	Ensure supervision by Team Leaders ad Supervisor during progressive rinse. Ensure that progressive rinse occurs when sprayers are still dressed up in their full PPE		RTI- NMCP, Ministry of Agriculture EPA
Environmental Contamination and residential exposure due to unused pesticide and empty sachets getting access to the local environment	Storage of empty sachets until manufacturer recapture or disposal option selected by host country Ensure that the warehouse is well secure and accountability of all stock is available by the store keepers.	Empty sachets collected and counted, stored in sealed drums	RTI, Supplier, EPA

8.3 EMMP Implementation

This EMMP will be implemented by RTI and NMCP who are directly involved in this project. However other institutions like the Environment Protection Agency (EPA), may undertake their own environmental management actions.

8.3.1 Environment Protection Agency

Environment Protection Agency (EPA) is the oversight institution over the environment in Liberia. Its role will be of monitoring compliance to the environmental indicators as identified in this EMMP. The role of Environment Protection Agency (EPA) will be:

- **Oversight Monitoring**

As the lead agency responsible for the protection of environment in Liberia, Environment Protection Agency (EPA) will play the leading oversight role of monitoring the activities of the project according to the Environment Protection Agency (EPA) Act.

- **Site Inspection Visits**

EPA will undertake site visits to inspect and verify for themselves the nature and extent of the impacts. EPA will also undertake site visits to inspect and verify for themselves the extent to which the mitigation measures proposed in this EMMP are being complied with or vice versa.

8.3.2 RTI/NMCP

RTI and NMCP will undertake monitoring of the activities to ensure internal compliance is achieved. The inspection and monitoring will be undertaken by the RTI Environmental Compliance Inspector based in Nairobi and will occur during the Pre-Spray phase; Spraying Phase and Post Spray phase. The inspectors will endeavor to ensure that all the mitigation measures highlighted in the EMMP are being followed. They will produce an internal compliance inspection report that will be shared with EPA sand USAID.

9.0 Conclusion and Recommendations

This chapter summarizes the key conclusions of the SEA study, under headings that follow those used in the impact assessment part of this EIA. These conclusions support the view that, with full and proper implementation of the measures identified in the EMMP the IRS project in Mambah-Kaba district is not likely to cause unacceptable impacts on the environment or the communities of the surrounding area. The key findings of the potential impact assessment are outlined below, under the following headings:

- Impact on the Natural Environment i.e. Water courses, Soils, Flora and Fauna
- Impact on Human Health

9.1 Impacts on Natural Environment

The IRS activities are likely to expose the natural environment to pesticide contamination during transportation, storage, spraying and post spraying activities related to IRS actions. Un-intentional release of the pesticide on the environment could lead to the contamination of water courses found in this area, as well as the soil, flora and fauna. Unintentional release to the external environment could occur through accidents or poor handling of the pesticide during the pre-spraying, spraying and post spraying phases of the IRS.

9.2 Impact on Human Health

Resident and worker exposure to the pesticide is potentially capable of causing human health impacts due to the toxic nature and composition of the pesticide. Residential exposure could lead to sickness or even loss of human life depending on the mode of exposure whether dermal, ingestion or through eye contact.

Exposure to residents or spray workers is likely to occur due to careless and improper handling of pesticides all through the IRS process which included pre, spray and post spray activities. Accidents can also lead to resident exposure and hence adverse impacts.

9.3 Recommendation

RTI as an institution has implemented IRS programs in several countries in sub Sahara Africa and a fairly good knowledge of the loop holes that could lead to exposure. It is recommended therefore that Information Education and Communication and training of the spray operators and residents remain a significant component of the mitigation measures. At the same time, stringent supervision and monitoring will be pursued in order to arrest any adverse impacts that could occur or occur before they cause any significant damage to the environment.

BIBLIOGRAPHY

1. Berkowitz, G. et al. 2003. Exposure to indoor pesticides during pregnancy in a multiethnic, urban cohort. Environmental Health Perspectives. 111:1; 79-85.

2. Food and Agriculture Organization of the United Nations (FAO). 1996. Pesticide Storage and Stock Control Manual.

3. Thompson, R. 2004. Draft Guidance Document: The Selection of Waste Management Disposal Options for the Disposal of Obsolete Pesticides and Contaminated Materials. Food and Agriculture Organization of the United Nations (FAO).

4. United States Agency for International Development. 2007. Integrated Vector Management Programs for Malaria Vector Control: Programmatic Environmental Assessment. http://www.ehproject.org/PDF/ehkm/ivm-env_assessment.pdf

5. UNDP Disaster MGT Unit & OCHA RSO-CEA - May 2003

6. World Health Organization (WHO). 2002. Manual for Indoor Residual Spraying: Application of Residual Sprays for Vector Control.

7. World Health Organization (WHO). 2005a. Safety of Pyrethroids for Public Health Use.

8. World Health Organization (WHO). 2005b. The WHO-Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2004.

9. World Health Organization (WHO). 2006. Pesticides and Their Application for the Control of Vectors and Pests of Public Health Importance. Department of Control of Neglected Tropical Diseases, WHO Pesticide Evaluation Scheme (WHOPES).

10. WWW.UNEP.ORG.UNCBD

11. Liberia Malaria Operational Plan FY 08.

12. Margibi County Development Plan

13. Environmental Protection Authority Act 2003

14. State of the Environment Report, Liberia 2006.

Appendix 1. Minutes of IRS Task Force Committee Meeting

ACTION MEMO

To: Dr. Gwenigale, Minister of Health

From: IRS Task Force, chaired by Jesse Duncan, Deputy Minister of Health

CC: Dr. Belay Kassahun (USAID), Tolbert Nyenswah (NMCP), Michael Albert (MENTOR Initiative)

Date: December 15, 2008

Re: Recommendations for the upcoming USAID/PMI funded IRS Campaign

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The IRS Task Force in Liberia met on 2 December 2008 at the National Malaria Control Program to discuss two issues regarding the upcoming IRS campaign under USAID/PMI that has been awarded to the Research Triangle Institute (RTI): the choice of **insecticide** based on timeframe available and the **location** of the initial campaign.

Insecticide – DDT vs Pyrethroids

While DDT has been recommended as one of the better insecticides for IRS, the time frame for which to obtain environmental approval to purchase, import and utilize this insecticide is significantly longer than it is for pyrethroids, due to several control measures required by the US Government. USAID and RTI estimate that DDT could not be used until at least 9-12 months from now, ie. USAID FY09.

Pyrethroids have been used successfully in Liberia for IRS in recent years. The safety and efficacy of pyrethroids in Liberia is therefore favourable for immediate use. They can therefore be used under USAID FY08.

Location – Urban vs Rural

Generally, the urban settings of Red Hill, Crabe Hole, Logan Town, and Clara Town have been the preferred choice for implementation based on need; however several issues of efficiency and effectiveness are confounding, favouring a rural setting of Mambah-Kaba for the initial campaign:

- *Anopheles melas* have been observed in the urban areas suggested but not the rural areas - IRS is not particularly effective where this breed of mosquito is present due to their feeding habits;
- In the urban setting there is greater **population movement** and access to multiple drug stores and clinics (which confounds data, and therefore is not ideal for an initial campaign were significant monitoring is paramount to the success of the rest of the campaign);
- Severe malaria and **malaria mortality** is generally a greater percentage in rural settings, and therefore an IRS campaign in a rural setting would be provide a greater impact;
- There are more sleeping spaces in mixed houses and shops where in the urban settings. These **dwellings often cannot be sprayed**. IRS is only effective where a high percentage of sleeping dwellings are sprayed;
- Operationally, **storage and training facilities** are already available in the rural setting at LIBR.

Final Recommendation

In order to utilize the funds dedicated to this activity under USAID FY08 in the most efficient and effective manner, the recommendation from USAID, CDC and RTI, and that adopted by the IRS Taskforce is the following:

- Concurrent Pyrethroid and DDT environmental approval process (begin immediately);
- Begin IRS in rural area with a pyrethroid insecticide by March 2009;
- Continue IRS with DDT in peri-urban areas in 9 to 12 months.

The IRS Taskforce also highlighted that before switching to DDT in 9-12 months time, the taskforce will meet to discuss the environmental approval that is approved to ensure it was appropriate for the Liberian context.

The IRS taskforce hereby seeks the Honourable Minister Gwenigale's approval on these recommendations.

Appendix 2. IRS Solid Waste Disposal Standard Operating Procedures

Standard Operating Procedures – Indoor Residual Spraying (IRS)	
Title: Required Equipment for IRS Operations	**SOP #:** (to be assigned by Abrar)
Author: RTI	**Approved by:** DRAFT
Effective Date: October 1, 2008	**Revision Number:** (0)

Purpose and Scope

Purpose

In the implementation of Indoor Residual Spraying (IRS), toxic wastes end up getting generated in the form of empty insecticide sachets, used gloves, used respiratory masks, material covering sheets, and used rinse barrels, contaminated materials e.g. sawdust, soils from accidental spills. These substances are generally toxic, contaminated and could pose a health and environmental hazard if they are not disposed in an environmentally sound manner.

The objective and purpose of this manual is to present an acceptable standard procedure (compliant with international and national standards) for the disposal of IRS wastes in all the countries that RTI is implementing IRS activities. Concurrently the objective is to ensure that all the countries have in place a hands-on tool/guide that provides them with the reference and direction for disposal of these wastes in accordance to the regulations put forward by World Health Organization and Food and Agricultural Organization for disposal of pesticides.

Scope

This manual details the standard requirements for storage of waste before eventual disposal, selection of an in-country incinerating facility including key criteria for selection, steps to take when no in-country incinerator is available, personal health and safety during disposal, responsibilities of different actors and proof/certificate of destruction. ***Note that this SOP does not include disposal of effluent or wash water waste from IRS activities. The disposal of IRS effluent is captures in a separate SOP.***

Current Status

The USAID-sponsored, RTI implemented Indoor Residual Spraying (IRS) program is at present storing the wastes (sachets, used gloves, containers, cartons, and respiratory masks) in most of the countries and in centralized warehouses pending the finalization of this Standard Operating Procedures (SOP) which will provide guidance on waste disposal.

In the preparation of the SOP for disposal of IRS waste, it is increasingly becoming evident that incineration of the IRS wastes, especially pyrethroids, is the ultimate procedure and requirement that will be adopted in all the countries. Incineration is a highly-proposed recommendation put forward by United Nations Environment Program, (UNEP) World Health Organization (WHO) and Food and Agricultural Organization (FAO) in relation to pesticide waste disposal especially for primary and secondary packaging materials and contaminated single use clothing.

Responsibilities

Chief of Party (COP)

1. Ensure that project staff inventory all the waste by category (masks, gloves, sachets, covering sheets, contaminated clean up materials e.g. sawdust, soils, cloth and barrels).
2. Ensure that the wastes are transported to the identified licensed incinerator and disposed in his/her presence.
3. Get letter of proof from the commercial facility owner attesting that the incinerator is licensed by the government to dispose toxic wastes.
4. Prepare contract for engagement of incineration facilities
5. Verify that disposal of the wastes occurred by:
    a) Government-Be present at the time of incineration and get some form of written document attesting to the effect that the wastes has been soundly destructed. The documentation should possibly indicate quantities of wastes incinerated, date of incineration, name of facility used and time.
    b) Commercial-Physical presence is not required; instead a certificate of destruction is required.
6. Send certificate of destruction to environmental specialists for record-keeping
7. Provide a summary report at the end of every spray round on the status of IRS waste

In Country Environmental Officers

1. The same duties as above can be discharged by the in-country environmental officers in countries where these personnel are available; otherwise the COP will assume the duties in the absence of an environmental officer.

Store Keeper

1. The store keeper is responsible for keeping the accurate inventory on a daily basis all of the IRS waste and records as stipulated in the IRS store keeping manual.

Procedure

1. IRS Waste Storage and Management

All the IRS waste must be collected at the end of the spray round and stored in centralized warehouses while waiting eventual disposal. Certain IRS waste, like empty sachets and respirators, is collected on a daily basis by the storekeeper whilst gloves and other waste types are collected periodically.

a. Safe and Secure Storage
   The storage facility must be lockable, have a roof in good condition to prevent water intrusion, have adequate ventilation to prevent heat build up, and be located in an area accessible to trucks and not susceptible to flooding. Design standards and a more complete description of requirements may be found in the Supplementary Environmental Assessment.
b. IRS Waste Stock Management Records
   The storekeeper is responsible for maintaining an accurate inventory of all IRS waste at hand. Forms used to maintain stock management records will also be used for this purpose.

2. Selection of IRS Waste Disposal Facility

Incineration of the IRS waste, also known as thermal destruction, is the standard method that will be used in the disposal of wastes in all the countries where RTI is implementing the IRS program.

The waste will only be disposed in incinerators that meet the following requirements;

1. Facilities assessed by RTI and found to satisfy international requirements and/or host government requirements for toxic waste disposal. For,
    a) Commercial Incinerators: they will have to be approved, accredited and licensed by host government regulating institutions for waste management–in cases where these exist. *A list of all the approved and licensed facilities will be sought from all the environmental agencies/authorities in cases where they exist.*
    b) Government hospital incinerators: RTI will conduct independent inspection and assessment before use
2. RTI constructed/procured incinerator which will have to be constructed to meet international standards.

3. Worker Health and Safety during Disposal of IRS Waste

In ensuring personal health and safety, when an RTI officer is physically present during the disposal process and observing the incineration of the waste, the officer will be required to be fully-dressed in the right PPE during the verification process.

In cases where RTI is using a government-owned incinerator (hospital) cognizant of the fact that there is inadequate supervision, including lack of PPE for the incinerator operators, in these health care facilities, RTI will supply the following PPEs;

a. Personal Protective Equipment (PPE) –
    - Broad-rimmed helmet
    - Face shield or goggles (face shield preferable)
    - Dust masks (vented version is preferable)
    - A Pair Coveralls
    - Nitrile rubber, neoprene, PVC or butyl rubber gloves long enough to cover forearm. (Lined or flocked gloves are preferable based on field experience).
    - Rubber boots

Timeline: Waste should be disposed at the end of each spray round and before the commencement of the next spray round to avoid pile up.

RTI Policy:

Attachments: List of licensed incinerators in IRS countries; incinerator specifications meeting international standards

Exceptions: None

APPENDIX 3 : EC Budget Items and Procurement List

Storage

Training for storekeepers

Physical Maintenance

- Materials/labor for store-house renovation
- Locks and keys for storage facilities
- Pallets for stacking insecticide and other equipment
- Construction of securable boxes for pesticide if storehouses cannot be properly secured

Emergency Kit

- 2 bags sawdust/sand
- Empty container to contain spillage residues
- Spade
- Brush
- Fire extinguisher

Health Kit

- Container of water or tap (inside)
- Bar of soap
- Eyewash set— *Ensure instructions are in host country language*
- Medical/first-aid kit— *Ensure instructions are in host country language*

Stock Management Kit

- Stock-book
- Bin cards
- Thermometer
- Pens

Storekeeper PPE

- Nitrile rubber, neoprene, PVC or butyl rubber gloves, without inside lining, long enough to cover forearm
- Rubber boots
- Overalls
- Goggles/face-shield
- Vapor masks for half-face respirators with organic vapor cartridges

Health Centers (should be provided by MOH& SW if possible)

Health Worker training in pesticide poisoning

Poisoning treatment meds—*Ensure instructions are in host country language*

Pregnancy test kits — *Ensure instructions are in host country language*

Transport

Training for drivers (see your SEA or PEA for guidance)

For vehicle washing, nitrile rubber, neoprene, PVC or butyl rubber gloves, without inside lining, long enough to cover forearm

Washing
For each central meeting area for spray teams (usually storage facilities, either temporary or permanent):

- Basins for face and hand washing *or* materials to construct temporary bathing facilities *or* materials to renovate existing facilities to accommodate the size and number of spray teams meeting for daily clean-up
- Basins for washing overalls *separate from basins for face/hand washing*
- Materials for wash area demarcation (hard coal/charcoal, saw dust, stone aggregates/gravel, fencing and wire mesh), *or* budget for construction/renovation of ablution block, *or* budget for construction/renovation of evaporation tank with locked grate
- 7 barrels/drums for progressive rinse (this is enough to triple-rinse)—often it is helpful if they are wide enough or deep enough to submerge the entire spray can
- 3 plastic cups to pour rinse-water into spray can
- Detergent for washing overalls
- For each Wash Person, PPE:
    - Chemical apron
    - Nitrile rubber, neoprene, PVC or butyl rubber gloves, without inside lining, long enough to cover forearm
    - Rubber boots
    - Goggles
    - Dust mask

Operations
For each Spray Operator, PPE:

- Broad-rimmed hat/helmet
- Face shield or goggles (face shield preferable)
- Dust mask or filtered mask
- 2 or 3 cotton overalls/spray operator
- Nitrile rubber, neoprene, PVC or butyl rubber gloves, without inside lining, long enough to cover forearm
- Rubber boots (in appropriate sizes that don't cause blisters; keep in mind in several countries the spray teams are composed of 50% women, so smaller boot sizes may be warranted; other shoes/boots will absorb the chemical and is not safe)
- Extra PPE in the event gloves get torn, face shields break, dust masks get contaminated (all this *will* happen)

For each Spray Operator, additional field equipment:

- 1 drop-cloth (can be a bed sheet or something similar) to cover household furniture
- Plastic cover, small handbag or something to prevent spray card from being impregnated with insecticide in the field

Non EC-Related Procurement Suggestions
Funnel with strainer (to easily rid debris out of water used in pump charge) for each spray operator

Identification Cards including name and picture for all program staff (including supervisors, team leaders and spray operators)

APPENDIX 4: Toxicological Profile for Bifenthrin (from USAID PEA for IVM)

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 (EXTOXNET, 1995; WHO/FAO, 1992). It is primarily available as a wettable powder or an emulsifiable concentrate (EXTOXNET, 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; EXTOXNET, 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; EXTOXNET, 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

• Duration	• Route	• Benchmark Value	• Units	• Endpoint	• Reference
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, [1alpha, 3alpha(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; EXTOXNET, 1995; HSDB, 2005)
Chemical Group:	pyrethroid (PAN, 2005; EXTOXNET, 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; EXTOXNET, 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 (EXTOXNET, 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^2 (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^{o}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 dose 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_{50} 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_{50}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 raged 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_{50} values range from 1,280 ppm in mallard ducks to 4,450 ppm in bobwhite quail. Oral LD_{50} 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, EPAtodes, 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_{50} is 0.00015 mg/L in rainbow trout and 0.00035 mg/L in bluegill sunfish (EXTOXNET, 1995; HSDB, 2005). Average LC_{50} 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_{50} 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).

APPENDIX 5 : Toxicological Profile for Deltamethrin (from USAID PEA for IVM)

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 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	*I*	*0.01*	*mg/k*	*Oral NOAEL for clinical signs in dogs at 1 mg/kg/day with UF of 100 applied*	*U.S.*
Acute	*O*	*0.01*	*mg/k*	*Acute RfD based on neurological effects in rats*	*U.S.*
Inter	*O*	*0.01*	*mg/k*	*Oral NOAEL for clinical signs in dogs at 1 mg/kg/day with UF of 100 applied*	*U.S.*
Chro	*O*	*0.01*	*mg/k*	*Chronic RfD based on clinical signs in dogs*	*U.S.*

Acute	*D*	*10*	*mg/k*	*Dermal NOAEL of 1000 mg/kg/day in rats with a UF of 100 applied*	*Barlo*

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-dimethyl-cyclopropanl-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_2CA, *trans*-hydroxymethyl-Br_2CA, 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 Koc 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_{50} 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_{50} 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_{50} in rats is 600 mg/m^3 (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 does of 25 mg/m^2 deltamethrin, skin irritation occurred one week after treatment, and runny nose and sneezing in the first days of use were reported for target does of 10–30 mg/m^2. 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-Phenoxybenxoic 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_{50} 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_{50} of more than 4,640 mg/kg diet was reported in ducks, and the 8-hour LD_{50} 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_{50} of 0.079 for technical deltamethrin and 0.4 µg ai/bee for the EC formulation. The contact LD_{50} 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_{50} 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_{50} 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_{50} value ranges from 82 µg/L in bleak to 210 µg/L in common carp. In Daphnia, the reported 48-hour LC_{50} 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)

APPENDIX 6 : Toxicological Profile for Lambda-Cyhalothrin (from USAID PEA for IVM)

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 beaks down rapidly in the body (IPCS, 1990a; EXTOXNET, 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 (EXTOXNET, 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. EPA (2002b)
Acute	Oral	0.005	mg/kg/day	Acute RfD based on neurotoxicity in dogs	U.S. EPA (2002b)
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. EPA (2002b)
Acute, Intermediate, Chronic	Dermal	0.1	mg/kg/day	Dermal NOAEL in rats with UF of 100 applied	U.S. EPA (2002b)

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^{o}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^{o}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-dimenthyl-cyclopropanecorboxylic 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 hydrolyzesd 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 (Koc) 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_{50} 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_{50} is reported for technical grade lambda-cyhalothrin in rats at 64 mg/kg (EXTOXNET, 1996). The oral LD_{50} 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_{50} 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_{50}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 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_{50} values in mallard duck are reported as greater than 3,950 mg/kg. Dietary LC_{50} 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_{50} of 0.9 µg/bee and an oral LD_{50} 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_{50} values range from 0.2 to 1.3 µg/L. It is also highly toxic to aquatic arthropods with 48-hr LC_{50} 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).

APPENDIX 7 : 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. Etoxfenprox 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
Acut	*Inh*	*0.1*	*mg*	*NOAEL for systemic effects in rats with UF of 100 applied*	*NYSD*
Acut	*Or*	*0.037*	*mg*	*Proposed chronic RfD based NOEL in rats with UF of 100 applied*	*NYSD*
Acut	*De*	*0.4*	*mg*	*LOAEL (skin lesions) in rats*	*NYSD*

• Duration	• Route	• Benchmark Value	• Units	• Endpoint	• Reference
				with UF of 1,000 applied	
Chro	*De*	*0.037*	*mg*	*Adopt chronic oral RfD; assume no first pass effects and 100% absorption*	*NYSD*
Can	*Inh*	*0.005*	*per*	*CSF for thyroid adenomas and carcinomas in rats*	*NYSD*

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 5.1×10^{-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 percentEtofenprox aerosol , 1 percentEtofenprox 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^2 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^2 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 or 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_{50} 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_{50} of >42.88 g/kg, a dermal 24-hour LD_{50} of 2.14 g/kg bw, and an inhalation LC_{50} of > 5.9 g/m^3 were reported. The oral LD_{50} in dogs was reported as >5.0 g/kg. The oral LD_{50} of Trebon 20 EC (20 percent etofenprox emulsifiable concentrate) is reported as >5 g/kg in both mice and rats, and the dermal LD_{50} 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 5.1×10^{-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^2 was recovered up to 96-hours after applications of ^{14}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_{50} of 49,000 µg/L in Japanese eel, while moderate toxicity is supported by the reported average LC_{50} 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 permethrin in both terrestrial and aquatic environments, serious adverse effects are not anticipated from chronic exposures (HSDB, 2005). No specific chronic data are available.

APPENDIX 8 : Toxicological Profile for Alpha-Cypermethrin (from USAID PEA for IVM)

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^3 (447 mg/kg/day)[3] 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

[3] *Conversion between mg/m^3 and mg/kg/day assumes, for Fischer-344 rats, an average body weight of 0.152 kg and inhalation rate of 0.17 m^3/day (U.S. EPA, 1988).*

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 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, alpha-cypermethrin, alfa-cipermetrina, alfacypermetrin, alfa cipremetrin,[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, alphametrin, 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 ectoparaciticide 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, ± 15 percent of the declared content; 25 to 100 g/kg, ± 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 hydrolyzess 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_{50} values in rats and mice vary greatly and depend on the formulation, concentration, and the vehicle (IPCS, 1992). Acute oral LD_{50} 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_{50} of 80 mg/kg is considered representative, higher values have been reported. In mice, the reported acute oral LD_{50} of technical alpha-cypermethrin is 35 mg/kg (in corn oil). Oral LD_{50} 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_{50} 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^3. 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 recommend 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 cyclpropan carboxylic ac 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-cyclprpane carboxlic 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_{50} values of greater than 2,000 mg/kg body weight. In feed, the reported LC_{50} 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_{50} for alpha-cypermethrin emulsifiable concentrate is 0.13 µg/bee and the 24-hour oral LD_{50} for alpha-cypermethrin in acetone was 0.06 µg/bee. The reported dermal LD_{50}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_{50} values range from 0.7 to 350 µg/L (IPCS, 1992). For rainbow trout, the reported 96-hour LC_{50} 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_{50} 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_{50} value for technical alpha-cypermethrin was 0.93 µg/L, while the reported 96-hour LC_{50} 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).

APPENDIX 9: Toxicological Profile for Cyfluthrin (from USAID PEA for IVM)

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; EXTOXNET, 1998)

Usage

Cyfluthrin is effective in combating a broad spectrum of insect pests in agricultural, public health, and structural applications (WHO, 2004; EXTOXNET, 1998). The main agricultural use of cyfluthrin is against chewing and sucking insects on crops (EXTOXNET, 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 ^{o}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^2, 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^2 (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 ^{o}C (and optimally at 15 to 30 ^{o}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-dimethylcyclopropancarboxcylic 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_{50} values range from 16 to 1,189 mg/kg body weight, depending on the vehicle used (WHO, 2004). The reported oral LD_{50}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_{50}s for cyfluthrin in polyethylene glycol and xylene are 500 and 270 mg/kg, respectively (HSDB, 2005), while the oral LD_{50} 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_{50}s ranging from 469 to 592 µg/L and a reported 1-hour LC_{50} greater than 1,089 µg/L (EXTOXNET 1998). The 4-hour LC_{50}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_{50} 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 deceased 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_{50} 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_{50}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_{50} 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_{50} for rainbow trout is 0.00068 mg/L, while in bluegill, carp, and golden orfe, the reported LC_{50}s are 0.0015, 0.022, and 0.0032 mg/L, respectively. In sheepshead minnow, an LC_{50} of 0.004 mg/L is reported (EXTOXNET, 1998). The 96-hour LC_{50} 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_{50}s include 2.42 ng/L for mysid shrimp. An EC_{50} 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).