The International POPs Elimination Project (IPEP)

Fostering Active and Effective Civil Society Participation in Preparations for Implementation of the Stockholm Convention

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Approaches to Effective Malaria Control that Avoid DDT in Kenya: Use of Bacillus thuringiensis israelensis (BTi)

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About the International POPs Elimination Project

On May 1, 2004, the International POPs Elimination Network (IPEN http://www.ipen.org) began a global NGO project called the International POPs Elimination Project (IPEP) in partnership with the United Nations Industrial Development Organization (UNIDO) and the United Nations Environment Program (UNEP). The Global Environment Facility (GEF) provided core funding for the project.

IPEP has three principal objectives:

- Encourage and enable NGOs in 40 developing and transitional countries to engage in activities that provide concrete and immediate contributions to country efforts in preparing for the implementation of the Stockholm Convention;

- Enhance the skills and knowledge of NGOs to help build their capacity as effective stakeholders in the Convention implementation process;

- Help establish regional and national NGO coordination and capacity in all regions of the world in support of longer-term efforts to achieve chemical safety.

IPEP will support preparation of reports on country situation, hotspots, policy briefs, and regional activities. Three principal types of activities will be supported by IPEP: participation in the National Implementation Plan, training and awareness workshops, and public information and awareness campaigns.

For more information, please see http://www.ipen.org

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This report is available in the following languages: English

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LIST OF ABBREVIATIONS

Bs	Bacillus sphaericus
BTi	Bacillus thuringiensis israelensis
COP	Conference of the Parties
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethene
DDT	Dichlorodiphenyltrichloroethane
DOMC	Division of Malaria Control
DOMTs	District Outbreak Management Teams
DVBD	Division of Vector-Borne Diseases
EPA	Environmental Protection Agency
FAO	Food Agricultural Organization
FPEAK	Fresh Produce Exporters' Association of Kenya
ICIPE	International Center for Insect Physiology and Ecology
ITN	Insecticide-Treated Nets
IPM	Integrated Pest Management
IRS	Indoor Residual Spraying
IVM	Integrated Vector Management
KEMRI	Kenya Medical Research Institute
KFC	Kenya Flower Council
LD50	Lethal Dose (median)
LLINs	Long-Lasting Insecticidal Mosquito Nets
NEMA	National Environment Management Authority
NGOs	Non-Governmental Organizations
PCPB	Pest Control Products Board
POMTs	Provincial Outbreak Management Teams
POPs	Persistent Organic Pollutants
USA	United States of America
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

BACKGROUND

The Government of Kenya signed the Stockholm Convention on Persistent Organic Pollutants (POPs) on the first day it was opened for signature, on May 23, 2001 and ratified and became Party to the Convention in September and December 2004 respectively. The Convention seeks to reduce, phase out and eliminate POPs production and use globally.

In Kenya, there have been conflicting positions on the advantages and disadvantages of using Dichlorodiphenyltrichloroethane (DDT) for malaria control. Some argue that use of DDT will save lives by reducing the number of malaria-related deaths while others argue that the long term exposure to DDT has greater negative effects. There is therefore an information gap on the use of DDT that needs to be filled and a consensus on the issue has not yet been reached.

Existing alternatives to DDT have been studied and much information generated through research on safety issues related to the use of DDT in malaria control programmes. This study therefore aims to establish the viability of *Bacillus thuringiensis israelensis* (BTi) as an alternative to DDT in malaria control in Kenya. It entails preparation of policy briefs on "Approaches to Effective Malaria Control that Avoid DDT". The same information will be used to lobby the Government to ban the use of DDT and replace it with available alternatives such as BTi and Integrated Vector Management (IVM).

Data collection methods entailed literature review on the various studies that have been conducted in Kenya on the subject matter. The research reports were mainly sourced from universities, NGOs and relevant research centers such as the International Center for Insect Physiology and Ecology (ICIPE) in Kenya. This study is expected to sum up the negative impacts of DDT use in malaria control and also generate scientific and historical facts on DDT and its effects on human health. Review of Government documents was also done at the Ministry of Environment and the National Environment Management Authority (NEMA) which is the Government focal point for the Stockholm Convention. This helped to establish the positions to be taken by the Government in as far as the DDT issue is concerned.

Field studies by ICIPE are still ongoing at the selected sites in various stations within the country. However, one field visit has been completed and it was preceded by an interview of one scientist based at ICIPE. The ongoing field visits will focus mainly on malaria endemic areas. Among the issues that the field visits are addressing are methods that have been and are currently used in malaria control, comparing with those methods using DDT and non-DDT alternatives and history of use and common illnesses in the research areas.

This report has been prepared and packaged to contain the following general topics among others: Historical background of malaria and its vector and host, plasmodium's life cycle, malaria occurrence, morbidity and mortality, symptoms of malaria; control measures of malaria focusing mainly on the use of DDT and larviciding; DDT in the Kenyan Environment; impacts of DDT; strategies to control and elimination use of DDT through the Stockholm Convention; and alternatives to DDT with main

emphasis on the application and use of larvicide *Bacillus thuringiensis israelensis* (BTi) and its related products. Also mentioned are other strategies as alternatives to DDT in the control of malaria such as insecticide-treated nets (ITN), house spraying, space spraying, integrated vector management (IVM), biological control and topics for further research.

The project results will therefore be used to help in influencing the national policy on malaria control and raise national awareness on the country position on DDT. The results may also be used to raise the level of awareness on issues of other POPs and hence accelerate the process of implementation of the provisions of the Stockholm Convention by the Kenya Government.

1.0 INTRODUCTION

1.1 Historical Background of Malaria

Malaria ranks among the three major health and developmental challenges facing most of the poorest countries in the tropical and sub-tropical regions of the world. As early as 2700 BC, a disease marked by high fever and an enlarged spleen was noted in ancient China as reported in ancient Chinese documents. Believing the disease was transmitted through the air, the sixteenth-century Italians called the disorder *mal'aria* (bad or evil air). *Plasmodium vivax* stowed away with the English going to Jamestown, while *Plasmodium falciparum* rode along with slaves from Africa[1].

In the United States, malaria had flourished for centuries in the South and in port cities like Boston and New York. During the civil war, armies on both sides of the war had been stationed in the south after sustaining more than 1.2 million cases of malaria. The southern United States continued to be afflicted with millions of cases of malaria each year into the mid-1930s. The Public Health Service began an anti-malaria campaign in 1942, and by 1953, the *Plasmodium* was considered to be tamed in the United States. Some authorities today, however, believe this public health campaign had less to do with malaria's retreat than did the country's increasing prosperity, which pushed millions of Americans out of the swampy hinterlands and into the cities[2].

In 1958 the World Health Organization (WHO) decided to wage a global campaign against malaria and sent workers into South American, African, and Asian villages to spray them with DDT. But except for areas such as Egypt and Southern Europe where the parasite had not been firmly established, in the end the spraying only succeeded in making the mosquitoes pesticide-resistant. By the 1960s, the WHO had scaled its Global Eradication of Malaria Program to one of worldwide malaria control[3].

[1] http://www.jhsph.edu/malaria/Malaria_Background.html
[2] http://www.jhsph.edu/malaria/Malaria_Background.html
[3] http://www.earthinstitute.columbia.edu/about/director/pubs/MalariaControlScienceOct02.pdf

1.2 Vector and Host

Malaria infection is caused by a protozoan parasite of the genus *Plasmodium*, four species of which infect human beings, the most common being *Plasmodium* vivax and most deadly being *Plasmodium falciparum.* The *Anopheles* mosquito serves as Plasmodium's delivery system, or vector. Only female mosquitoes can transmit it since males don't take blood meals. *Anopheles* mosquitoes bite mainly during night time hours.

1.3 Plasmodium's Life Cycle

The female *Anopheles* mosquito ingests the reproductive stage of the parasite when it feeds on blood from someone who already has malaria. The parasites then incubate in the insect's mid-gut for a week or more, maturing until they reach an infective form, and are reintroduced into humans when the mosquito feeds again on blood of non-infected persons.

A biting mosquito transfers about 10 percent of its parasite load into the victim's capillaries or the tissue around the blood vessels. The parasites make their way to the person's liver in less than 30 minutes of entering the bloodstream and penetrate the liver cells (hepatocytes). During the period when the parasites are maturing further in the liver, as little as eight days or as long as several months the infected person does not feel ill. Two kinds of malaria, *P. vivax* and *P. ovale*, can relapse, and some parasites can remain dormant in the liver from several months to four years after a person is infected[4].

Once the parasites leave the liver and re-enter the bloodstream, they invade and multiply in the red blood cells, periodically bursting the cells. Their further development leads to the formation of gametocytes (the parasite's sexual stages), which are picked up and transmitted to others when another mosquito feeds on blood from the infected person.

1.4 Where Malaria Occurs

Malaria threatens nearly 40 percent of the people in the world - 2.4 billion people - mostly in the tropics and subtropics. The disease is currently endemic in 90 to 100 countries. In 1990, 80 percent of cases were in Africa, with the remainder found in countries such as India, Brazil, Afghanistan, Sri-Lanka, Thailand, Indonesia, Vietnam, Cambodia and China. *Plasmodium falciparum* is the predominant species being responsible for over 120 million new cases and all the malaria deaths per year globally. *P. falciparum* is responsible for the alarming drug-resistant strains now emerging in the most endemic areas[5].

About 1,200 cases of malaria are diagnosed in the United States each year. Most of these are "imported" by military personnel and travellers to, or immigrants from, countries where malaria is common. Malaria has occasionally been spread locally in the United States by infected mosquitoes stowed away on international airlines, or, on rare occasions, by mosquitoes there that have bitten someone who was infected.

[4] www.cdc.gov/malaria/faq.htm - 48k
[5] http://www.jhsph.edu/malaria/Malaria_Background.html

1.5 Morbidity and Mortality

Despite mankind's longstanding struggle to control mosquito populations, the World Health Organization currently estimates that each year malaria causes 300 to 500 million infections and 1.5 to 3 million deaths each year. This is an alarming rate given that during the six-month Ebola outbreak in the Democratic Republic of the Congo (the then Zaire) in 1995, about 250 people died while malaria kills over 5,000 Africans every day[6].

The parasite seems to increase greatly one's susceptibility to other infections via generalized immunosuppression. A baby born to a pregnant woman infected with malaria will have a 40 percent greater chance of low birth weight, and congenital malaria may account for as many as half of all childhood deaths in Africa[7].

1.6 Symptoms of Malaria

For most people, symptoms begin ten days to four weeks after an infective bite. Symptoms of malaria include high fever and flu-like illness with shaking chills, sweating, headache, muscle aches, tiredness, and sometimes nausea, vomiting, and diarrhoea. The parasite alters human red blood cells, causing them to stick to the sides of the blood vessels, eventually blocking capillaries to the brain and other organs. If not promptly treated, severe infection with *P. falciparum* may lead to unrousable coma, severe anaemia, cerebral malaria, hypoglycaemia, renal failure, acidosis, repeated convulsions and death.

1.7 Use of DDT as a Control Measure for Malaria

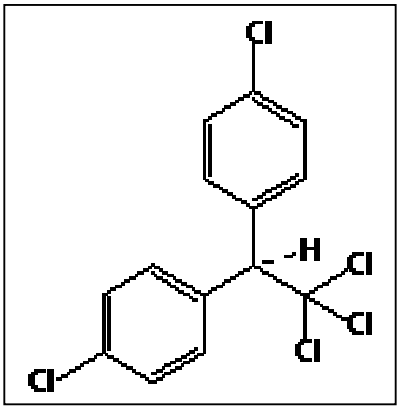
In the absence of vaccines and effective drugs, malaria has been fought by spraying with insecticides such as DDT, coating marshes with paraffin (to block development of mosquito larvae), draining stagnant water, sleeping under bed nets, and preventing future occurrences of disease through drugs. New control strategies are therefore urgently needed: not only are mosquitoes becoming more and more resistant to insecticides each year, but *Plasmodium* is shrugging off more and more once-effective drugs as well. Given the complexity of the malaria parasite's life cycle and the omnipresence of the a*nopheles* mosquito, a vaccine is probably the best chance for gaining control of malaria in a cost-effective manner. However, there are a number of control methods that have been applied to stop the disease from spreading. Most of the methods are mainly chemical based with some already banned due to their negative impacts on the environment, human health and ecology.

DDT being the first of the chlorinated organic insecticides was originally prepared in 1873, but it was not until 1939 that Paul Muller of Geigy Pharmaceutical in Switzerland discovered the effectiveness of DDT as an insecticide. He was awarded the Nobel Prize in Medicine and Physiology in 1948 for this discovery[8].

DDT is an organochlorine insecticide used mainly to control malaria. Its use on crops has generally been replaced by less persistent insecticides. It was extensively used

[6] http://www.jhsph.edu/malaria/Malaria_Background.html
[7] www.rbm.who.int/amd2003/amr2003/summary.htm - 16k
[8] http://www.swissinfo.org/sen/swissinfo.html?siteSect=671&sid=1746554&cKey=1052205600000

during the Second World War among Allied troops and certain civilian populations to control insect typhus and malaria vectors, and was then extensively used as an agricultural insecticide after 1945[9].



Some of the trade or other names include Anofex, Cesarex, Chlorophenothane, Dedelo, p,pÕ-DDT, Dichlorodiphenyltrichloroethane, Dinocide, Didimac, Digmar, ENT 1506, Genitox, Guesapon, Guesarol, Gexarex, Gyron, Hildit, Ixodex, Kopsol, Neocid, OMS 16, Micro DDT 75, Pentachlorin, Rukseam, R50 and Zerdane.

The use of DDT increased enormously on a worldwide basis after World War II, primarily because of its effectiveness against the mosquito that spreads malaria and lice that carry typhus. The World Health Organization estimates that during the period of its use approximately 25 million lives were saved[10]. DDT seemed to be the ideal insecticide as it was cheap and assumed to be of relatively low toxicity to mammals (oral LD_{50} is 300 to 500 mg/kg). However, problems related to extensive use of DDT began to appear in the late 1940s. Many species of insects developed resistance to DDT, and DDT was also discovered to have a high toxicity towards fish. The chemical stability of DDT and its fat solubility compounded the problem. DDT is not metabolized very rapidly by animals. But instead, it is deposited and stored in the fatty tissues. The biological half-life of DDT is about eight years. That is, it takes about eight years for an animal to metabolize half of the amount it assimilates. If ingestion continues at a steady rate, DDT builds up within the animal over time.

The use of DDT was banned in the United States in 1973, although it is still in use in some other parts of the world. However, the build up of DDT in natural waters is a reversible process for instance, the Environmental Protection Agency (EPA) of USA reported a 90% reduction of DDT in Lake Michigan fish by 1978 as a result of the ban. The atmospheric deposition is the current source of new DDT contamination in the Great Lakes[11].

DDT, and its break-down products DDE and DDD, are persistent, bio-accumulative, and toxic (PBT) pollutants targeted for elimination. Harmful effects of DDT include being probable human carcinogen, damages the liver, temporarily damages the nervous system, reduces reproductive success, can cause liver cancer and damages reproductive system among others. Exposure to DDT occurs by eating contaminated fish and shellfish, breast milk, eating food directly exposed to DDT and eating crops grown in DDT contaminated soil.

Potential Sources to the environment include DDT in soil absorbed by some growing plants and by the animals or people who eat those plants, DDT in water absorbed by

[9] http://www.worldof molecules.com/pesticides/ddt.htm-38k
[10] http://pubs.acs.org/hotartcl/cenear/980105/paul.html
[11] http://www.epa.gov/glnpo/bnsdocs/wkgpupdates/99updatepest.html

fish and shellfish in those waterways, atmospheric deposition, soil and sediment runoff, and improper use and disposal.

1.8 DDT in the Kenyan Environment

According to the draft report of the inventory of POPs in Kenya, DDT was first introduced in Kenya as an acaricide in 1956 to combat the tick menace. It was banned for use in livestock in 1976. It was subsequently banned for agricultural spray in 1986 but only restricted for use in disease vector control. Restriction was occasioned by the health and environmental effects implicated in its use. For example residues were found in foodstuffs of animal origin, increased resistance of pests and its bioaccumulation in the environment.

A study carried out in Kenya in the mid-1980s indicated high levels of DDT were used in both agricultural and public health undertakings. High levels of DDE and DDT were observed from a test of 367 domestic eggs from 61 farms in Central Kenya and 41 maternal blood, milk, subcutaneous fat and umbilical cord blood samples from mothers who delivered through caesarean section in the Kenyatta National Hospital. It means that other Kenyans have been exposed to DDT through the food pathways and have bequeathed DDT and other persistent organic pollutants to their children who are now more than 20 years old. Similarly another longitudinal study indicated high levels of DDT in mother's milk. The study indicates that levels of DDT in the mothers' sera ranged from 1.69 mg/kg in the milk fat of nomads in Loitokitok to 18.73 mg/kg milk fat in human milk from Rusinga Island[12].

The implication is that the mean estimated sum of DDT exceeded the daily tolerable intake by 17 times. DDT has not been imported into Kenya since 1985. Before the ban about 70 tons were used annually for agricultural pest control on maize and cotton. However, a FAO inventory of DDT in Kenya taken in March 2001 indicated that there were close to 3.42 tons of DDT in stockpiles. A recently conducted inventory of DDT indicated that there were stores with stocks of DDT amounting to 1,100 kg.

1.9 **Impacts of DDT**

1.9.1 Toxicological effects **of DDT**

a) **Acute toxicity:** DDT is moderately to slightly toxic to studied mammalian species via the oral route.
b) **Chronic toxicity:** DDT has caused chronic effects on the nervous system, liver, kidneys, and immune systems in experimental animals.
c) **Reproductive effects:** There is evidence that DDT causes negative reproductive effects in test animals.
d) **Teratogenic effects:** There is evidence that DDT causes teratogenic effects in test animals as well.
e) **Mutagenic effects:** The evidence for mutagenicity and genotoxicity is contradictory. However, in humans, blood cell cultures of men occupationally exposed to DDT showed an increase in chromosomal damage.

[12] http://www.oztoxics.org/ipepweb/library/news%20documents/Summary%20Kenya%20-%20Situation%20Report.pdf

f) **Carcinogenic effects:** The evidence regarding the carcinogenicity of DDT is equivocal.
g) **Organ toxicity:** Acute human exposure data and animal studies reveal that DDT can affect the nervous system, liver, kidney.
h) **Fate in humans and animals:** DDT is very slowly transformed in animal systems.

1.9.2 Ecological effects of DDT

a) **Effects on birds:** DDT may be slightly toxic to practically non-toxic to birds.
b) **Effects on aquatic species:** DDT is very highly toxic to many aquatic invertebrate species.
c) **Effects on other animals (non-target species):** Earthworms are not susceptible to acute effects of DDT and its metabolites at levels higher than those likely to be found in the environment, but they may serve as an exposure source to species that feed on them.

1.9.3 Environmental effects

a) **Breakdown in soil and groundwater:** DDT is very highly persistent in the environment, with a reported half life of between 2-15 years and is immobile in most soils. Routes of loss and degradation include runoff, volatilization, photolysis and biodegradation (aerobic and anaerobic).
b) **Breakdown of chemical in surface water:** DDT may reach surface waters primarily by runoff, atmospheric transport, drift, or by direct application (e.g. to control mosquito-borne malaria). The reported half-life for DDT in the water environment is 56 days (in lake water) and approximately 28 days in river water. The main pathways for loss are volatilization, photo-degradation, adsorption to water-borne particulates and sedimentation. Aquatic organisms, as noted above, also readily take up and store DDT and its metabolites.
c) **Breakdown of chemical in vegetation:** DDT does not appear to be taken up or stored by plants to a great extent. It was not seen to be translocated into alfalfa or soybean plants, and only trace amounts of DDT or its metabolites were observed in carrots, radishes and turnips all grown in DDT-treated soils. Some accumulation was reported in grain, maize and rice plants, but little translocation occurred and residues were located primarily in the roots.

2.0 ALTERNATIVE METHODS AND POLICY REVIEW TO ELIMINATE USE OF DDT IN KENYA

Due to the detrimental effects of DDT, the countries and governments had to come together and chart the way forward that would seek to control and ultimately eliminate the use of DDT. The Stockholm Convention was the global agreement to achieve this goal. Also alternatives that would be effective with little or no impacts on the environment, ecology and human health were to be sought. One such other control method that was discovered as a possible substitute of DDT was *Bacillus thuringiensis israelensis* commonly known as *BTi.*

2.1 The Stockholm Convention on DDT

The Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted and subsequently signed by 92 states and the European Community on 23 May 2001 when it was opened for signature. The Stockholm Convention is a global treaty to protect human health and the environment from persistent organic pollutants (POPs). POPs are chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of living organisms and are toxic to humans and wildlife. In implementing the Convention, Governments are called upon to take measures to eliminate or reduce the release of POPs into the environment.

The Stockholm Convention falls short of outright ban of DDT production and use and where it may be permitted strict conditions have been set. The Convention states that each Party shall restrict its production and use of DDT in accordance with the provisions of Annex B on restrictions.

Annex B: Restriction Part II DDT of the Convention states the following:

1. The production and use of DDT shall be eliminated except for Parties that have notified the Secretariat of their intention to produce and/or use it. A DDT Register is hereby established and shall be available in the public. The Secretariat shall maintain the Register.

2. Each Party that produces and or uses DDT shall restrict such production and/or use for vector control in accordance with the World Health Organisation recommendations and guidelines on the use of DDT and when locally safe, effective and affordable alternatives are not available to the Party in question.

3. In the event that a Party not listed in the DDT Register determines that it requires DDT for disease vector control, it shall notify the Secretariat as soon as possible in order to have its name added forthwith to the DDT Register. It shall at the same time notify the World Health Organization.

4. Every three years, each party that uses DDT shall provide to the Secretariat and the World Health Organization information on the amount used, the conditions of such use and its relevance to that Party's disease management strategy, in a format to be decided by the Conference of the Parties, in consultation with the World Health Organization.

5. With the goal of reducing and ultimately, eliminating the use of DDT the Conference of Parties shall encourage:

a) Each party using DDT to develop and implement an action plan as a part of the implementation plan specified in Article 7. This action plan shall include:
(i) Development of regulatory and other mechanisms to ensure that DDT use is restricted to disease vector control;
(ii) Implementation of suitable alternative products, methods, and strategies, including resistance management strategies to ensure the continuing effectiveness of these alternatives.

(iii) Measures to strengthen health care and to reduce incidences of the disease.

(b) The Parties, within their capabilities shall promote research and development of safe alternative chemical and non-chemical products, methods and strategies for Parties using DDT, relevant to the conditions of those countries and with the goal of decreasing the human and economic burden of disease. Factors to be promoted when considering alternatives or combinations of alternatives shall include human health risks and environmental implications of such alternatives. Viable alternatives to DDT shall pose less risk to human health and the environment, be suitable for disease control based on conditions in the specific Parties in question and be supported with monitoring data.

6. Commencing at its first meeting, and at least every three years thereafter, the Conference of the Parties shall, in consultation with the World Health Organization, evaluate the continued need for DDT for disease vector control, on the basis of available scientific, technical, environmental and economic information including:

a) The production and use of DDT and the conditions set out in paragraph 2 above;
b) The availability, suitability and implementation of the alternatives to DDT; and
c) Progress in strengthening the capacity of countries to transfer safely to reliance on such alternatives.

7. A Party may, at any time, withdraw its name from the DDT registry upon written notification to the Secretariat. The withdrawal shall take effect on the date specified in the notification.

2.2 Current Policy Issues Related to use of DDT in Kenya

For most African countries, malaria has become an overwhelming public health problem, leading some governments to consider using DDT for malaria control in the midst of a heightened debate about its advantages and disadvantages. This report analyses the nature of the DDT debate in Kenya by describing current DDT policy plus malaria and insecticide control as alternatives to DDT use, examining the factors that influence malaria control policy formation and assessing human health impacts of DDT. Even though DDT use for indoor residual spraying (IRS) continues in some other countries and is viewed as a viable malaria control option, receptiveness to alternative control measures still reigns high. This choice occurs in the midst of decentralization that has had a profound impact on malaria control in some countries and the POPs Treaty that is used simultaneously as a rationale for a reintroduction of DDT and its continued prohibition. However, research necessary to make informed decisions on malaria control policy is still lacking not only in Kenya but also in other African countries, hence a need to educate malaria and insecticide control specialists on the human health impacts of insecticides used for vector control, including DDT.

Kenya's decentralization is slightly more limited compared to Ethiopia and Uganda. In 1999, Kenya's Health Sector Reform Secretariat issued The National Health Sector Strategic Plan: 1999-2004. Because of the reform agenda, says the National Malaria Strategy, "…traditionally vertical programmes such as malaria control will need to change radically. The Division of Malaria Control (DOMC) will no longer direct, fund and provide staff for activities in districts. Districts will take on this role

themselves, turning to higher levels for specialized advice and quality control" (Kenya Ministry of Health 2001c). Now, the DOMC provides a strictly policymaking, capacity building and advisory role in malaria control. This major transition has likely hindered the ability of the country to implement adequate malaria control measures. In the transition from a vertical to a decentralized program, Kenya's vector control strategy has recently been promoting the establishment of community spray teams to replace technical spray teams for indoor residual spraying (IRS). WHO guidelines stipulate that technical teams should be utilized to carry out IRS using DDT. It is also important to note that, in the future, decentralization may also aid Kenya's capacity to enforce pesticide policies. The Chair of Kenya's Pesticide Control Products Board is currently establishing offices in several regions of the country to increase the enforcement capacity of the Board. In recent years, enforcement actions were taken directly from the PCPB office in Nairobi.

Under the Stockholm Convention, parties are allowed to use DDT for disease vector control, and are encouraged to use alternative disease vector control measures. At the time of the interviews, Ethiopia, Uganda and South Africa were parties to the Stockholm Convention and Kenya was not. Of these four countries, Ethiopia and South Africa were widely using DDT for malaria vector control, Uganda's Ministry of Health had decided to reintroduce DDT and Kenya has conflicting positions on whether to reintroduce DDT or not.

Kenya has created strategic plans for malaria control, which detail the methods used and the challenges faced by the national government in implementing malaria control on the whole (and not just vector control). These strategic plans, as well as national legislation, vector control guidelines and other documents are already available and provide a more comprehensive understanding of malaria control policy and insecticide policy within the country.

2.3 The POPs Treaty

During the last decade of the twentieth century, many countries became increasingly concerned about certain chemicals that were persistent in the environment and toxic to humans and wildlife. As a result, United Nations officials and national representatives developed an international treaty aimed at banning an initial list of twelve "persistent organic pollutants" (POPs): DDT, Aldrin, Dieldrin, Endrin, Chlordane, Heptachlor, Hexachlorobenzene, Mirex, Toxaphene, Polychlorinated Biphenyls, Dioxins and Furans.

Although DDT was slated to be banned in the POPs Treaty, concerned groups from malarious nations successfully lobbied that the POPs Treaty allow for the use of DDT for public health measures. Parties to the Stockholm Convention are allowed to use DDT for "disease vector control," under conditions outlined in Part II of the Treaty (Annex II). Kenya was among the 151 nations that signed the POPs Treaty that went into force on May 17, 2004.

2.4 Vector Control and DDT in Kenya

Approximately 70 percent of Kenya's land is prone to malaria epidemics. The regular epidemics occur in the western highlands. The semi-arid regions in the north-eastern

and eastern parts of the country experience epidemics only during heavy flooding. Endemic areas are limited to areas primarily in the areas surrounding Lake Victoria, the floor of the Rift Valley, the central parts of the Eastern and Central provinces and Kenya's coastal regions.

Of the approximately 31 million Kenyans, over 20 million are "at constant risk of malaria" (Kenya Ministry of Health 2001c). Malaria kills approximately 26,000 children per year in Kenya and about 170 million working days (an average of 5.5 working days per person) are lost due to malaria per year. Malaria accounts for 30 percent of all outpatient attendance and 19 percent of all admissions to Kenyan health facilities (Kenya Ministry of Health 2001c).

IRS is usually conducted in 16 highland epidemic-prone districts within the country. District Outbreak Management Teams (DOMTs) and Provincial Outbreak Management Teams (POMTs) are responsible for epidemic control and the Divisions of Malaria Control, Environmental Health, and Vector Borne Diseases are responsible for training spray teams and mobilizing resources for the districts. Districts are required to use insecticides recommended by the Ministry of Health that are registered for household use by the Pest Control Products Board (PCPB) (Kenya Ministry of Health 2001c). Districts typically use synthetic pyrethroids like lambdacyhalothrin (Icon) for IRS.

The Division of Malaria Control encourages districts to acquire outside funding to purchase insecticides, sprayers and training materials. In recent years, however, districts have requested funds from the Division for the purchase of these items (Kenya Ministry of Health 2001d).

Surprisingly, IRS is barely mentioned as a vector control method in the National Malaria Strategy 2001-2010; rather, ITNs are the major focus for malaria vector control. DDT is not mentioned at all and the Ministry of Health has announced that DDT will not be used for malaria vector control in Kenya (Bosire 2004). The Ministry of Health has not chosen to use DDT for malaria control since DDT was banned as an agricultural product in1986. The National Environmental Management Authority (NEMA) is vehemently opposed to DDT reintroduction, as is the Chief Executive of the Pest Control Products Board (PCPB). They take the position that, so long as there are alternatives, DDT should not be used for malaria control. The Chief of the PCPB has expressed concerns that DDT reintroduction would compromise Kenya's $300 million horticultural industry. Stakeholders such as the Fresh Produce Exporters' Association of Kenya (FPEAK) and the Kenya Flower Council (KFC) feel threatened by the prospect of losing their export markets if DDT is reintroduced. The European Union constitutes approximately 90 percent of Kenya's horticultural export market (Kenya High Commission 2004).

Additionally, Kenya is the world's leading producer of natural pyrethrum, producing 80 percent of the global supply. The Pyrethrum Board of Kenya produces three vector control chemicals: Pylarvec (larviciding), Pymos (IRS) and Pynet (for ITNs). Some government officials believe that national malaria control strategies should support Kenya's own pyrethrum industry instead of DDT imports (Songa 2004). Two malaria control and insecticide control specialists, who were interviewed for this study, believe that Kenya has the capacity to control DDT from its import to its end use.

Four other interviewed specialists, however, believe that Kenya does not have this capacity. A survey conducted by Egerton University supports the latter interviewees' conclusions, revealing that seven percent of households in the Nakuru district use DDT on their farms, despite Kenya's 18-year ban on agricultural use of DDT (Ramas 2004). As Kenya is currently not able to enforce its complete ban on DDT, questions should be raised about Kenya's capacity to regulate DDT use if it is reintroduced for malaria vector control.

Individuals in the Division of Vector-Borne Diseases (DVBD) in the Ministry of Health support the reintroduction of DDT; however, the DVBD is unable to implement any plans for DDT reintroduction without approval from the Ministry of Health and the Division of Malaria Control. In spite of opposition in NEMA, the PCPB and the Ministry of Health, the DVBD is developing a proposal that includes DDT use as an epidemic stopgap measure during a 7-year timeframe, an assessment of the knowledge that Kenyans have about integrated vector management and consequent training of community members in methods of integrated vector management. This proposal will be in the form of a cabinet memo, which will then be proposed in parliament. One interviewee indicated that DVBD officials are most likely unclear of their mandate, as the DVBD cannot develop malaria control strategies for the Division of Malaria Control. If the Ministry of Health were to approve the DDT use for malaria vector control, an Environmental Impact Assessment (EIA) would have to be conducted prior to DDT reintroduction.

i. Other vector control methods: Bed nets are the primary method of vector control for malaria prevention in Kenya; however, their use by the public is extremely low, and in some areas can range from 5-10 percent. Private firms and NGOs are currently using marketing strategies to create demand for bed nets. Kenya has a strong commercial sector that sells bed nets, as well as the insecticides to treat them. These firms and organizations sell hundreds of thousands of bed nets per year; nevertheless, approximately 10 million ITNs are required to protect the population, and would require re-impregnation every year. The Ministry of Health seeks to "scale up" the use of ITNs along with mass net re-treatments at the community level. Like Uganda, Kenya's Division of Malaria Control seeks to drastically reduce taxes and tariffs on ITNs (Kenya Ministry of Health 2001b). The Ministry of Finance has implemented a policy where the value-added tax on mosquito nets is zero; however, the insecticides with which to treat them still have a value-added tax of 15 percent (Kenya Ministry of Health 2001d).

The Pest Control Products Act, 1982 (Cap 346) prohibits the sale of pre-treated bed nets; thus, individuals must purchase bed nets and insecticides separately, and impregnate the bed nets themselves. This particular measure in the Pest Control Products Act was intended as a quality-control measure to avoid treatment of ordinary nets, which are not meant to be impregnated, that would be sold in the market. This legislation will likely be changed in the near future, as long-lasting insecticidal mosquito nets (LLINs) provide an alternative to ITNs. (While ITNs are nets treated by dipping them in insecticide, LLINs have insecticides impregnated in the resin coating of the net that provides a time-release of the insecticide). The Kenyan Ministry of Health has temporarily registered LLINs until the law is changed.

The Kenyan government also encourages the sale of non-treated bed nets that consumers dip into an insecticide themselves. Knowledge regarding the safe use of these insecticides for impregnating and re-impregnating is unknown (Kenya Ministry of Health 2001b).

***ii. Integrated vector management*:** The Division of Malaria Control does not conduct, but recommends that the public pursue, alternative vector control methods apart from ITNs. These include use of larvivorous fish, larviciding, filling in/draining breeding sites, tethering cattle for zooprophylaxis, aerial space spraying in urban areas and using mosquito coils, repellents and household screens. The Division of Malaria Control will "provide technical advice to employers, municipal councils, [District Health Management Teams] and community groups on alternative methods of local vector control and will ensure supporting reference material" (Kenya Ministry of Health 2001c). Overall, the government is generally receptive to IVM, although one interviewee believes that science surrounding IVM is lacking. The National Environmental Management Authority (NEMA) supports the use of alternative pesticides and integrated vector management rather than DDT reintroduction.

3.0 NEED FOR ALTERNATIVES TO DDT

3.1 Why alternatives

Kenyan scientists have been embroiled in a deepening controversy over whether Kenya should lift a ban on the pesticide DDT in a bid to reduce deaths from malaria. A government-commissioned taskforce was set up as a result in a bid to reveal its advice on whether the pesticide was to be reintroduced. This illustrated the sharp division between two of the country's leading research organisations, the Kenya Medical Research Institute (KEMRI) and the International Centre of Insect Physiology and Ecology (ICIPE), both based in Nairobi[13].

Researchers from ICIPE and others argued that the health and environmental risks of reintroducing DDT was considerable, and that the East African region as a whole was to suffer if the ban were lifted. But researchers from KEMRI argued that the pesticide was needed to combat malaria, which kills 700 Kenyans a day and that Kenya's decision to ban DDT in 1990 was taken hurriedly and without adequate data.

But opponents of lifting the ban which was mooted in early 2003 by the Minister for Environment and Natural Resources, pointed to the fact that the pesticide was forbidden in many countries because of its harmful effects on humans and the environment. The whole debate on DDT should be looked at in the wider context of economics, environment and Kenya's external markets for products such as horticultural and fish products. This was especially relevant particularly at a time when Europe has tightened its restrictions on insecticide residues on East African products. The use of environmentally unfriendly chemicals has also had a heavy toll on the fishing industry from

[13] http://www.scidev.net/gateways/index.cfm?fuseaction=readitem&rgwid=4&item=News&itemid=971&language=1

DDT contamination in Lake Victoria, which is shared by Kenya, Uganda and Tanzania, resulted in a European ban on imports of fish products from the region between 1997 and 2000. Reintroduction of DDT in Kenya would require all countries in the region to invest in equipment needed to monitor levels of the chemical in products destined for export.

In Kenya the following alternatives to DDT are viable and supported by the Government in its bid to replace the use of DDT in malaria vector control. Some of the following are major alternatives that have been successfully utilized in different parts of the world. It is only a matter of effective and adequate policy formulation and implementation by most government to strengthen and promote the use of the alternatives in malaria control.

3.2 Use of Pyrethrum or Pyrethroids

The ultimate goal of the Stockholm Convention is to eliminate DDT. Parties that request exemption to use DDT are required to actively promote research and development of safer and affordable alternatives. Pyrethrins are currently rated as the safest alternatives to DDT because they are biological products. Toxicity of natural pyrethrum as a plant has not been established but studies on the toxicity levels of various pyrethrum products is still ongoing at the Pyrethrum Board of Kenya. The Pyrethrum Board of Kenya has recently produced pylarvex, pymos and pynet to be used in different settings in the control of malaria vector. These products (Pymos™ 0.6 EC, Pynet ™ 5 EC and 0.5 EC) consist of natural pyrethrins, synergists and emulsifiers. Under limited laboratory testing Pymos™ 0.6 was found to have an enhanced residual capacity greater than five months.

3.3 Insecticide Treated Nets (ITN)

Insecticide-Treated Nets or ITNs provide protection against adult mosquitoes. The netting material is treated with synthetic pyrethroids insecticide, which is relatively safe. The insecticide repels mosquitoes and inhibits them from enjoying their blood meal even when there are large holes in the nets. The most commonly used pyrethroids are permethrin, deltamethrin and lambda cyhalothrin. Studies in Ghana, Gambia, Kenya and Tanzania found that ITNs reduced child illness by 29% to 63% and childhood mortality by between 17% to 63% depending on net coverage and malaria transmission pressure. These results are comparable to those of DDT in door house spraying. The main handicap of this program is the possibilities of resistance to pyrethroids – which are the only chemicals available. Also there is not yet any data on the long-term effects of ITNs.

3.4 House Spraying

Initially house spraying was dependent on DDT but gradually shifted away to organophosphates like malathion, fenitrothion or carbamates, propoxur, and bedniocarb. Currently most programs use synthetic pyrethroids.

3.5 Space Spraying

This is the application of non-residual insecticides to the outdoor environment in order to immobilize infective mosquitoes and contain transmission. This is particularly recommended for urban areas where many people congregate outdoors. However this should be an emergency undertaken only under exceptional circumstances – especially during an epidemic.

3.6 Integrated Vector Management (IVM)

This is the use of a cost effective combination of vector control measures that are appropriate to local conditions and priorities and relatively safe for human health and the environment. From the vector control stand point, IVM is generally less risky and more effective due to combination of one or more vector control methods. Profound in this method is the combination of both chemical and non-chemical methods. However chemicals are used as the last line of intervention. IVM methods include public health measures like drainage of still and swampy waters. In rice growing areas these include, drainage of canals to avoid water stagnation, shifting of planting schedule to avoid optimal mosquito breeding conditions; and introduction of aquatic plants *Azolla*, which is also valuable as natural fertilizer and also covers the whole water surface thereby interfering with mosquito oviposition, larvae and pupae. Clearance of pond algae could have dual benefits since the algae can be used to manufacture fancy paper as well as eliminate mosquito menace.

3.7 Biological Control

Larvivorous fish is most commonly used in this method. The most commonly used is *Tilapia nilotica* and *Gambusa affinis.* These two species have been used in North America and also eliminated malaria from Palestine, Israel and Italy.

3.8 Current Research

Current research particularly by USEPA principally centers on natural chemical control. These are naturally occurring and leave no undesirable effects in the environment. Experiments with semiochemicals – chemical signals that are released externally by organisms with information content for other organisms indicate that pheromones[*] and allelochemicals[#] could be used to lure mosquitoes to traps. Sex pheromones could be used to deter ovipositioning, for mass trappings and for interfering with mating. Genetic control with the aim of interfering with reproduction of mosquitoes by affecting the sex cells directly thus increasing sterility is another possibility.

Gamma radiation has also been used to sterilize male (culex) mosquitoes. The males are then released to mate with the anopheles. Radiation induced translocation could also be another applicable method. Only one release would be needed and this only needs to be at only half the mosquito population. In this method gamma-Radiation is

[*] Chemicals produced as messengers that affect the behavior of other individuals of insects or other animals. They are usually wind borne but may be placed on soil, vegetation or various items.
[#] Chemicals produced by one species that modify the behaviour of a different species and are important for parasite-host and plant-pest interactions

used to create a deleterious trait (an exchange of chromatin between chromosomes). The translocated individuals are then mated to produce homozygotes for the translocation. Large numbers are then bred and both sexes are then released to mate with the wild population. Half of the potential offspring of such matings often fail to materialize. Half the remaining viable offspring often carry the translocation in the homozygous form.

3.9 Larviciding

This is the killing of the mosquito larvae and is always a supplementary measure in the Integrated Vector Control Programs. The organophosphate temophos is always used. However, some botanical products appear to be promising larvicides. These include neem, *Azadirachta indica.* Commercial formulations of the toxins of *Bacillus thuringiensis israelensis (BTi) are* available already.

Bacillus sphaericus or B. sphaericus (Bs) on the other hand is a naturally occurring spore forming bacterium in soil and aquatic environments. It produces delta-endotoxin, which is toxic to certain mosquito species like *culex, aedes, psorosphora, mansonia* and *anopheles*. *B. sphaericus* produces two protoxins, which are ingested by the larvae. Protoxins are digested but get activated by enzymes and alkaline conditions in larval midgut. Toxins disrupt the midgut causing fluid leakage. The midgut pH drops, spores germinate and sphaericus grows leading to death of the larvae within 48 hours. *B. sphaericus* has residual action in highly organic habitats and the spores germinate in dead larvae. Both *BTi* and *Bs* do not have significant effects on beneficial insects, fish and plants. They also have no effect on the mosquito predators. Field-testing of *BTi* and *Bs* has revealed that their activity varied depending on larval habitat, mosquito species and general ecology. They both provided control for a two-week period. Both larvicides proved ineffective in breeding sites with high algae content while their efficacy was equally comparable to temophos.

Village level production of bacteria can be cheaper and live microorganisms may produce a longer-term impact. For example in Peru, the pathogen bacterium BTi is produced locally using coconut with water as a culture media. Spores are inserted into the coconut through a hole in the shell, which is then plugged. The bacterium is expected to multiply in 2-3 days. The coconut is then broken and thrown into a mosquito-infested body of water. In many experiments *BTi* killed all mosquito larvae and stopped all laval growth for 45 days (International *Ag-Sieve* 4 (1991), No.2. – Bt Coconut Bombs Strike Malaria Vector).

3.9.1 Bacillus thuringiensis israelensis (BTi)

Bacillus thuringiensis israelensis (BTi) is a naturally occurring soil bacterium that can effectively kill mosquito larvae present in water. It is one of the many strains of *Bacillus thuringiensis*, each having unique toxicity characteristics. BTi is very specific for mosquitoes and black flies, and has some toxicity toward certain other dipterans (including midges). BTi is the primary material used for mosquito control because of its low toxicity to non-target species. Commercially available BTi strains are sold under the trade names Aquabac®, Teknar®, Bactimos®, and Vectobac®. When community mosquito control is needed to reduce mosquito-borne diseases, use of

larvicide applications to the breeding source of mosquitoes is recommended. Larvicides are more effective and less toxic than adult mosquito sprays, and the applications are unlikely to result in human exposure.

BTi spores that are eaten by mosquito larvae release toxins into the mosquito's gut, causing the larvae to stop eating and die. *Bacillus thuringiensis israelensis* serotype h-14 (BTi) and *B. sphaericus* strain H-5a5b (strain 2362) or *Bs* are the major agents commonly used. Larviciding occurs when the bacteria produce a crystal that is poisonous to mosquito larvae. *BTi* delta-endotoxin consists of five protoxins, which are ingested by the larvae. Protoxins are activated by enzymes and alkaline condition in larval midgut to become toxic. The toxins attack midgut causing pore enlargement and cell destruction. The midgut pH drops to neutral causing the larvae to cease digesting food. The larvae die within 48 hours[14].

3.9.2 Use of BTi to Control Malaria in Kenya

Field studies in Kenya have established that the communities at the sites normally applied the BTi to water bodies where mosquito larvae live. Since mosquitoes generally prefer to breed in standing water, typical locations where BTi were used included storm water retention ponds, catch basins and shallow areas and paddy rice fields such as Mwea Tebere Rice Irrigation Scheme in Kirinyaga District of Kenya. In the control of the mosquito demonstrations are ongoing in Malindi in Mombasa and Kirinyaga and Kissi Districts in Kenya where demonstrations on the BTi are currently undergoing. BTi products are recommended due to their low toxicity to non-target organisms.

According to Dr. Gathure and Prof. Francosin both Program Officer at ICIPE working on the BTi field stations, the BTi is only effective against actively feeding larvae, and does not affect mosquito pupae or adults. The products that contain BTi are available in liquid, briquettes (small blocks) and granular formulations. These formulations can be applied to water bodies by hand, with a sprayer, or aerially. The interviews revealed that BTi breaks down quickly in the environment and may need to be reapplied regularly. This will depend on the formulation and environmental conditions as BTi may remain effective from 24 hours to over one month[15].

Already a BTi production facility has been set up at the ICIPE with a view to manufacture the BTi locally though with the patent and authorization of the US based company that currently produces the product. It was established that the plant is economically viable not only when in full operation but also with strong back-up of Government policy to promote the use of BTi in the country. Some of the strategies that would ensure its economic viability are to create an enabling environment such as tax free and other incentives for its production and consumption.

[14] National Pesticide Information Center, 2000. Bacillus thuringiensis technical fact sheet.

[15] Washington State Department of Ecology. Aquatic Mosquito Control, National Pollution Discharge Elimination System, Waste Discharge General Permit. Permit no: WAG – 992000. Effective Date: May 10, 2002.

Currently, the product BTi is not used in large quantities in the country due to its uniqueness and much has not been done to promote its large scale importation, manufacturing and utilization.

Some products that contain BTi, such as Mosquito Dunks® and Mosquito Bits®, are available for private residential use in some countries such as America. In using these products, it is important to carefully follow the label instructions and to apply only to waters that will not drain off the property (e.g. ornamental ponds or other closed systems). If water on private property is connected to or has the potential to reach surface waters, then only a licensed pesticide applicators may apply the product.

The trials in the field stations have also demonstrated that no measurable health effects were seen in laboratory animals that ingested large concentrations of BTi. Cases involving human health effects following exposure to BTi are extremely rare. Direct exposure to BTi has been shown to cause skin and eye irritation in some animals. Cases of eye and skin irritation in humans have also been reported following direct exposure with some *Bacillus thuringiensis* products. Pets are unlikely to experience health effects from exposure to BTi based on the results from numerous studies involving laboratory animals[16].

The scientists also indicated that BTi is non-toxic to mammals, birds, and fish as laboratory studies showed no effects were observed when a right amount of concentrations of BTi are applied. Few studies, however, have closely examined potential long-term ecological impacts of BTi application. Some studies however suggest that continuous application of BTi over a period of 2-3 years to wetlands may result in an overall decrease of biodiversity[17].

Since BTi is generally applied to areas that are inaccessible to the public, exposure is unlikely. Common sense steps, such as avoiding areas during scheduled larvicide applications, will further reduce the chances for exposure.

Secondary or “inert” ingredients in pesticide formulations do not have to undergo the same stringent testing as active ingredients (i.e. BTi). Some strains of *Bacillus thuringiensis* have the potential to produce various toxins (exotoxins) that may exhibit toxic symptoms in mammals. However the manufacturing process includes monitoring to prevent these toxins from appearing in products. Tests have not shown commercial formulations of BTi larvicides to be more toxic than the isolated active compounds.

Working with the local communities in the field stations to control mosquito larva, BTi is placed in areas of standing water where mosquitoes breed, such as ditches and shallow ponds of which after sometime, the larvae are counted to demonstrate the effectiveness of BTi to the community. This bacterium damages the digestive system of the mosquito larva when they eat it, causing the larva to starve to death.

[16] National Pesticide Information Center, 2000. Bacillus thuringiensis technical fact sheet.

[17] Siegel, JP and JA Shadduck, 1990. Mammalian Safety of Bacillus thuringiensis israelensis in Bacterial Control of Mosquitoes and Black Flies: Biochemistry, Genetics and Applications of Bacillus thuringiensis israelensis and Bacillus sphaericus, pp 202-217. Editors: Barjac and Sutherland. New Brunswick: Rutgers University Press.

The community also embraces the use of BTi as it does not pose any threat to human and animal health. They are also taught not only the mechanism that makes BTi effective but also the handling of the BTi in accordance with directions provided.

The bacteria BTi occurs naturally in the soil and is harmless to mammals, fish, birds, and insects other than mosquitoes and black flies. BTi only becomes toxic in the stomachs of mosquito and black fly larvae. The presence of sunlight and microorganisms cause the insecticidal toxin to biodegrade quickly in the environment.

It has been determined that products containing BTi do not pose any health risks to humans or mammals. Although only mild skin and eye irritation has been reported with direct contact, it is best to keep children away from areas that have been treated. Public service announcements identifying the geographic areas to be treated need to precede any application of BTi.

In situations where removal of water or remediation is not possible or is cost prohibitive, there is a licensed product available for domestic use. One product currently on the market, Aquabac, is available and a limited number of lawn maintenance companies are using it. This product contains the larvicide BTi.

There are limitations to using this product. For example, it will not be effective in water with high organic matter, the Culex species of mosquito may not be as susceptible to this particular larvicide as are other mosquito species, and the product will have to be applied on a weekly basis.

3.10 Other simple approaches

An interview with Dr. Gathure apart from the use of BTi, residents could still use a more effective way to control mosquito populations for example to reduce the amount of standing water where mosquitoes can breed. He recommended that the following steps could also be taken by the communities to reduce mosquito habitat:

- Empty containers that hold standing water old tires, buckets, plastic covers, pots and earthenware and toys;
- Change water in birdbaths, fountains, wading pools and animal troughs at least twice a week;
- Recycle unused containers that may collect water bottles, cans etc.;
- Make sure roof gutters drain properly and clean gutters in the rainy season;
- Fix leaking outdoor faucets and sprinklers.

Table 1: Some Products of Bacillus thuringiensis israelensis (BTi)

Product Attributes	**PreStrike® *(S)-Methoprene***	**Mosquito Dunks® *BTi***	**Mosquito Bits™ *BTi***	**Mosquito Stop™ *BTi***	**Mosquito Beater® Plunks *BTi***
Frequency	Every 30 Days	Every 30 Days	Every 7 to 14 Days	Every 7 to 14 Days	Every 7 to 14 Days
Larvae Affected	Older larvae; *Prevents older larvae from adulthood*	Young Only; *Will not prevent older larvae from becoming adults*	Young Only; *Will not prevent older larvae from adult*	Young Only; *Will not prevent older larvae from adults*	Young Only; *Will not prevent older larvae from adults*
Effect on the Food Chain	Larvae remain at the water surface to be eaten by predators	Larvae die and cannot be eaten by natural predators	Larvae die and cannot be eaten by natural predators	Larvae die and cannot be eaten by natural predators	Larvae die and cannot be eaten by natural predators
Application Rate	1 Teaspoon treats 53 sq. ft.	1 Dunk treats 100 sq. ft.	1 Teaspoon treats 25 sq. ft.	1 Packet treats 100 sq. ft.	1 Plunk treats 50 sq. ft.
Mode of Action	Works by contact or ingestion	Must be ingested	Must be ingested	Must be ingested	Must be ingested
Period of Protection	Protects up to 30 days in water	Lasts up to 30 days in standing water	Lasts up to 48 hours in water	Lasts up to 48 hours in water	Lasts up to 48 hours in water
Disbursement	Disperses in water	Easily floats away	Disperses in water	Disperses in water	Disperses in water
Water Clarity	Leaves water crystal clear	Leaves water cloudy	Leaves water cloudy with a yellow tint	Leaves water cloudy with a yellow tint	Leaves water cloudy with a yellow tint
Water Aesthetics	Granules sink to bottom	Unsightly floating debris	Unsightly floating debris	Unsightly floating debris	Unsightly floating debris

4.0 EXPERIECES FROM OTHER COUNTRIES

Malaria control specialists in East African countries are typically not knowledgeable enough about malaria control policies of other countries. Although there are some initiatives on policies, there is no best experience from the countries to consider as a single package. For example the South African experience is never a good one since it is wholly dependent on pesticides. Perhaps what someone might say is that "the health sector reforms currently being implemented in many African countries emphasize decentralization of malaria control programs. However the process is often under-funded and are operated vertically which exclude community participation. The best policy option is that one which emphasizes decentralization of malaria control programs. These approaches need to integrate community involvement, which ensures sustenance of such programs."

Promotion and enforcement of compulsory periodic IRS as the "backbone" of the country's malaria program has been happening in South Africa's malaria control program where spraying is conducted once per year, before rainy season begins towards the end of the year. South African policies are administratively vertical (within the province) where provincial malaria control personnel work closely with district and sub-district personnel and the districts and sub-districts are responsible for the actual implementation of malaria control policies. Provinces create and implement malaria control policies through a vertical system, where malaria control policy is developed, pesticides are procured, and control actions are implemented at the

province level. Additionally, government decentralization plays a key role in the effectiveness of vector control strategies.

There is a need for a policy to empower provinces to create and implement malaria control programs. For successful programs, leadership at provincial and lower government levels should be responsible for procuring sustainable alternatives and implementing malaria control policies.

A prudent approach would be to formulate policies that will ensure active ITN use which implies the involvement of the private sector. In Uganda there is an active ITN by commercial sector that the government is actively supporting in three ways: eliminating taxes on ITNs, eliminating tariffs on ITN imports and restricting free donations of ITNs to emergency situations. In addition, the government subsidizes ITNs for children less than five years of age, pregnant women and those living below the poverty line (Uganda Ministry of Health 2001).

Promotion of policies that support research and diversity of alternatives to insecticides are necessary. Similar research is ongoing in South Africa to evaluate existing and new insecticides as well as different groups of insecticides in order to determine their usefulness for IRS. The ultimate aim is to use safer insecticides out of the different insecticide groups as part of a resistance management program. The results of the ongoing research will determine the safety level.

Policies that will encourage incorporation of DDT issues in the training curriculum for specialists will increase knowledge about DDT among the specialists in and the neighbouring countries. In South African for example, specialists are quite aware of the malaria control regimes in other Southern African countries. Department of Health officials recognize that bordering nations' malaria programs can positively or negatively impact malaria prevalence in South Africa; thus, the South African government actively communicates with and advises other countries on their malaria control programs.

5.0 CONCLUSIONS

Malaria is a disease that has caused more sufferings and death to millions of humans since time immemorial. The analysis of the nature of malaria and the serious health problems it causes to humans has been of concern to the international communities, governments, research and academic institutions, medical fraternity, and the population in general.

The elimination of the deadly plasmodium that causes the disease is an issue that requires immediate and concerted attention. As a result, the environment, the ecology and the human and animal health has been jeopardized both consciously and unconsciously mainly through the use of chemical products such as DDT to control the adult anopheles mosquito that is responsible for the transmission of the plasmodium.

Even though it is estimated that the introduction of chemicals such as the DDT in the early years of 1930s in the control of mosquitoes saved over 25 million lives, it equally did more harm to both the biotic and abiotic environments in which it came into contact with. Given the Stockholm Convention Provision to continue using DDT for malaria control through exemption, where a Party or a non party to the Convention is authorized to produce and or use DDT, a strict monitoring mechanism must be put in place to ensure that the laid down recommendations and guidelines on the use of DDT are adhered to.

From the studies, it has been established that there are more strategies that can be applied to control malaria. These strategies are as effective as DDT. Apart from the widely used methods such as insecticide-treated nets (ITN), house spraying, space spraying, integrated vector management (IVM), and biological control, larviciding using *Bacillus thuringiensis israelensis (BTi)* has been seen to be equally effective as DDT and without the negative impacts on the environment, human and animal health.

Due to the recent introduction of *BTi* in the war against malaria in Kenya, it is not yet widely used due to the low level of production. However, its application is increasing with increased awareness and production. With the high level of government support, its use is likely to increase in the next few years. The findings of this study therefore support phasing out of DDT and substituting it with IVM which includes the larvicide *Bacillus thuringiensis israelensis* as an effective malaria control strategy. Where other viable alternatives to DDT that pose less risk to human health and the environment are to be used, close monitoring of application of these alternatives must be put in place.

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