Proposed dichlorodiphenyltrichloroethane (DDT) use for mosquito control in Uganda; Assessment of possible benefits and effects

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Table of Contents

Overview

DDT is a pesticide that was widely used in agriculture and mosquito control in the early 1940s (Maguire, 2004). DDT proved to be a very effective strategy to prevent the spread of malaria, albeit with several setbacks as was later discovered (Carson, 1962; Martin, 2008). Because of its success in mosquito control, a few countries still use it as a preventive strategy(van den Berg, 2009). Uganda is only in the process of trying to re-introduce the use of DDT(Wendo, 2004).

Uganda is a land locked country located in East Africa. It extends about 800 km inland from the Indian Ocean. Uganda is bordered by Tanzania and Rwanda to the South, the Democratic Republic of Congo to the West, Sudan to the North and Kenya to the east.

Uganda has a land surface area of 241,139 square kilometers. A report in the Encyclopedia of Earth has estimated this to be about twice the size of the state of Pennsylvania. Most of the food is provided through subsistence farming and about 27 percent of land use is devoted to this effect.

The world fact book has ranked Uganda as the one hundred and fourth poorest country in the World with a Gross domestic product (GDP) of $15.66 billion and a GDP per capita of $1,300 (CIA, 2010). Uganda is a poor country that needs to put its resources to maximum use. Despite this despicable poverty, it faces a high burden of diseases, malaria being a major contributor.

The Malaria burden

Malaria is a complex parasitic disease transmitted by anopheles mosquitoes. It is mainly confined to the tropics where Uganda is situated.

Between 1997 and 2002, malaria epidemics were wide spread in Africa and 41 countries were affected. The estimated death rate during this period was 155,000-300,000 (Worrall, Rietveld, & Delacollette, 2004).

In Uganda, malaria accounts for more than 25% of disease burden. Malaria is responsible for every one in five child deaths in hospitals(20%); one in three patients attending the outpatient department(33%); 25% of all persons admitted in hospitals; and over 100,000 child deaths every year, or 350 deaths every day (MOH, 1995). These figures have not significantly changed over the years(MOH, 2008).

The disease also causes other multiple health problems which include spontaneous abortions, low birth weight and severe anemia.

Although malaria affects all age groups and gender, the most affected populations are pregnant women and children below 5 years who experience the severest forms of malaria(MOH, 1995).

Uganda's minister of health at a press briefing in 2004 reported that Uganda loses about USD 347 million each year as a result of Malaria (Wendo, 2004).

Given the public health importance of malaria and the associated economic levels, it is of paramount importance that the Ugandan government takes all reasonable efforts to combat such a huge problem the country is faced with.

Traditionally Uganda has a number of interventions to stop the spread of malaria. First is the prevention of contact between humans and mosquitoes through the use of insecticide treated mosquito nets (ITNs) and house screening. Other measures are: reduction of the mosquito population through the use of larvicides to target the larva stages of mosquitoes, clearance of bushes around homes and indoor residual spraying with pyrethroids. Last but not least is the reduction of malaria parasites through prompt diagnosis and treatment of individuals with malaria (MOH, 2001).

Recently, the suggested addition of dichlorodiphenyltrichloroethane (DDT) to the arsenal has generated considerable debate.

History, toxicology and effects of DDT

DDT was discovered accidently by a graduate student in 1874, but it was not until 1939 that its insecticidal use was discovered, a work for which Dr.Paul Muller of Geigy in Switzerland was awarded a Nobel prize for medicine in 1948 (Maguire, 2004). Dr. Maguire further states that DDT was widely used in

World War II to protect troops and civilians from insect borne diseases. It was indeed a wonder drug until the 1960s when problems started to accumulate as reported in the United States of America (Carson, 1962). Biologists identified harmful effects in birds, fish and wild life. Toxicological studies started showing DDT's chronicity in humans.

More recent studies have elucidated more health effects of DDT over the years. Studies in South Africa and Mexico have showed high levels of DDT in samples of people living in DDT sprayed houses (Aneck-Hahn, Schulenburg, Bornman, Farias, & de Jager, 2007; Bouwman, Cooppan, Becker, & Ngxongo, 1991; De Jager, et al., 2006)

There has also been evidence that the fetus can be exposed through the placenta and young children through lactation (Bouwman, Sereda, & Meinhardt, 2006).
Exposure of adults is through direct contact with DDT in the environment; this can be through indoor dust (Herrera-Portugal, Ochoa, Franco-Sanchez, Yanez, & Diaz-Barriga, 2005).
The fact that DDT gets biomagnified in the food chain is another area of concern through which humans can be exposed.
Many studies, though not all have been consistent, have showed a myriad of health effects associated with DDT. These effects include inter-alia: fertility loss, leukemia, pancreatic cancer, neurodevelopment deficits, diabetes, and breast cancer (Beard, 2006; Cox, Niskar, Narayan, & Marcus, 2007).

There has also been reports of increased cases of breast cancer among women that were exposed to DDT at a young age (Cohn, Wolff, Cirillo, & Sholtz, 2007).
Several animal studies have also showed carcinogenic, immunotoxic, neurotoxic and reproductive effects directly related to DDT (Turusov, Rakitsky, & Tomatis, 2002).
Furthermore, the Pesticide Action Network International has listed a number of other evidence-based human effects of DDT. These include: higher incidence of undescended testes, poor sperm quality, premature delivery and reduced infant birth weight, miscarriage, reduced breast milk production, neurological effects; including development delays among babies and toddlers exposed to DDT in the womb, elevated risk of breast cancer, and other cancers, nervous system and liver impacts due to occupational exposure to DDT (PAN, 2000).
The adverse effects of DDT can potentially offset the health gains from malaria prevention, if for example infant survival from malaria could be offset by preterm birth (van den Berg, 2009).

Environmental effects have also been widely studied. DDT is a persistent molecule that is slowly degraded to its main metabolic products. These are dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD). Both DDE and DDD have similar physicochemical properties as DDT but different biological activities (van den Berg, 2009).
DDT further spreads through volatilization and runoff. It has a strong affinity for organic matter in the soil and aquatic sediments with half lives of 3-7 months in tropical soils and up to 15 years in temperate soils (Varca & Magallona, 1994).

DDT has a strong binding capacity with fatty tissues of most organisms. This coupled with its great stability (persistent organic pollutant) leads to its biocentration and biomagnifications in the food chain at higher trophic levels (Kelly, Gobas, & McLachlan, 2004). The half life of DDT in human beings is more than four years and that of its metabolites is probably longer than this (Longnecker, 2005).

There is also much evidence indicating that DDT is toxic to insects, shrimp, and fish (Fisk, et al., 2005; Metcalf, 1973). DDT also adversely affects the reproduction of birds and reptiles through thinning of egg shells(Ratcliffe, 1967).

Another issue of great concern is mosquito resistance to DDT. From the time DDT was introduced hitherto, several studies have reported continued resistance to this pesticide with over 50 species of anopheline mosquitoes becoming resistant (Hemingway, Beaty, Rowland, Scott, & Sharp, 2006; Ranson, et al., 2000).

Early studies attributed DDT resistance to its use in agriculture, since many vectors breed in such environments (Mouchet, 1988).

With more research this school of thought has been dropped by many scientists. It's currently widely believed that DDT resistance is triggered by the use of synthetic pyrethroids (Diabate, et al., 2002). This is certainly due to cross resistance between DDT and pyrethroids. This is referred to as the sodium channel mutation affecting neuronal signal transmission, controlled by the kdr or knock down resistance gene (Martinez-Torres, et al., 1998).

Vectors that possess the kdr gene are therefore resistant to both DDT and pyrethroids. This is a major problem in malaria control since DDT and pyrethroids are the major insecticides used for the control of mosquitoes.

The WHO reports that the kdr gene has been observed even in countries without history of DDT use (WHO, 2006).

Why DDT in Uganda?

Despite all the health and environmental concerns, the Uganda government embarked on a debate to re-introduce DDT. The government has come up with evidence as well as a number of reasons to defend the use of DDT as a vector control method.

First is the malaria burden that poses great health problems as well as economic losses to the country (Wendo, 2004).

Second is the history of DDT use in Uganda; DDT was used mainly to control cotton pests from the 1950s to 1970s.Its use along the Victoria Nile river also led to the eradication of Simulium damnosum with subsequent elimination of onchocerciasis (Uganda Ministry of Health,1995).

Between 1959 and 1960, the WHO conducted a pilot malaria control project in western Uganda where DDT was used for indoor residual spraying (IRS). The WHO team used 2g/m^2 DDT to spray dwelling houses and kraals (De Zulueta, Kafuko, Cullen, & Pedersen, 1961).

When the DDT debate began in Uganda, a group of scientists from one of the leading universities in Uganda (Makerere University Kampala) and the Uganda National Academy of Science (UNAS) conducted a study on the residents of this previously exposed area. They concluded that after 45 years of DDT spread no detrimental effects to man, plants or animals and the general environment were observed (UNAS, 2006). The Ugandan government therefore capitalized on this and gave a further push for DTT. The problem is that this study was conducted by organizations that obtained funding from the government, and therefore one cannot rule out possible conflict of interest. Also of concern is the fact that they didn't conduct this study before but rather this debate came up! The government also states that several African countries like Zambia, South Africa, Mozambique, and Zimbabwe still use DDT for malaria control and no major problems have been reported from these countries(van den Berg, 2009).

In addition the Uganda government has received overwhelming support from the USA and WHO as regards DDT IRS. The US government through its President's Malaria Initiative (PMI) has more than tripled funding for malaria control to USD 9.5 million in 2006-2007.This funding has no restrictions to IRS of DDT and actually encourages DDT Legislation. The WHO also strongly supports the DDT IRS campaign (Wendo, 2004).
Furthermore The Stockholm Convention which seeks to eliminate certain chemicals to which DDT belongs has condoned DDT use as long as it is for public health purpose like IRS (UNEPI, 2002).
The problem is that DDT sprayed indoors may end up in the environment especially when such houses get demolished for some reason.

There is therefore need to seek for a proper sustainable solution to the malaria problem in Uganda without necessarily resorting to DDT use.

Alternatives to DDT

It is very important for all governments not just that of Uganda to realize that malaria is an environmental problem that needs concerted efforts of all stakeholders in dealing with this problem.
The authors of the book Malaria *Vector Control without DDT: Sustainable Alternatives* clearly elucidate several mosquito control measures that are applicable to individual and community levels.
They classify them under five headings namely: reduction of human mosquito contact, destruction of adult mosquitoes, and destruction of larvae, source reduction, and social participation. The authors provide basic approaches that can be used to fight this disease without necessarily using DDT (Adriaens & Lemmens, 2006).
A number of success stories that controlled malaria without DDT use have been reported all over the world. Of particular importance is the Environmental management for Malaria control that was used in the copper mining communities of Zambia. This approach reduced the mortality and morbidity by 70-95% within a 3 -5 year period. This program was not only successful at reducing the effects of malaria, but it was very cost effective. The estimated cost per death and malaria attacks averted were USD 858 and USD 22.20 respectively. The costs per disability adjusted life years (DALY) averted were USD 524-591. This was only for the initial three year period; the approach averted an estimated 4173 deaths and 161,205 malaria attacks over the entire 20 year period of implementation (Utzinger, Tozan, Doumani, & Singer, 2002).
This program was based on vegetation clearance, modification of river boundaries, draining of swamps, oil application to open water bodies and house screening. All these are possible approaches which have been shown to be cost effective (Goodman & Mills, 1999).

Another example is the Vietnam campaign against malaria conducted in 1991. Vietnam excluded DDT from its malaria control programs. This approach reduced malaria deaths by 97% and cases by 59%. It was based on drug distribution, use of bed nets and health education(PAN, 2000).

I therefore believe that even in situations where indoor spraying is considered, less harmful pyrethroids should be used instead of DDT. More research in this area is also needed because of the noted cross resistance between DDT and pyrethroids.

Research Needs

A lot of work has been published about DDT use right from the time of Carson's Silent Sring that opened the eyes of the public to the harmful effects of DDT (Carson, 1962). From the readings I have done to come up with this paper, I realized that more research is still needed as far as mosquito control and DDT use are concerned.

First, the cross resistance between DDT and pyrethroids has posed major concerns(Martinez-Torres, et al., 1998).
Pyrethroids are the most readily available alternative to DDT. There is therefore need for more research to look into possible alternative chemicals. This will give sufficient time to study their toxicology before being introduced on the market.

There is also need for more research in the vector modification. The area of mosquito sterilization has been talked about but not much success has been registered yet (van den Berg, 2009). More mosquito characteristics need to be studied. These may be very paramount in applying appropriate strategies.

There is need for research to help revise the WHO guidelines for DDT indoor spraying of $2g/m^2$ DDT repeated every 6 months. Research needs to be done to find out if smaller concentrations can be used or even durations longer than 6 months.

There is also need for a comprehensive cost assessment of DDT or its alternatives that takes into account side effects (van den Berg, 2009). Several studies have been done comparing the cost of DDT versus alternatives, but they lack strength because many have not put side effects into consideration.

There is also need to have comprehensive studies that look at health effects of DDT in countries that are currently using IRS with DDT. Much work has been done on the environmental effects but not the health effects of DDT in humans.

Even though some studies have showed that water and soil samples from countries that practice IRS have higher levels of DDT than countries without IRS (Vieira, Torres, & Malm, 2001; Yanez, Ortiz-Perez, Batres, Borja-Aburto, & Diaz-Barriga, 2002), some experts believe that these studies still need further verification (van den Berg, 2009). There is therefore need for more research in this area.

In conclusion, sustainable and cost effective malaria control strategies are needed. These should focus on environmental control other than resorting to DDT use.
This approach involves destruction of breeding sites of mosquitoes, chemical control with pesticides other than DDT, biological controls such larvivorous fish, and use of insecticide treated mosquito nets.
The plan to re-introduce DDT and all its evils will not help if we do not deal with the mosquito breeding places.
Fortunately in 2008, the high court of Uganda prohibited DDT use after a long court battle between the government and environmentalists(van den Berg, 2009).
Debates are still going on between the government and environmentalists; therefore there is need for more information and evidence about DDT.
However, in agreement with the WHO, I believe that DDT spraying should be considered under certain special circumstances e.g. for control of epidemics, vector control in areas of economic importance, as well

as refugee camps-where interventions like ITNs can hardly help, and initial protection of non-immune settlers in development areas (Goodman & mills, 1999).

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