DDT Loosing Grounds in India: Alternatives imminent

Toxics Link
Factsheet
Number 38/May 2011

1. Introduction

1.1 DDT - the most controversial Persistent Organic Pollutant (POP)

Dichloro Diphenyl Trichloroethane or DDT, the first generation synthetic pesticide, for long had the dubious distinction of being an angel chemical against malaria vector and agricultural pests. Since its successful immediate impact in vector control, especially mosquitoes and typhus among the civilians and troops during World War II, DDT has a long history of being, including its widespread application in agriculture and public health programmes across the globe.

However, in the western world, especially in the US, DDT's fairy status got a jolt with Rachel Carson's (an American biologist) discovery about its horrendous ecological and health impact; who in her 1962 book titled 'Silent Spring' indexed the environmental cost of DDT's indiscriminate use in the US. Her suggestion that DDT causes cancer and its agricultural use could endanger biodiversity resulted in huge public outrage and its subsequent ban in the US in 1972.

Nonetheless, even the UN's Stockholm Convention (2001/2004) on Persistent Organic Pollutants (POPs) could only restrict its march allowing countries to use it for vector control. It is thus perhaps the most controversial of the twenty-one POPs.

1.2 The glitch

While so much going against DDT in the developed world and various international forums, it is still considered one of the best and cheapest answers against mosquitoes that spread the no-vaccine diseases like malaria and dengue. With safer, reliable and economical alternatives to DDT still at bay or perchance not commercially validated, the molecule continues to be in use for vector control in several countries including India. In fact the only argument that goes in DDT's favour is 'mosquitoes and malaria' that directly impact about 300 million[1] lives each year, mostly in the underdeveloped and developing countries.

DDT's use in agriculture although was globally banned with the UN's Stockholm Convention on POPs listing it in Annexure B (meant for its restrictive and conditional use); India debarred its use in agriculture way back in 1989 owing to credible scientific evidences of its ill impact on ecology and life. However, the fact remains that India is the largest producer (China is the only other DDT producing country) and also the sole exporter of this molecule in the world, malaria again being the only argument for it.

Box 1: Quote unquote

"My fly cage was so toxic after a short period that even after very thorough cleaning of the cage, untreated flies, on touching the walls, fell to the floor. I could carry on my trials only after dismantling the cage, having it thoroughly cleaned and after that leaving it for about one month in the open air.." *– Paul Müller, on his discovery of DDT, Nobel Lecture, December 11, 1948 - Nobel lectures, physiology or medicine, 1942-1962 - By Nobelstiftelsen World Scientific[2];*

"You could eat a spoonful of it and it wouldn't hurt you."- *Dr Donald Roberts, professor of tropical public health at the Uniformed Services University A Study of Our Decline - By Philip Atkinson[3];*

If there's nothing else and it's going to save lives, we're all for it. Nobody's dogmatic about it –*Greenpeace spokesperson Rick Hind, after Greenpeace stopped their effort to completely ban DDT, January 11, 2005[4].*

Researchers worldwide although agree to the fact that DDT has helped in saving millions of life in its early years of application, there are scientific evidences confirming its fading effectiveness in controlling mosquitoes and malaria while simultaneously infusing unwanted toxic burden on ecology and living beings. The Indian experience in this regard is not different; the vector resistant to DDT was first noticed way back in '70s[5].

In the year 2006, WHO although approved indoor residual spraying of DDT for vector control until safer and economic options are available, several countries including India are on the lookout for safer chemical and non-chemical alternatives due to limitations of the DDT regime.

Box 2: DDT Chronicle

1873 –	DDT synthesized by a German chemist Othmar Zeidler for no purpose
1939 –	Insecticide properties of DDT discovered by Paul Müller.
1944 –	DDT was first introduced in India in 1944 by the British and American armies in Orissa and Karnataka.
1947 –	In 13 southern states, over 4,650,000 houses were sprayed with DDT
1948 –	Paul Müller awarded the Nobel Prize in Physiology and Medicine.
1949 –	Malaria eradicated from Italy.
1951 –	Malaria eradicated from the U.S.
1953 –	The Government of India (GOI) launched the National Malaria Control Programme, with indoor residual spraying (IRS) of DDT
1955 –	The World Health Organization (WHO) makes plan to eradicate malaria worldwide.
1961 –	DDT use reaches its peak. It was registered for use on 334 agricultural products.
1962 –	Rachel Carson's book Silent Spring blamed environmental destruction on DDT.
1969 –	Residues of DDT and its metabolites (such as DDE) found worldwide.
1970 –	WHO announces that malaria has been eradicated in 37 countries
1972 –	EPA bans DDT in the U.S.
1976 –	WHO gives up malaria eradication programme
1989 –	India Banned DDT for agricultural use
1998 –	POPs Treaty proposes banning DDT.
2001 –	POPS Treaty grants a temporary health-related exemption for use of DDT for malaria. Stockholm Convention came into force in 2004
2006 –	WHO approved DDT use for vector control till safer alternatives are developed

2. History chronicles

DDT is the first of the chlorinated organic insecticides synthesized in 1874 by an Austrian/German chemist Othmar Zeidler for no purpose. However, its vector controlling strengths were discovered only in 1939 by a Swiss scientist Paul Hermann Müller who was awarded the Nobel Prize in Physiology for Medicine in 1948. After the World War – II, DDT was inducted as an agricultural insecticide, and soon its production and use peaked It is estimated that since 1940 close to 2 million tonnes of DDT has been produced globally[6].

DDT was the main product used in the global efforts, supported by the WHO, to eradicate malaria during 1950s and 1960s. This campaign resulted in unbridled use of DDT but significantly reducing malaria transmission in Taiwan, the Caribbean, the Balkans, parts of northern Africa and Australia and dramatically reducing mortality in Sri Lanka and India.

However, DDT was less effective in tropical regions due to the continuous life cycle of mosquitoes and other infrastructure and administrative issues. It was not applied at all in Sub-Saharan Africa due to these perceived difficulties

During the same period, DDT was made available to farmers in Europe and America. Its use in agriculture spread to other countries mainly to protect field crops from pests like potato beetles, coddling moth in apples, corn earworm, cotton bollworm and tobacco budworms.

With the publication of Rachel Carson's Silent Spring in 1962, however, the hype and the euphoria around DDT got diluted. From 1969, the attention got sifted to controlling and treating of malaria and the goal of eradication got abandoned. Due to concerns over safety as well as administrative, managerial and financial challenges, the countries slowly curtailed the use of DDT in vector control. Additionally, the vectors were also developing resistance to DDT. Efforts shifted from spraying to the use of bednets impregnated with insecticides and other interventions. The ugly truth of cancer, nervous disorders, reproductive dysfunctions etc. started finding linkages to DDT. Behind the veil of being a wonder chemical, which saved lives, DDT emerged as a Persistent Organic Pollutant (POP). This means that it could aggressively persist in the environment long after its initial application, sometimes up to 30 years in soil depending upon local conditions.

At present DDT is banned or restricted for vector control in about 60 countries[7] and it is illegal to import in 102 countries. As of 2008 only 12 countries reported use of DDT as IRS, including India and some Southern African states[8]. However, due to change in climate across the globe, DDT could again see its resurgence as vector control chemical, if alternative methods fail to find due recognition in the vector control programmes.

3. India's tryst with DDT

DDT was first introduced in India in 1944 by the British and American armies in Orissa and Karnataka[5]. Between 1948 and 1952, malaria-control demonstration projects revealed the unprecedented effectiveness of DDT in interrupting transmission even at dosage as low as 0.5-g/m2. In 1953, the Government of India (GOI) launched the National Malaria Control Programme NMCP, with indoor residual spraying (IRS) of DDT at 1 g/m2. Simultaneously, it established a DDT production plant (The Hindustan Insecticides Ltd., HIL) to meet the needs of the NMCP. Later in 1958, due to DDT's phenomenal success in controlling malaria, NMCP was turned into the National Malaria Eradication Programme (NMEP) with India joining WHO's global malaria eradication effort. NMEP is now under the National Vector Borne Disease Control Programme (NVBDCP) that has the mandate for prevention and control of six vector borne diseases including Malaria.

DDT's application in the agricultural sector did not start until later, and up to the launch of green revolution after which, its use was rampant in the field to cover crops like cereals, pulses, oilseeds like mustard, fiber crops, horticulture, and tobacco from a number of pests as well in the storage and warehouses.

However, DDT was banned for its use in agriculture in 1989, primarily due credible scientific evidences against its ill impact on ecology and human health. It is another fact that agro-insects such as singhara beetle, diamond back moth, tobacco caterpillar and mustard aphid and many other insects developed resistance to DDT in as early as 70's itself. However, its illegal diversion to agriculture has been a concern even today. For example, DDT's clandestine use has been reported in mango production in Karnataka[9]. Its use by some libraries to protect books from worms has also been reported[10].

From a modest beginning in the mid 40s under the public health campaign, India is now the largest producer and consumer of DDT. According to the Farm Chemicals Handbook 2001, DDT is produced only in India and China. HIL is the sole manufacturer of technical grade DDT in India, and has production capacity of 6,344 MT annually[24]. According to various reports of the Department of Chemicals & Petrochemicals, Ministry of Chemicals & Fertilizers, Government of India and the HIL, India produces about 6000 MT of DDT depending upon the demand while exports anywhere between 12-25% to some European and African countries. The export quantity varies greatly from year to year.

4. India, Malaria and DDT

Historically, India had spent about one-third of its national health budget on malaria control, mainly through DDT. At the start of the DDT-based malaria control campaign in 50s', the estimated annual malaria incidence was 75 million cases and about 8,00,000 deaths. With DDT, the malaria incidence rate reached its lowest value in 1966: 1,08,394 reported cases and no malaria deaths at all. As a collateral benefit, it eliminated kala-azar and plague and even wiped out nuisance household insects. Such a spectacular success made the use of DDT popular in India.

However, the magic effect gradually faded as the rural mosquito species (A. culicifacies) that transmits 65 percent of India's malaria, evolved to withstand or avoid the killing effect of DDT. The resistance spread and a dramatic resurgence of malaria occurred beginning early 70s'. That was the beginning of the decline of DDT[5 and 30].

India's DDT-malaria story thus is an important and interesting case where even after waning effectiveness of this molecule it is still used in rural areas for indoor spraying applications.

DDT however, is no longer used for malaria control in urban areas under the Urban Malaria Scheme (UMS) in favor of pesticides like malathion and synthetic pyrethyroids, though in cities like Delhi even this is being replaced by integrated approaches. For example, back in 1997, the World Bank approved $164 million for the Malaria Control Project in India to promote alternatives to indoor spraying of DDT.

4.1 Malaria Vs DDT in recent decades

Several researches have indicated that DDT has lost its effectiveness against malaria and the collateral benefits against several nuisance insect faded away during its journey of half a century. V P Sharma, 2003, noted that even at the height of malaria-eradication efforts DDT-spraying did not interrupt malaria transmission in 51 million people even after 13 to 17 years of regular DDT spraying, which had started in 1958. The author draws examples from past decades (80s' and 90s') concluding that the annual parasite incidence (API) and subsequently malaria cases in states likes Assam, Gujarat, Karnataka and Maharashtra went northward even after several rounds of DDT spraying. He cites three main reasons for the DDT failure; (a) pest resistance as the malaria control authorities failed to understand they had only a few years to eradicate malaria before resistance set in, (b) National Anti-Malaria Programme has been unable to meet the minimum requirements for programme efficacy set out by WHO – the formulation (75% WP) and dosage of DDT (2 g/m2), and (c) due to several social and cultural factors DDT could not cover the required area and thus there were several pockets where vector continued to breed.

India's poor track record in management of its vast stream of waste could be considered as another major cause for vector breeding and multiplication.

In 2009, RTIs were filed by Toxics Link, New Delhi with the state health departments and National Vector Borne Disease Control Programme (NVBDCP), Ministry of Health, Government of India to gather

Table 1: Average number of annual malaria cases in millions, P. falciparum cases in millions and average annual malaria deaths during last three decades in India[11 and 12]

Decade	Total cases (million)	P. falciparum cases (million and as % of total	Average Deaths (#) per annum
1980s	1.9	0.64 m (34%)	241
1990s	2.4	0.95 m (40%)	786
2000s	1.74	0.85 m (49%)	972

Figure 1: Number of malaria cases and supply of DDT 50% to the states in kgs[11]

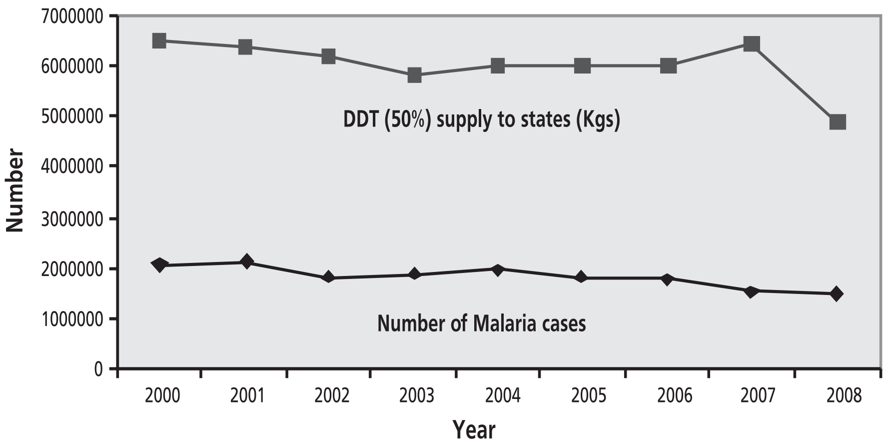

Table 2: Number of malaria cases and supply of DDT 50% to NVBDCP and then States in kgs[11 and 13]

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Malaria cases (#)	2,022,670	2,096,517	1,842,730	1,885,120	1,965,947	1,819,118	1,787,423	1,539,265	1,515,665
DDT Supply (Kgs) to NVBDCP by HIL	7,000,000	6,150,000	6,042,000	8,208,000	8,500,000	8,560,000	6,825,000	6,000,000	6,821,000
DDT Supply (Kgs) to state by NVBDCP	6,500,000	6,400,000	6,174,000	5,850,000	6,000,000	6,000,000	6,000,000	6,450,000	4,930,000

information on DDT supply, usage and incidence of malaria cases. The information that came through, although had gaps but provided some useful insight into the whole issue, categorically pointing towards fading magic of DDT.

The declining effectiveness of DDT is quite evident from Table 1 and Figure 1. The annual average malaria cases could be seen rising in the 90s while marginally declining in the last decade. However, the malaria incidence rate of last decade is comparable to that of 80s'. Plasmodium falciparum cases have also been found to be rising throughout the last three decades, both in absolute and percentage terms. Unfortunately, the average casualty too rose over the last three decades; clearly suggesting DDT is loosing strength.

Figure 1 depicts that although the total supply of DDT to various Indian states during the period 2000-2008 has been close to 6 million Kgs annually, the average annual malaria incidence remained almost constant.

In conclusion, various researches and statistics clearly point towards perpetual failure of DDT in controlling malaria menace in the recent decades and thus suggesting that the time has come to rigorously look for safer but cost-effective alternative regime. DDT is undoubtedly an avoidable toxic burden.

4.2 DDT demand-supply channel and gaps in usage

The DDT demand-supply in India is guided through the bottom-up approach. Since public health is a State subject, the demand for DDT comes from the states to the Ministry of Health and Family Welfare (MoHFW), which raises indent, based on the demand of various State Health Departments on annual requirement of DDT to HIL and approved by DDT Mandate Committee HIL contacts various State Program Officers to find out distributions at different districts / locations[13].

Lets us take an elaborate look. The Primary Health Centres (PHC) is the basic unit in the rural area for delivery of primary health care in an integrated manner (22,975 around the country). At the district level, District Malaria Offices have been established under District Chief Medical and Health Offices (DCMHO) by the states (565 around the country). The Chief Medical Officer at the PHC assesses the demand based on population to be covered under IRS (for example, around 800kgs / 5000 population is demanded in West Bengal during 2009[11]) and forward this demand to the respective state level health department via DCMHO, who subsequently send the aggregate state-level demand to the MoHFW. However, alternatively the PHC can send in their demand directly to the NVBDCP or HIL, informing the district and state level authorities.

However, available statistics reveals discrepancies in DDT supplied to NVBDCP and then to the states and its use at the state level indicating spillage in the process (Table 2 and 3). Out of the total 27 states to which the RTIs were applied to gather information on DDT usage in the recent years, only 10 responded. From the period 2000-2009 for which the data on DDT usage were obtained for the ten states (Table 3), a total of 7,965 MT of DDT seems to be unaccounted for. Debarring

Table 3: State-wise DDT supply, usage and surplus statistics (period 2000-2009)[11]

States	DDT Supplied (MT)	DDT Used (MT)	Surplus (MT) or spillage
Assam	11326	10103	1223
Chattisgarh	6317	1204	5113
Rajasthan	6073	3905	2168
West Bengal	2688	3944	(-) 1256*
Tripura	2501	2141	360
Nagaland	1790	1653	137
Mizoram	905	850	55
Himachal Pradesh	203	97	106
Uttarakhand	177	122	55
Sikkim	31	26	5
Total	32011	24046	7965

* (-) means deficit
* MT – Metric ton or simply ton

West Bengal, where statistics show a deficit (supplied less than the demand), in all other reporting states there is a 'leftover' or surplus amount.

From the year-wise data obtained, it can be concluded that this surplus is not a standalone phenomena but a cumulative stockpile figure aggregating over the years. Further, Table 2 shows DDT supply to NVBDCP in excess of about 20% of the actual subsequent supply to states annually.

The question is what is happening to this 'remainder' stock. Is this surplus adjusted in subsequent years for supply to states or there is leakages. This need to be answered by the government, as Toxics Link's survey finds there is lack of awareness regarding handling and storage of DDT.

The latest estimates on the DDT stock-piles[13], however, points towards only 41 tons of expired DDT 50WP in the state of Himachal Pradesh.

5. Increasing evidences of impact on ecology and health

The acute toxicity of DDT was described quite well even by its discoverer Paul Müller (Box 1). Subsequently, its perpetual toxicity and persistence in the environment also got proved. Even its breakdown products, DichloroDiphenyl-dichloroEthylene (DDE) and DichloroDi-phenylDichloroethane (DDD), are highly persistent and have similar physicochemical properties and are known to travel across continents.

A summary of DDT's impact on ecology and life is provided in Table 4.

A WHO study of 1996 found higher levels of DDT in water or soil samples in India, in areas with DDT residual spraying than in areas without spraying. Box 3 illustrates a few important India specific studies on DDT's ill impacts in the recent years. These studies are the proof that the chemical and its by-products have eventually made in-routes into the food chain, which is even more worrying.

Table 5 further depicts DDT's toxic trail in various aquatic media and the species inhabiting such media across India.

Table 4: Common trails and impact of DDT in various receptors

Receptor	Impact
Environment	Depending on conditions, it can persist from 22 days to 30 years. Travel long distances and contaminate food chains. The breakdown products DDE and DDD are stored mainly in body fat.
Human beings	DDT and DDE are very resistant to metabolism; in humans, their half-lives are 6 and up to 10 years, respectively. Potential mechanisms of action on humans are geno-toxicity and endocrine disruption and have been linked to diabetes. In the United States, these chemicals were detected in almost all human blood samples tested by the Centers for Disease Control in 2005, many years after its ban. The United States National Toxicology Program already classifies them as "probable" human carcinogens.
Wildlife	Toxic to a wide range of animals in addition to insects, including marine animals and amphibians. They impact the reproductive system. In wildlife and laboratory animals DDT and its breakdown products are shown to have hormone-disrupting impacts.
Microorganisms	Algae, and planktons, present in water are affected even with small amount of DDT. The microorganisms affected by DDT do not usually die. Instead, they tend to keep the DDT within themselves and thus DDT enter into the food chain
Birds and fish	DDT is most famous for its effect on birds and causes thinning of eggshells. Some species affected by DDT are osprey, eagles, pelicans, falcons, and hawks. In fish, the study on ill impact has been found difficult to study but the possible problem probably involves its presence in the plasma membrane.

Box 3: DDT's ill impact in India in recent years[14 and 18]

- Residues of DDT were detected in 59.4% of 1080 samples of wheat grain and in 78.2% of 632 samples of wheat flour from across the country. However the concentration was much below compared to earlier studies – Toteja G.S. et.al, 2006;
- Residues of DDT were detected in about 58% samples of rice. Its maximum residue limit of 0.1 mg kg (-1) in cereals recommended by Codex was exceeded by about 2% of the samples examined – Toteja G.S. et.al, 2003;
- There was a significant negative correlation between body weight of newborn babies and p.p'-DDE in maternal blood and p.p'-DDE in cord blood - Siddiqui 2003;
- Study shows transfer of DDT from pregnant mothers to the foetus - Siddiqui 2003;
- Study showed a correlation between mothers with systolic blood pressure greater than 115 mmHg had greater levels of DDE than those with systolic pressure less than 115 mmHg - Siddiqui 2002;
- Study in North India found that the daily intake of DDT residues in one-month old infant was above the ADI in 85% of the samples - Gupta 2001
- Effluents from HIL, New Delhi was tested for DDT on zebra fish - Ruparelia 2001;
- The rate of oxygen consumption in fresh water fish was noted to be decreasing with increasing duration of exposure and concentration level - Gurusamy 2000;
- Studies in Uttar Pradesh revealed that DDT levels in blood of people occupationally part of malaria programme were significantly higher than in groups not so exposed – Dua, 1998;
- In India the daily intake of DDT has been shown exceeding the Acceptable Daily Intake level by to 18% - WHO, 1996;

Source: Country Situation on POPs in India, IPEN, Toxics Link, 2006

Table 5: DDT trail in various media and living beings across India[14]

Location	Receptor
Delhi, Agra, Kanpur, Ahmedabad, Mumbai, Chennai, Nagpur, Kolkata, Varanasi, Allahabad	Drinking water
Kumaon	Stream
Yamuna, Delhi, Urban and Hooghly, Kolkata, Urban	River and Drain
South India Agricultural belt	Bat, Birds (resident & migrants), Egg Yolk
Ganges and Ganga at Patna	Dolphin, Fish
Ganga Canal Near Delhi	Benthic Macro-vertebrae (worms, leeches, crayfish etc.)

The draft National Implementation Plan, Stockholm Convention on POPs, Ministry of Environment and Forest, Government of India, March 2011 indicate improper state of transportation, handling, storage and disposal of DDT, the stockpiles and DDT bags in states like Mizoram, West Bengal, Chhattisgarh and Himachal Pradesh resulting in contamination of soil and water in these states. For example in Chhattisgarh, in at-least seven locations DDT concentration in the soil samples was much higher than the limit value of 50mg/kg.

It can therefore be concluded that the bad impact of DDT on ecology and life in India is only growing by the time, while there seems to be stagnation in its efficacy to arrest the malaria vector.

6. Finding Alternatives to DDT for India

It is time India finds safer and economical alternatives to DDT. And this needs to be done without loosing much time, as vector control and public health trade-off is definitely going against DDT. Since malaria is completely a local ailment and its intensity and spread depends on local conditions, the controlling mechanism will also have to be location specific. This means that with indigenous mechanism the disease can be controlled to a large extent and the blanket application of vector control chemicals could thus be phased out. In case of India even community-based bioenvironmental initiatives have been demonstrated to be quite effective[5 and 30].

There are also international evidences of non-DDT control methods for malaria. A WHO study of January 2008 points out that mass distribution of insecticide-treated mosquito nets and artemisinin–based drugs cut malaria deaths to half in Rwanda and Ethiopia, the countries known to have high malaria burden. Vietnam has enjoyed declining malaria cases and a 97% mortality reduction after switching in 1991 from a poorly funded DDT-based campaign to a program based on prompt treatment, bed nets, and parathyroid group insecticides. In Mexico, effective and affordable chemical and non-chemical strategies against malaria have been so successful that the Mexican DDT manufacturing plant ceased production due to lack of demand. A study in the Solomon Islands found that impregnated bed nets resulted in reduced DDT spraying.

Further, a study in Thailand found the cost per malaria case prevented of DDT spraying ($1.87 US) to be 21% greater than the cost per case prevented of lambda-cyhalothrin–treated nets ($1.54 US). Similarly, in Mexico this alternative found with the same efficacy with 25% lesser cost[6].

Table 6, 7 and 8 provide a summary of non-DDT alternatives for vector control, both chemical and non chemical. While Table 6 shows the matrix of WHO recommended alternative insecticides for indoor residual spray, Table 7 tabulates various

Table 6: Insecticides recommended by WHO for IRS against malaria vectors[15]

Insecticide compounds and formulations	Class *	Dosage (g/m2)	Duration of effectiveness (months)
Alpha-cypermethrin WP and SC	PY	0.02-0.03	4-6
Bendiocarb WP	C	0.1-0.4	2-6
Bifenthrin WP	PY	0.025-0.05	3-6
Cyfluthrin WP	PY	0.02-0.05	3-6
Deltamethrin WP, WG	PY	0.020-0.025	3-6
Etofenprox WP	PY	0.1-0.3	3-6
Fenitrothion WP	OP	2	3-6
Lambda-cyhalothrin WP and CS	PY	0.02-0.03	3-6
Malathion WP	OP	2	2-3
Pirimiphos-methyl WP and EC	OP	1-2	2-3
Propoxur WP	C	1-2	3-6

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

Table 7. Alternative methods for malaria vector control[16]

Vector management method	Vector stage	Risk	Resources/delivery
Chemical methods			
Insecticide-treated bed nets	Adult	Resistance; toxicity	Free distribution; social, marketing; commercial
Indoor residual spraying	Adult	Resistance, toxicity	Spray teams
Chemical larviciding	Larva	Resistance; effect on ecosystems	Spray teams
Repellents and attractants	Adult	Toxicity	Local; commercial
Insecticide sponging of cattle	Adult	Toxicity; resistance	–
Non-Chemical methods (details of control process provided in Table 8)			
Source reduction	Larva	–	Local
Habitat manipulation	Larva	–	Local; agriculture sector
Irrigation management	Larva	–	Local; agriculture sector
Design of irrigation structures	Larva	–	Irrigation sector
House improvement	Adult	–	Local; development programs
Predation	Larva	–	Local; programs; agric. sector
Microbial larviciding	Larva	Resistance	Local; programs
Fungi	Adult	–	–
Genetic methods	Adult	To be studied	–
Botanicals	Larva/adult	Toxicity	Local
Polystyrene beads	Larva	–	–
Zoophrophylaxis	Adult	–	–

Table 8: Simple alternative practices that could phase-out DDT in vector control[16]

S. No	Vector management practices	Control process
1	Source reduction	Eliminating vector's breeding habitat through drainage, land leveling, filling, etc.
2	Manipulation of natural habitat	Cleaning water bodies, flushing of streams, straightening of riverbanks etc.
3	Irrigation management	Good irrigation structure so that water does not stagnate for long. See that flooding is not done where not required
4	House improvement	Proper construction and screening could reduce mosquitoes by 3 times
5	Predation: Mosquito	Larvivorous fish (guppy) have frequently been reared and released for controlling vector breeding in small water tanks and wells.
6	Microbial larvicides	Bacteria, Bacillus thuringiensis israelensis and B. sphaericus, produce toxins that are used in formulations as microbial larvicides. They are toxic to mosquitoes only. Conventional microbial strains, recombinant bacteria are being developed.
7	Fungi	A selected fungus has shown promising results for controlling adult Anopheles mosquitoes.
8	Genetic methods	Two genetic approaches – 1) the sterile insect technique involves the introduction of specific genes into a wild vector population through mating; 2) the genetic odification of the ability of the natural vector population to transmit the parasite
9	Botanicals	The traditional burning of local plants and leaves is commonly used for its mosquito repellent effect; such as burning of dried neem leaves and cake. There are herbs such as tulsi that can repel mosquitoes.
10	Polystyrene beads	Expanded polystyrene beads have been used to control vector breeding in small confined water collections, for example in borrow pits, wells or small water tanks. A thin layer prevents egg deposition and causes suffocation of mosquito larvae present in the water.
11	Zooprophylaxis	It refers to attracting vectors to domestic animals in which the pathogen cannot amplify. In areas where malaria vectors have a strong preference to feed on livestock rather than on humans, the spatial planning of livestock management can, in theory, reduce malaria transmission in humans.

chemical and non-chemical methods that could phase out DDT.

For chemicals alternatives however, it is necessary that the impact on human health and ecology be examined carefully.

In Indian context, alternatives described in Table 8 could actually be very helpful. Some of the major factors of early ineffectiveness of DDT in vector control in India has been our life-style, socio-cultural factors and living ambiance. Some scholars feel that these factors have contributed much to the rise in malaria cases in India. Table 8 talks exactly about such alternative methods, which are simple to work on for conditions like ours with possibly high degree of effectiveness. Also, they are cost-effective and have almost negligible side effects and spillover impacts.

7. Conclusion and recommendations

From above discussions and observations it can be concluded that:

i. DDT has possibly lost its effectiveness in its purpose of use (that is, in vector control) and thus its continual application would only add to the growing toxic burden;

ii. the current database on DDT in India depicts gaps in demand, supply and usage. With the lack of proper infrastructure and awareness about its storage at unit level, there are possibilities of mismanagement and spillage in the whole process;

iii. there could be DDT's illegal diversion into restricted usage and also illicit trade in the border regions as some media reports suggests. This could have serious ramifications on ecology and human health;

iv. there are growing evidences of contamination in media and food chain across various states of India; and,

v. a number of countries have already vouched against DDT. There are exemplary evidences of safer and cost-effective alternatives even in India;

Recommendations

i. Need for comprehensive assessment of DDT's efficacy in vector control in India. This would clear the doubt whether use of DDT is necessary any further;

ii. Promising innovative technologies, particularly non-chemical and simple practices, need further impetus in terms of research funding and promotion;

iii. Need for strengthening voices internationally for phasing out DDT and promoting safer alternatives;

iv. Since, a good portion of DDT produced in India is exported, we need to re-look at this business model. The question is why India should produce for export purpose while in any case DDT is becoming ineffective;

v. Strict monitoring of spillage of DDT is needed so as to contain its illicit diversion into restricted activities and trade, if any;

vi. It is of common knowledge that the vector multiplication is largely a factor of local conditions and climate. Poor state of waste and wastewater management in India is definitely one local factor for vector multiplication. This issue needs to be addressed immediately;

vii. As DDT seems to be going out of business sooner or later, the disposal plan for obsolete and stocked chemical as well as the storage bags must be readied before hand.

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