UNITED NATIONS ENVIRONMENT PROGRAMME

Stockholm Convention on Persistent Organic Pollutants

اتفاقية استكهولم بشأن الملوثات العضوية الثابتة • 关于持久性有机污染物的斯德哥尔摩公约 • Convention de Stockholm sur les polluants organiques persistants
Convenio de Estocolmo sobre Contaminantes Orgánicos Persistentes • Стокгольмская конвенция о стойких органических загрязнителях

Report of the DDT expert group on the assessment of the production and use of DDT and its alternatives for disease vector control

9 November 2016

Geneva, Switzerland

Acronyms and Abbreviations

a.i.	Active ingredient
BMGF	Bill & Melinda Gates Foundation
CL	Cutaneous leishmaniasis
COP	Conference of the Parties
CS	Capsule suspensions
DDT	Dichloro-diphenyl-trichloroethane
DFID	Department for International Development
DDMS	Disease Data Management System
EMP	Environmental Management Plan
EMRO	World Health Organization Regional Office for the Eastern Mediterranean
EU	European Union
FAO	Food and Agricultural Organization
GEF	Global Environment Facility
GFATM	Global Fund to Fight AIDS, Tuberculosis and Malaria
GPIRM	Global Plan for Insecticide Resistance Management
IGR	Insect Growth Regulators
IRS	Indoor residual spraying
IRM	Insecticide resistance management
ITN	Insecticide treated nets
IVCC	Innovative vector control consortium
IVM	Integrated vector management
LLINs	Long-lasting insecticidal nets
MT	Metric tonnes
NIPs	National implementation plans
NMCPs	National malaria control programmes
PMI	President’s Malaria Initiative
POPs	Persistent Organic Pollutants
POPRC	Persistent Organic Pollutants Review Committee
TDR	Special Programme for Research and Training in Tropical Diseases
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
VCAG	WHO Vector Control Advisory Group
VL	Visceral leishmaniasis
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme
WP	Wettable powder

Contents

I. Introduction

1. Dichloro-diphenyl-trichloroethane (DDT) is listed in Annex B the Stockholm Convention on Persistent Organic Pollutants, with an acceptable purpose for the production and use of DDT for disease vector control in accordance with Part II of this Annex. Such production and use, as provided in paragraph 2 of Part II of Annex B, is restricted for disease vector control in accordance with the World Health Organization (WHO) recommendations and guidelines on the use of DDT and when locally safe, effective and affordable alternatives are not available to the Party in question. Availability of DDT has no time limitation according to the Convention.

2. Paragraph 6 of Part II of Annex B of the Convention requires that, commencing at its first meeting and at least every three years thereafter, the Conference of the Parties (COP) shall, in consultation with the WHO, evaluate the continued need for DDT for disease vector control on the basis of available scientific, technical, environmental and economic information. As the COP has ordinary meetings every two years, in line with the process for the reporting on and assessment and evaluation of the continued need for DDT for disease vector control set out in annex I to its decision SC-3/2, it undertakes an evaluation of the continued need for DDT for disease vector control at each of its ordinary meetings.

3. The process for reporting on and assessment and evaluation of the continued need for DDT, adopted in decision SC-3/2, also has established an expert group to undertake an assessment of relevant information. The DDT expert group, in accordance with the process, shall:

(a) Undertake a situational analysis on the production and use of DDT and the conditions for such use, including a review of the responses by countries to the questionnaire;

(b) Evaluate the availability, suitability and implementation of alternative products, methods and strategies for Parties using DDT;

(c) Evaluate the progress in strengthening the capacity of countries to shift in a safe fashion to reliable or suitable alternative products, methods and strategies, based on a review of the opportunities and needs in countries for sustainable transition;

(d) Make recommendations on the evaluation and reporting mechanisms set out in paragraphs 4 and 6 of Part II of Annex B of the Convention;

(e) Consider and assess the actions being taken by Parties to accomplish the following:

(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 such alternatives;

(iii) Measures to strengthen health care and to reduce the incidence of the disease being controlled with DDT;

(iv) Promotion of 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 with the goal of decreasing the human and economic burden of disease. Factors to be promoted when considering alternatives or combination of alternatives shall include the 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 Parties in question and be supported by monitoring data;

(f) Make recommendations to the Conference of the Parties on the continued need for DDT for disease vector control and on any actions deemed necessary to reduce the reliance on DDT in the light of the assessments undertaken pursuant to subparagraphs (a) to (e) above.

4. The COP, in its evaluation of the continued need for DDT for disease vector control at its seventh meeting held in 2015, in its decision SC-7/2, concluded that countries that are relying on DDT for disease vector control may need to continue such use until locally safe, effective, affordable and environmentally sound alternatives are available for a sustainable transition away from DDT.

5. In the same decision, the COP decided to evaluate the continued need for DDT for disease vector control, on the basis of scientific, technical, environmental and economic information, including that provided by the DDT expert group, at its eighth meeting, with the objective of accelerating the identification and development of locally appropriate, cost-effective and safe alternatives.

6. The COP also endorsed the key elements of the road map for the development of alternatives to DDT prepared by the United Nations Environment Programme (UNEP), in response to an invitation by the COP, and invited the UNEP to lead the implementation of the road map in consultation with the WHO, the DDT expert group and the Secretariat.

7. The DDT expert group, in collaboration with the WHO, conducted an assessment of available scientific, technical, environmental and economic information related to the production and use of DDT for disease vector control.

8. To facilitate the process of compiling the above information, the DDT expert group met through various channels including webinars, online meetings and emails to discuss and agree on the format and outline of the preliminary report that forms the framework for the expert group to report to the COP for its consideration during its eighth meeting.

II. Situation analysis of the production and use of DDT

9. Paragraph 4 of Part II in Annex B of the Convention requires Parties, registered to use DDT for acceptable purposes, to provide information in every three years to the Secretariat and WHO on the amount used, the conditions of such use and its relevance to the Party's disease management strategy. The DDT expert group undertakes assessments every two years in parallel to the meetings of the COP. Information on production and use of DDT was provided by Parties for the period 2012 to 2014 and made available to the DDT expert group in its assessment for the eighth meeting of the COP. Furthermore, additional information obtained from producers and key users are summarized in this section of the report. In addition, the report on the effectiveness evaluation of the Stockholm Convention pursuant to Article 16 of the Convention as it pertains to DDT (UNEP/POPS/DDT-EG.6/INF/2) was considered in the review of information and in the development of conclusions and recommendations.

A. Sources and amounts of DDT production and use for the period 2012-2014

10. The Secretariat distributed the adopted DDT questionnaire to the 178 Parties to the Convention to provide information on production and use of DDT for disease vector control covering the 2012-2014 reporting cycle. A total of 30 Parties responded to the DDT questionnaire (Table 1). Among these respondents were 10 Parties out of the 17 registered for acceptable use/production of DDT. The 7 countries in the DDT Register that did not submit their questionnaires for 2012-2014 include Swaziland, Ethiopia, Uganda, Botswana, Marshall Islands, Namibia and Venezuela. Of the 10 responding Parties, 3 (India, South Africa and Mozambique) reported use of DDT for disease vector control. Zambia and Swaziland had reported use of DDT in the reporting cycle 2009-2011. Gambia reported DDT use in 2006-2008 and in 2009-2011, but did not notify the Register of acceptable purposes at the time and has not since submitted information on DDT use. Myanmar withdrew from the DDT Registry in February 2012 and, as of June 2014, China has withdrawn from the DDT Registry and has stopped all production and use of DDT in malaria elimination efforts (Stockholm Convention n.d.). The Global Monitoring Plan from 2015 reported use of DDT in the Democratic People's Republic of Korea for vector control and illegal use of DDT for agricultural purposes by farmers in Lao People's Democratic Republic– neither country is registered to the Convention (Stockholm Convention 2015a).

Table 1: Information on the use of DDT during reporting cycle 2012-2014 based on country responses to the DDT questionnaire distributed to all Parties by the Secretariat to the Stockholm Convention.

Category	Parties	Status of use 2012-2014
Listed in the DDT Register	India	Reported use
	South Africa	Reported use
	Mozambique	Reported use
	Eritrea	No reported use

	Madagascar	No reported use
	Mauritius	No reported use
	Morocco	No reported use
	Senegal	No reported use
	Yemen	No reported use
	Zambia	No reported use
	Botswana	Did not submit report
	Ethiopia	Did not submit report
	Marshall Islands	Did not submit report
	Namibia	Did not submit report
	Swaziland	Did not submit report
	Uganda	Did not submit report
	Venezuela	Did not submit report
Parties that previously reported use of DDT but have not notified the Register	Gambia	Did not submit report
Parties not in DDT Register that submitted a completed questionnaire	Argentina	No reported use
	Germany	No reported use
	Hungary	No reported use
	Maldives	No reported use
	Mexico	No reported use
	Myanmar	No reported use
	Pakistan	No reported use
	Serbia	No reported use
	Singapore	No reported use
	Slovak Republic	No reported use
	Gabon	No reported use
	Ireland	No reported use
	Japan	No reported use
	Monaco	No reported use
	Nepal	No reported use
	Peru	No reported use
	Spain	No reported use
	Sri Lanka	No reported use
	Saint Lucia	No reported use

(a) Global production[(a)]

11. The information provided by the Parties to the DDT questionnaire covering the 2012-2014 reporting cycle showed that India was the only producer of DDT. All DDT products were produced at the Hindustan Insecticide Ltd factories[(b)], which is the only registered production site for DDT in the world. India's production of DDT technical grade material (98-99% a.i.) was 3,664.00 Metric Tons (MT) in 2011-12; 3,368.00 MT in 2012-13; and 3,168.00 MT in 2013-14 – adding up to 10,200.00 MT in total production from 2011-2014 (Table 2).

Table 2. Production of DDT in India during reporting cycle 2012-2014.

Technical grade DDT	**Net output per year (MT)**			**Total output (MT)**
	2011-12	**2012-13**	**2013-14**	
Technical grade material (98-99% active ingredient)	3,664.00	3,368.00	3,168.00	10,200.00

12. The total production of technical grade DDT in reporting cycles 2009-2011 (10,246.00 MT) and 2012-2014 (10,200.00 MT) has remained mostly unchanged. However, as reported in the effectiveness evaluation report the average production over the past 12 years shows a modest decline (van den Berg 2016).

[a] All the information regarding DDT production, use and export from India are reported by financial year starting from 1st April of every year and ending by 31st March of the next calendar year. All the Financial approval and sanctions, supply orders for use within the country and export is done by financial year.

[b] Locations of factories: Cochi and Rasayani Mahar.

13. Of the technical grade material produced in the period 2012-2014 was 91% was reported used in India to prepare DDT formulations of 50% Wettable Powder (WP) for domestic use. The remaining 9% of DDT was exported during the 2012-2014 reporting cycle.

(b) Export and import of DDT

14. According to the available information, Ethiopia, India and South Africa are the only three countries with an export/re-export of DDT 75% WP (Table 3). In India, DDT is exported directly from the Hindustan Insecticide Ltd factory (Rasayani Unit). India exported DDT formulations of 75% WP in all three reporting years: 393.75 MT in 2011-12; 369.80 MT in 2012-13; 101.37MT in 2013-14; and 353.90 MT in 2014-15. India exported DDT to South Africa, Mozambique, Zimbabwe, Botswana, Namibia and Gambia during reporting cycle 2012-2014.

15. Ethiopia re-exported a small amount of DDT to South Africa in 2012, and South Africa re-exported a small amount of DDT to Swaziland in all three years.

16. Zimbabwe imported a significant quantity of DDT (698.12 MT) from India during the reporting cycle of 2012-2014.

17. Mozambique imported 201.67 MT of DDT from India during the reporting cycle of 2009-2011. However, during this reporting cycle they only imported a small amount in 2014 (73.03 MT). Whether this reflects stockpiling of previously imported DDT or an actual reduction in use for the given years is unknown at this point.

18. Swaziland has not submitted any information on their DDT import, use or stock in this reporting cycle, but in the last reporting cycle of 2009-2011, they reported import and use of DDT. In reporting cycle 2009-2011, Ethiopia reported no use of DDT and did not include information on stocks of DDT.

Table 3: Global export and import of DDT 75% WP in MT as reported by India and South Africa.

Exporting Country	Importing Country	Amount of DDT 75% WP in MT				Total amount of DDT 75% WP in MT
		2011-12	2012-13	2013-14	2014-15	
India	South Africa	45.50	44.13	40.48	25.49	155.60 (116.70*)
	Mozambique	NR	NR	NR	73.03	73.03 (54.77*)
	Zimbabwe	162.75	219.10	60.89	255.38	698.12 (523.59*)
	Botswana	NR	30.00	NR	NR	30.00 (22.50*)
	Namibia	176.00	76.57	NR	NR	252.57 (189.42*)
	Gambia	9.50	NR	NR	NR	9.50 (7.12*)
Ethiopia	South Africa	NR	0.0005	NR	NR	0.0005 (0.0003*)
South Africa	Swaziland	NR	5.00	2.50	2.50	10.00 (7.50*)
Total in MT		393.75	374.80	103.87	356.40	1228.82 (921.61*)

* 98-99% of DDT

NR- No reported imports

(c) Stocks of DDT

19. According to the country responses for the reporting period 2012-2014, only six countries reported having stocks of DDT (Table 4): Argentina reported an unspecified amount of DDT residues[c]; El Salvador reported 5.40 MT of DDT 99% powder[d] stored at a safe facility; India reported 321.75 MT of DDT 98-99% a.i. in 2014 stored at district level under supervision of VBD officials according to Government approved guidelines; Mozambique reported 56.69 MT of DDT 75% WP stored in locked containers with usable stock; Mauritius reported 5.00 MT of DDT technical grade flakes (98-99% a.i.) stored in a UN approved facility; and South Africa reported 10.67 MT of DDT 75% WP stored at secure dedicated facilities.

20. The reported amount of DDT in stock in South Africa is well below the reported amount of imported DDT. This may reflect use-patterns immediately prior to reporting or that some DDT stocks are being stored at decentralized level.

21. During reporting period 2009-2011, Gambia had reported 14.00 MT of 75% WP in good and usable condition; Swaziland reported that it had unspecified stocks of obsolete DDT in need of

[c] The definition of residues is unclear from the country response to the 2012-2014 DDT questionnaire.

[d] 99% powder is not a known material, but this is what El Salvador has reported and therefore it has been left un-altered. It could be that they meant technical grade material instead of powder.

disposal; and Jordan reported a stock of obsolete DDT of approximately 3.00 MT. A research article on DDT substitutes indicated that in 2012, Bangladesh had 602.00 MT of obsolete DDT stockpiled in storage facilities that were inadequate, resulting in seepage, pilferage, weathering and misuse, leading to environmental contamination and health hazards (Rahman 2013).

Table 4: Stocks of DDT in MT as reported by countries in the DDT 2012-2014 questionnaire.

Country	Total amount in storage (MT)	Formulation type and a.i.%
Argentina	Not specified	Residues
El Salvador	5.40	99% Powder
India	321.75 in 2014	98-99% a.i.
Mozambique	56.69	75%WP
Mauritius	5.00	Flakes[(e)]
South Africa	10.67	75% WP

22. The national implementation plans (NIPs) submitted under Article 7 of the Stockholm Convention require that Parties provide indications of the quantity, quality and location of DDT stockpiles and obsolete DDT in their countries. They are also required to address illegal trafficking and use of DDT for purposes other than public health vector control. However, the reporting on stockpiles may be incomplete in terms of countries reporting and the level of details reported including the formulation, the conditions under which DDT is stored, and the degree of obsolete qualities. Inaccurate amounts imported can lead to accumulation of obsolete stocks that are costly to remove later on.

(d) Repackaging and disposal of DDT stockpiles

23. A WHO-UNEP-GEF-EMRO-project, which ran from 2009-2014, reported the destruction of the majority of DDT waste identified in the eight participating countries.[(f)] Among these, Jordan disposed 22.27 MT of obsolete DDT, Morocco disposed 48.08 MT of concentrated DDT, and Iran repacked and destroyed 28.70 MT of DDT in 2014(World Health Organization 2014c). In 2015, Mauritius disposed 139.00 MT of DDT by exporting it to France where it was (UNDP & GEF 2015). China reported the disposal of 1,600.00 MT of DDT as a result of their 5 year GEF/UNDP supported project to introduce alternative products to dicofol-DDT production and use(Chen & Kwan 2013). In 2015, GEF approved a project in Guatemala that includes disposal of 15.00 MT of DDT(GEF 2015b). Operations are on-going to clean up and safely dispose of obsolete pesticide stocks, for example under the auspices of the Africa Stockpiles Programme(ASP 2010) and other GEF projects(World Health Organization n.d.). The new *'Road Map for the Development of Alternatives to DDT'*, led by the UNEP Chemical Branch, has included the elimination of DDT stockpiles and waste as one of its 3 key activities. This effort will focus on updating national inventories, collecting obsolete stocks, and repackaging and disposing obsolete stocks(Fiedler 2015). Further information on the export of DDT for final disposal is provided in the report on the effectiveness evaluation of the Stockholm Convention prepared by the effectiveness evaluation committee(Fiedler 2015).

B. Trends in DDT use for vector control

24. According to the available information from the DDT questionnaire, DDT was used in India, Mozambique and South Africa between 2012-2014 (Table 5). The total amount of DDT used per year has declined in South Africa from 84.56 MT 75% WP in 2009 to 24.61 MT 75% WP in 2014, as well as in India from 6,830.00 MT 50% WP in 2009 to 6,183.00 MT 50% WP in 2014. In Mozambique the total amount of DDT used per year has significantly increased from 1.40 MT 75% WP in 2009 to 15.70 MT 75% WP in 2014; however, as can be seen from Table 5, Mozambique reported in the questionnaire that zero amounts of DDT was used in the years 2012 and 2013.

[e] Residues, flakes and powder are not further defined by the country respondents to the 2012-2014 DDT questionnaire.

[f] Djibouti, Egypt, Islamic Republic of Iran, Jordan, Morocco, Sudan, Syrian Arab Republic and Yemen.

Table 5: Amount of DDT used by countries during the reporting cycle 2012-2014 in MT.

Country	Year	Amount of formulated material used (MT)	
		Annual	Total for Reporting cycle
India	2012	6,421.00 (50%WP)	18,786.00 (50%WP) (9,393.00*)
	2013	6,182.00 (50%WP)	
	2014	6,183.00 (50%WP)	
Mozambique	2012	No reported use	15.70 (75%WP) (11.77 *)
	2013	No reported use	
	2014	15.70 (75%WP)	
South Africa	2012	31.72 (75%WP)	96.62 (75%WP) (72.46 *)
	2013	40.29 (75%WP)	
	2014	24.61 (75%WP)	

*98-99% of DDT

25. Madagascar, Mauritius and Pakistan reported that they would consider using DDT in the future if malaria outbreaks occurred. None of the 30 countries that submitted the DDT questionnaire reported using DDT for purposes other than disease vector control.

26. As reported by South Africa and Mozambique in the reporting cycle 2012-2014, malaria was the primary disease targeted by DDT and the use of DDT covered 10% and 2% of the population at risk for malaria transmission, respectively (Table 6). India reported that DDT was used for the control of malaria and visceral leishmaniasis (VL). According to available information from the DDT questionnaire, indoor residual spraying (IRS) with DDT covered 50% (30 million out of 60 million) of the population at risk for malaria transmission in India in 2014. However, according to the World Malaria Report 2015, the total number of people living in high malaria transmission areas in 2014 in India is 181.3 million, and another 997.4 million people live in low malaria transmission areas. Furthermore, the report estimates that in 2014, 44 million people in India were covered by IRS and 45.3 million of the population in high transmission areas are covered by both insecticide treated nets (ITNs) and IRS(World Health Organization 2015f). As communicated by India[(g)], mosquito mortality between 40-80 % with DDT also gives epidemiological impact on the presumption of excite-repellency by DDT.

27. According to the UNEP Road Map, the total use of DDT per year for malaria control in India has been reduced from 5,694.00 MT 50% WP in 2009 to 3,513.00 MT 50% WP in 2014, whereas the use of DDT for VL control has seen a steady increase every year from 1,000.00 MT 50% WP in 2009 to 2,670.00 MT 50% WP in 2014(Stockholm Convention 2015b). Overall, a reduction in DDT use in India for both malaria and VL was 511 MT. India reported that IRS with DDT covered 78% of the population at risk for VL transmission in 2014. Three studies from 2015, indicate that DDT is used against sandfly vectors in India because DDT is currently the only chemical approved for VL control by the Indian government(Fiedler 2015; Coleman et al. 2015; Kumar et al. 2015).The current policy on IRS for VL in India is to spray two rounds per year with DDT in villages with reported cases in the current and previous three years. However, sandfly vectors have shown resistance to DDT in some VL settings in India(Coleman et al. 2015; Kumar et al. 2015). Synthetic pyrethroids are now being evaluated by the Indian Government in order to obtain permission to use these for sandfly control(World Health Organization 2015d).

Table 6. DDT use for disease control in 2014 as reported by countries in the 2012-2014 DDT questionnaire.

Country	Disease	Main vectors targeted	% total population at risk covered by DDT use in 2014
India	Malaria	*An. culicifacies, An. stephensis, An. fluviatilis, An. minimus, An. dirus, An. sundiacus*	50%
	Visceral leishmaniasis	*P. argentipes*	78%
Mozambique	Malaria	*An. gambiae, An. funestus*	2%
South Africa	Malaria	*An. funestus, An. arabiensis*	10%

g India National Vector Borne Disease Control Program

(a) Role of DDT in malaria elimination efforts

28. WHO's *'Global Technical Strategy for Malaria 2016-2030'* calls for the elimination of malaria in at least 10 countries by 2020, but they are optimistic that this can be accomplished in 21 countries by 2020[h](World Health Organization 2016a). As malaria transmission continues to decline in many malaria endemic countries, National Malaria Control Programs (NMCPs) should prepare to undergo a paradigm shift as the focus changes from malaria control to actual elimination and continued interruption of transmission. Efforts required for malaria elimination and prevention of re-establishment are fundamentally different from those of malaria control, as case detection and elimination of transmission foci are emphasised(World Health Organization 2007). DDT has been proposed to play a continued role in malaria elimination as malaria programs enter the final stages of the elimination continuum, but with enhanced surveillance in elimination settings, more effective targeting of IRS may reduce the total quantities of DDT needed. Examples of countries that have successfully eliminated malaria in the recent past using DDT are Morocco and Mauritius. Mauritius has opted to keep DDT for emergency purposes. China and Myanmar, however, have opted not to keep DDT for emergency purposes as part of their ongoing national malaria elimination programs.

29. As shown in Table 6, DDT is still used in malaria control efforts in India and Mozambique and in malaria elimination efforts in South Africa. The available information on export and import (see Table 3) suggests that DDT is also used for vector control in Ethiopia (even though use of DDT was formally stopped in 2009). According to the World Malaria Report 2015 and the WHO, Swaziland, Namibia and Botswana are using DDT as part of their malaria elimination efforts(World Health Organization 2015f).

30. In July 2013, Health Ministers from a number of African countries agreed to adopt the use of DDT in their malaria control and elimination efforts at a meeting in the African Union(Premium Times 2013). The use of DDT may be justified by a series of observations from South Africa. In 1996, South Africa changed from DDT to deltamethrin usage in IRS, creating the opportunity for pyrethroid resistant populations of *An. funestus* to re-establish in the north-eastern border regions of the country. The reappearance of *An. funestus* after several decades of absence was associated with a severe outbreak of malaria during the period 1996-2000 leading to the re-introduction of DDT within months. The malaria incidence in South Africa has declined markedly since then(Maharaj et al. 2005; Coetzee et al. 2013) with no reports of epidemic activity and the country is now earmarked for malaria elimination by 2020 (South African DOH 2011). Pyrethroid resistant *An. funestus* has been contained and kept out of South Africa through a system using DDT for traditional houses and pyrethroids for modern cement structures. According to the WHO, the same spraying practice is applied in Namibia and Swaziland (National Vector Borne Disease Control Program of Namibia and Swaziland)(Chanda et al. 2015).

31. As noted above, a number of countries have discontinued their use of DDT after successful elimination of malaria and are now reliant on other insecticide classes for prevention of re-introduction. It is important that vector susceptibility to these insecticides is monitored very carefully to ensure timely introduction and use of alternatives, effective insecticides (incl. DDT) should resistance occur, as well as timely implementation of rotations to prevent resistance build-up. Notably, the World Malaria Report 2015 listed evidence of resistance to DDT(i) in 42 out of the 95 countries with on-going malaria transmission (see Appendix 1). This indicates that the use of DDT for elimination purposes may be limited in many settings(World Health Organization 2015f).

C. International and national policies, guidelines and regulatory measures on DDT use

32. According to the World Health Organization Pesticide Evaluation Scheme's (WHOPES) 2010 survey, 16% of the 107 responding member States, did not have any national legislation on registration and control of public health pesticides. Specific legislation on storage, transport and proper disposal of public health pesticides lacked in 28%, 37% and 44% of the responding countries, respectively (World Health Organization 2011b). Notably, in reporting cycle 2012-2014, 26 countries reported having and

[h] Algeria, Botswana, Cabo Verde, Comoros, South Africa, Swaziland, Belize, Costa Rica, Ecuador, El Salvador, Mexico, Paraguay, Suriname, Iran, Saudi Arabia, Bhutan, Nepal, Timor-Leste, China, Malaysia, Republic of Korea.

[i] The report does not specify the exact geographical location for the testing, to which extent or in which vectors there is resistance to DDT in the various countries.

enforcing national laws and regulations on DDT use. Madagascar, Maldives, Peru and Mozambique reported that they do not have such laws and regulations.

33. According to the DDT questionnaire, the Ministry of Health was responsible for assessing the public health risk of using DDT and other insecticide/pesticide in the majority of the responding countries. However, in many countries, it is the Ministry of Agriculture that is responsible for regulating import, use and disposal of pesticides, including public health pesticides. Unfortunately, the Ministry of Health or the Ministry of Environment (responsible for use of the products) often have insufficient communication with the Ministry of Agriculture (responsible for regulation in most countries) to harmonize regulations and pesticide management practices so as to minimize human and environmental risks. If DDT is not used for agricultural purposes, but solely for public health, the Ministry of Agriculture may be less interested in the formulation and up keep of regulations. Direct communication between agencies is therefore needed. As an example, in India the Central Insecticide Board under the Ministry of Agriculture has the registration committee under the Chairmanship of Director General Health Services[j]. This board regulates the use of pesticides in agriculture as well as in public health.

34. The import, packaging, registration, transportation, storage and disposal of DDT and other public health pesticides is based on the FAO/WHO guidelines and country rules and regulations. In some countries where disease vector control programs are supported by development partners such as the President's Malaria Initiative (PMI), the insecticide spray operators are trained in safe use, mixing, handling and disposal, to minimize human exposure and environmental contamination in accordance with WHO guidelines. Such programs also include quality assurance on application of insecticide by follow-up bio-efficacy verifications. For countries where facilities are inadequate to undertake product quality assurance of insecticides used, including DDT, options should be made readily available to send the samples abroad for quality testing to places such as India, South Africa and Europe.

35. The WHO has published the *'Guidelines for Procuring Public Health Pesticides'* that elaborates on purchase requirements and quality control(World Health Organization 2012d). The guidelines focus on the procurement of correct amounts of appropriate high quality public health products in order to avoid accumulation of obsolete stocks. The guidelines aim to promote fairness, transparency, integrity, accountability and quality assurance in the procurement process and are meant to assist governments and stakeholders in preparing their own local standard operating procedure on procurement and quality control of pesticides. According to the country responses for the 2012-2014 reporting cycle, India, South Africa, Mozambique, Zambia, Mexico and Pakistan all reported having a system in place for quality control of DDT (other public health pesticides were not mentioned).

36. As highlighted in the previous report by the DDT expert group in 2009-2011, India has developed and implemented an Environmental Management Plan (EMP) with support from the World Bank. The EMP has six codes of practices, namely, 1) transport of insecticides for IRS activities, 2) storage and management of insecticide stocks, 3) community responsibility during IRS activities, 4) use and maintenance of personal protective equipment, 5) indoor residual spraying and 6) disposal of waste water, empty bags/containers and biomedical wastes. However, despite of this plan, implementation for safe use needs to be improved.[k]

(a) Safety issues related to DDT use

37. In 2011, WHO published a report, *'DDT in IRS: Human Health Aspects',* in order to provide specific advice to the COP. The report highlights issues relating to hazard assessment, exposure assessment and risk characterization on use of DDT in disease vector control. A detailed analysis of the human health risks is available in the WHO report(World Health Organization 2011a).

38. In June 2015, the International Agency for Research on Cancer under the WHO, classified DDT as 'probably carcinogenic to humans (group 2a)'. The classification was supported by findings of positive associations between DDT exposure and Non-Hodgkin Lymphoma, testicular and liver cancers in animals and humans(International Agency for Research on Cancer 2015). The 2011 WHO report described the above included an estimate of the risk of cancer associated with current use of DDT in IRS, taking a precautionary approach and assuming that DDT does in fact cause cancer.

39. Studies from South Africa and Oman have highlighted that IRS with DDT have led to elevated levels of DDT concentrations in humans for up to 16 years after spraying of households and the immediate areas, when the necessary precautions for protection are not followed(Gerber et al. 2016; Booij et al. 2016).

[j] Government of India (Personal communication)

[k] Personal communication; WHO

40. On human and environmental safety issues, among those responding to the 2012-2014 DDT questionnaire, the three DDT using countries (India, South Africa, Mozambique) as well as Madagascar, Mauritius, Mexico, Morocco, Pakistan, Senegal, Yemen and Zambia reported that they have community awareness programs in place to raise attention to the safety issues related to DDT use. Of these, eight countries (India, Gambia, Mauritius, Mexico, Pakistan, South Africa, Uganda and Yemen) also reported having a system in place for monitoring exposure to DDT for spraying operators. However, implementation of this system needs to be improved in India.[l] The agencies in charge of assessing the risks in these countries are the Health and Environment ministries.

III. Implementation of vector control products, methods and strategies

A. Vector control capacities, policies and guidelines at national level

41. Vector control efforts have had a significantly positive effect on malaria transmission and other vector-borne diseases worldwide(Bhatt et al. 2015). For example, the prevalence of *P. falciparum* infection in endemic Africa has decreased by 40% from 2000 to 2015 due to these efforts in combination with other factors[m], highlighting the need for continued focus on such interventions(Bhatt et al. 2015). In 2016, the WHO launched the *'Global Technical Strategy for Malaria 2016-2030'*(World Health Organization 2016b) that emphasizes the importance of: tailoring responses; country ownership and leadership; strengthened surveillance; equity in access to health services; and innovation in malaria control tools, to ensure this continued successful progress towards malaria elimination(World Health Organization 2016a).

42. As most malaria affected countries are in the control phase of the malaria elimination continuum, it is essential that effective vector control, ongoing surveillance and operational research is developed, implemented and maintained, as part of the preventive interventions of this phase. This aspect also applies to control efforts of other vector-borne diseases. In 2012, the WHO published the Global Plan for Insecticide Resistance Management (GPIRM) as a key technical recommendation. In connection to this, the PMI stated in 2015 that *'as countries scale up their Insecticide Treated Nets (ITN) and IRS programs, it becomes increasingly important that they develop resistance management strategies, national entomological monitoring plans, and NMCPs, to articulate how and where ITN and IRS can be most efficient and mitigate the threat of insecticide resistance in the disease vectors'*. The main issues of GPIRM implementation has been summarized as being: poor uptake at national level, limited availability of vector control tools and financial, human and infrastructural resources(Mnzava et al. 2015). In many countries these programs are lacking human capacity and infrastructure at all levels to ensure proper design, implementation, management, monitoring and quality assurance of vector control and surveillance activities. Reinforcement of in-country institutional capacity to educate and train skilled staff could ensure the necessary expertise and action within vector control and surveillance. Bridging the gap between national policy and guideline development and the implementation of control and surveillance activities at field level should also be considered as a key priority(World Health Organization 2014d).

43. In 2013, the WHO Global Malaria Programme issued guidance for capacity building in entomology and vector control with key recommendations for countries as well as national and international partners(World Health Organization 2013c). In the absence of national policies and regulatory measures, each country should adapt the relevant recommendations and directives of the WHO, FAO and the Secretariat to the Stockholm Convention – for the use of DDT and alternative methods of vector control.

44. In 2015, the WHO released a note on the importance of sustaining vector control efforts in low and zero malaria transmission areas until they are WHO certified malaria free. The note highlights how discontinuing vector control can present a high risk of malaria resurgence. Furthermore, it provides guidance on which geographical areas and conditions considered unsuitable for the scaling back of malaria vector control(World Health Organization 2015c).

B. Insecticide resistance management (DDT and alternatives)

45. All vector control programs, in which insecticides are used, should be based on proactive resistance monitoring at the national level. According to the obtained responses to the 2012-2014 DDT questionnaire, 17 countries have a national resistance monitoring system for DDT and other

[l] For more information: www.who.int/malaria/areas/vector_control/insecticide_resistance_database/en/.

[m] Incl. rapid diagnostic tests and improved treatment, socio-economic development, declining vector populations without intervention, etc.

insecticides [n]. Of these, 12 countries reported assessment of vector susceptibility to DDT as shown in Table 7[o]. As reported by the 12 countries it appears that Mozambique remains the only country to report a fully DDT-susceptible *Anopheles* population. However, *An. funestus* in South Africa, Mozambique, Malawi, Zambia and Zimbabwe are also fully susceptible to DDT. *An. funestus* is as good as absent from South Africa's malaria endemic regions essentially because of DDT use (personal communication; Basil Brooke & WHO). Ethiopia has not reported on the use of their available DDT stock, but has reported widespread resistance to DDT for *An. arabiensis* and *An. gambiae s.l.* throughout the country(World Health Organization 2015f). DDT was the primary choice for malaria control in Ethiopia up until 2009, but since 2010 the country has switched to carbamate and organophosphates due to the high level of DDT cross-resistance with pyrethroids(Ethiopia Ministry of Health 2014). It should be noted that insecticide resistance can be highly variable over short distances and certainly within countries, most of the responding countries reported in-country information on variation of resistance, but some of the geographical locations are very broad.

Table 7: Available information on vector susceptibility to DDT from the 2012-2014 DDT questionnaire.

Country	**Vector species**	**% mortality**	**Year and location of test** (if available)
Eritrea	*An. arabiensis*	88.3%	2014 (Gash- Barka Region)
India	*An. culicifacies*	80-85%	2013 (Andhra Pradesh, Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Nagaland, Mizorum, Odisha, Rajastan, Tripura, Uttar Pradesh, Uttarakhand, West Bengal)
	P. argentipes (sandfly)	50-60%	2014 (Bihar)
Madagascar	*An. gambiae sl*	46-87%	2015 (Haute Terre Centrale)
Morocco	*An. labranchiae* *Cx. pipiens*	50% 5-89%	2014 (Larache) 2014 (Meknes, Marrakech, Skhirat)
Mozambique	*An. gambiae* *An. funestus*	98-100% 99-100%	2014 2014
Pakistan	*An. culicifacies* *An. stephensi*	67-75% 60-69%	2011 (high transmission areas) 2011 (high transmission areas)
Peru	*Ae. aegypti*	0%	2014 (Loreto)
Senegal	*An. gambiae sl* *An. pharoensis*	0.9-52% 87%	2014 (Dakar, Soudano-Sahel, Soudanien) 2014 (Nord Delta)
Singapore	*Ae. albopictus* *Ae. aegypti* *Cx. quinquefasciatus*	18-60% 17-41% 0%	1979 (Island wide) 1979 (Island wide) 1979 (Island wide)
South Africa	*An. arabiensis*	81-97%	2015 (Mamfene - Northern Kwa-Zulu Natal, Hectorspruit, Mpumalanga)
Sri Lanka	*An. subpictus* *An. vagus* *An. culicifacies*	93% 78% 16-26%	2014 (South province) 2014 (East province) 2013 (North province)
Venezuela(Figueroa Acosta et al. 2014)	*An. albimanus*	100%	2013 (Aragua)

46. The reported susceptibility to DDT of vector species of diseases than malaria, especially the *Aedes* and *Culex* genera, indicate high levels of resistance, especially in Peru, Morocco and somewhat in Singapore[p]. Notably, there is an increasing focus on *Aedes* spp. as a vector for several important arboviral diseases including Zika and dengue and the possible control of this vector using DDT. However, two recent studies from the Zika affected Colombian Caribbean Region(Fonseca-González et al. 2011; Maestre-Serrano et al. 2014) and four recent studies from India(Yadav et al. 2015),

[n] El Salvador, Eritrea, India, Madagascar, Mauritius, Mexico, Morocco, Mozambique, Nepal, Pakistan, Peru, Senegal, Singapore, South Africa, Sri Lanka, Yemen and Zambia.

[o] The assessments were based on different methods in each country. The methods reported by the countries in the DDT questionnaire include: the WHO Standard Susceptibility Test; WHO Cone-Bioassay insecticide impregnated papers; CDC Bioassay; and OMS.

[p] The susceptibility test from Singapore is from 1979, thereby making it difficult to make any serious statement based on this data (personal communication; WHO).

Nigeria(Ayorinde et al. 2015), Malaysia(Ishak et al. 2015) and USA(Marcombe et al. 2014) each conclude that there is significant resistance to DDT in *Ae. aegypti* populations in the study areas, indicating that alternatives to DDT will be needed in these settings. The Indian study also indicated that *Aedes* were resistant to OP Temephos, but fully susceptible to pyrethroids.

47. In 2015, WHO reported 50% susceptibility to DDT for *P. argentipes* of VL in three states in India and suggested that DDT should not be used in public health programs for this vector(World Health Organization 2015d).

48. Several reports from the WHO and PMI, and research studies from around the world have reported resistance to non-DDT insecticides in different mosquito species that are of importance to vector-borne disease elimination efforts(World Health Organization 2015f; President's Malaria Initiative 2015; Kabula et al. 2014; Matowo et al. 2015; Mulamba, Riveron, et al. 2014; Quiñones et al. 2015a; Sande et al. 2015; Thomsen et al. 2014; Olé Sangba et al. 2016; Himeidan et al. 2011; Cisse et al. 2015; Dai et al. 2015). According to the World Malaria Report 2015, 60 out of the 78 countries that monitor resistance reported mosquito resistance to at least one insecticide used in long-lasting insecticide treated nets (LLINs) and/or IRS(World Health Organization 2015f). Data from ten International Centers of Excellence for Malaria Research showed that most of the primary malaria vectors exhibit insecticide resistance of varying magnitude to almost all classes of insecticides, particularly to the synthetic pyrethroids, and spanning all mechanisms of resistance(Quiñones et al. 2015b). To date, anopheline resistance has been identified for all major chemical classes used for vector control, i.e. pyrethroids, organochlorines, carbamates and organophosphates(Corbel & NGuess 2013).

49. According to the available information from the reporting cycle 2012-2014, 14 countries reported resistance to non-DDT insecticides in various vectors, however mortality rates were not provided (Table 8). Only a few of these countries noted the specific location of the investigated populations. Hence, the reported information may not always reflect within-country variations of resistance.

Table 8. Insecticide resistance in vectors as reported by countries in the 2012-2014 DDT questionnaire.

Country	**Insecticide class**	**Vector species**	**Year and location of test** (if available)
Eritrea	Pyrethroids	*An. arabiensis*	2014
India	Pyrethroids*, Organophosphates** Organochlorines (DDT)	*An. culicifacies, An. stephensis* *An. culicifacies, An. stephensis*	2014 (Gujarat, Tamil Nadu) 2014 (Andra Pradesh, Assam, Chhattisgarh, Madhya Pradesh, Tamil Nadu, Maharashtra, Gujarat)
Madagascar	Pyrethroids***	*An. gambiae s.l.*	2015 (61-70% mortality in the southern part)
Mexico	Pyrethroids, Organophosphates****,	*Not specified*	2014
Morocco	Pyrethroids, Organophosphates, Carbamates	*Cx. pipiens*	2014
Mozambique	Pyrethroids, Carbamates Pyrethroids	*An. gambiae* *An. funestus*	2014 2014
Pakistan	Pyrethroids (in some areas), Organophosphates (country wide)**	*An. culicifacies, An. stephensi*	Not specified
Peru	Pyrethroids, Organophosphates, Carbamates	*An. albimanus, Ae. aegypti*	2014
Senegal	Pyrethroids,	*An. gambiae s.l.*	2014 (South and

	Carbamates		Niayes areas for carbamates)
Singapore	Pyrethroids, Carbamates Pyrethroids	*Ae. aegypti, Cx. quinquefasciatus* *Ae. albopictus*	Not specified (Island wide)
South Africa	Pyrethroids Carbamates Organochlorines (DDT)	*An. arabiensis* *An. funestus* *An. funestus* *An. arabiensis* *An. arabiensis*	2015 (KwaZulu Natal & Mpumalanga provinces) 2000 (KwaZulu-Natal) 2000 (KwaZulu-Natal) 2015 (KwaZulu-Natal) 2015 (KwaZulu-Natal)
Sri Lanka	Carbamates Organophosphates	*An. subpictus* *An. culicifacies*	Not specified
Venezuela(Figueroa Acosta et al. 2014)	Pyrethroids Organophosphates Carbamates	*An. albimanus* *An. albitarsis s.l.* *An. albimanus,* *An. braziliensis* *An. albitarsis s.l.* *An. albimanus, An. albitarsis s.l.*	2013 (Zamora) 2015 (Aragua) 2013 (Zamora) 2014 (Amazonas) 2015 (Aragua) 2013, 2015 (Aragua)
Yemen	Pyrethroids	*Not specified*	Not specified
Zambia	Pyrethroids, Carbamates	*Not specified*	Not specified

*Alphacypermethrin, **Malathion, ***Permethrin, ****Temephos

50. Insecticide resistance is generally recognized in the form of mutation-driven physiological changes, mainly target-site and metabolic resistance. Target-site resistance may not confer operational failure of vector control on its own, but could pose a major threat in concert with metabolic resistance(Hemingway et al. 2013). Notably, the shift from complete pyrethroid susceptibility to country wide metabolic resistance can occur over the space of less than 12 months, as recently observed in Malawi(Hemingway 2014). Metabolic resistance can significantly impact vector control efforts, especially for IRS. For example, it was mono-oxygenase mediated resistance that enabled the *An. funestus* population in Kwa-Zulu-Natal, South Africa, to become highly resistant to pyrethroids, consequently forcing the NMCP to return to using DDT in addition to the continued use of pyrethroids(Mouatcho et al. 2007) because it was also shown this population had retained susceptibility to DDT. This approach successfully reduced malaria incidence to pre-epidemic levels. The widespread use of pyrethroids in public health and agriculture and the increasing metabolic resistance to pyrethroids are recognized as the main challenges to effective vector control(Hemingway 2014). As a result there has been a significant decrease in the use of pyrethroids for IRS, while the continued use of pyrethroids in LLINs, as regulated by the WHOPES, may be questioned although LLINs can continue to provide protection despite resistance(Strode et al. 2014).

51. Insecticide Resistance Management (IRM) strategies are facing mosquito populations that have been exposed to different classes of insecticides and may consequently have developed multiple and cross-resistance(Quiñones et al. 2015a). Recent studies from Malawi and China illustrate how increased resistance levels and the rise of multiple resistance highlight the need for rapid implementation of an IRM strategy to preserve the effectiveness of existing insecticide-based control efforts(Riveron et al. 2015; Chang et al. 2014a). Use of organophosphates or carbamates for IRS are WHOPES approved alternatives to DDT and pyrethroids, but may have an economic impact on malaria control programs due to much higher product and operational costs (increased number of rounds of spraying compared to DDT and pyrethroids). Furthermore, these insecticides may cause acute human toxicity in sprayers if safety guidelines are not adhered to (Quiñones et al. 2015b;Breman et al. 2007).

52. Resistance in the form of behavioral changes in the vector, such as shifts from indoor to outdoor biting and resting, is an increasingly recognized form of insecticide resistance(Quiñones et al. 2015b;Sokhna et al. 2013). Recent studies from Uganda(Mulamba, Irving, et al. 2014), Papua New

Guinea(Mulamba, Irving, et al. 2014), Kenya(Mwangangi et al. 2013) and Equatorial Guinea(Reddy et al. 2011) revealed significant changes to the behavior of their major malaria vectors such as; avoiding surfaces with insecticides; increased outdoor transmission due to shifts from the dominant and highly endophilic vector, *An. gambiae s.s.*, to the exophilic vector *An. arabiensis*; and the promotion of exophilic behavior in *An.gambiae s.s*. populations. These findings underscore the importance of accurate species detection and understanding of behavioral patterns for successful vector control, and the need to identify avenues for control of outdoor transmission, especially in elimination settings.

53. A direct link between program failure and insecticide resistance in *An. funestus* has been demonstrated in South Africa(Hargreaves et al. 2000) and strong evidence is available from Zimbabwe and Zambia(Choi et al. 2014). Control failure may be curtailed if national IRM strategies and vector control options are guided by timely evidence of insecticide susceptibility for local vector populations. Thus, it is critical that routine monitoring and surveillance of physiological and behavioral resistance are in place and alternative products/methods are available in the affected countries. This includes monitoring of cross and multiple resistance between pyrethroids and the alternative chemical classes for use in IRS, including DDT. Only a few NMCPs have the capacity to conduct effective IRM(Mnzava et al. 2015).

54. The use of different insecticides with separate modes of action either in rotation or in combination is proposed as a strategy to mitigate or delay insecticide resistance. The PMI highlights that there is now sufficient data from their control programs to conclude that carefully chosen rotations of insecticides, mosaics, or mixtures of insecticides will efficiently slow down the rate at which operationally significant levels of insecticide resistance will be selected(President's Malaria Initiative 2016; President's Malaria Initiative 2015). However, a study from China cautions that long-term use of various classes of insecticides may in fact select for multiple resistance due to high selection pressure. The study reported high metabolic resistance to the four main insecticide classes for *An. sinensis* in areas with prolonged and extensive use of each insecticide class for control of agricultural pests as well as public health disease vectors(Chang et al. 2014b). The potential impact of agricultural activities on insecticide resistance has also been reported from African countries including Tanzania and Sudan, where resistance studies suggest correlation between use of agricultural insecticides and resistance selection in anopheline vectors(Reid & McKenzie 2016; Nkya et al. 2014; Abuelmaali et al. 2013). These observations stress the importance that in relevant regions, NMCPs reflect the coordinated action between the Ministries of Health and Agriculture. This argues for timely resistance monitoring to guide selection of insecticide class and the need to include the agricultural sector in the management of resistance development.

55. Standard bioassays remain the core methods for resistance monitoring by many surveillance programs. Molecular markers of resistance, however, are increasingly used to complement conventional bioassays for early tracking of resistance development. The capacity of conducting molecular test is presently only fully implemented at a few research institutes. Notably, studies in Zambia, Zimbabwe and Burkina Faso have shown how intensity tests can be used to quantify the strength of resistance(Quiñones et al. 2015b). To this end, WHO has commissioned an update of the current insecticide susceptibility testing guidelines for adult mosquitoes to include protocols for assessing resistance intensity(World Health Organization 2013a). However, while molecular markers are well established for known target site resistance mutations, they are still inadequately characterized for metabolic resistance. Thus, it is still premature to rely on molecular markers as the sole tool for comprehensive resistance monitoring(Riveron et al. 2014). Additionally, molecular markers cannot impart information on the intensity of resistance phenotypes.

56. Several online tools are available to guide IRM strategies. IR mapper presents the possibility for combining a comprehensive database and online mapping of anopheline insecticide resistance in most malaria endemic countries(Anon n.d.; Knox et al. 2014). The IR-mapper provides a visual map of the temporal and spatial distribution of resistance. It also specifies the extent of available data highlighting regions where data are lacking. VectorBase (IRBase) also contains a global insecticide resistance database(University of Notre Dame & Imperial College London n.d.). In addition, the WHO Regional Office for the Eastern Mediterranean (EMRO) is currently developing a comprehensive insecticide resistance database including records from the 1940s to 2012(UNEP 2014). The aim is to facilitate data sharing and establish benchmarks on resistance status among malaria vectors in the region. A global database of insecticide resistance has been established and since 2014 the World Malaria Report includes a summary report of insecticide resistance (WHO World Malaria Report 2015).[(l)]

57. A commonly overlooked factor for use of IRS in vector control is the lack of community acceptance or compliance to the intervention. The reluctance by some communities to permit the spraying of houses tends to intensify as the disease burden decreases in the face of successful

elimination agendas. As such the use of IRS (with or without DDT) in the final stages of the elimination continuum may be less feasible than planned in some communities. Hence intensified community engagement and more targeted approaches based on good surveillance are needed.

58. In the absence of new insecticides approved for vector control, it is critical that NMCPs develop efficient IRM strategies that are based on timely data on vector susceptibility to the available insecticides. IRM strategies should be implemented as soon as there is a change in national vector control policies. The WHO Global Malaria Programme has developed the GPIRM to provide guidance to countries for developing effective management of insecticide resistance(World Health Organization 2012b; World Health Organization 2013c). The implementation of GPIRM has been initiated in some countries, but is yet to achieve wider traction. In addition, the PMI supports many of the IRS programs in Africa and has invested in building capacity for monitoring of insecticide resistance in order to enable better decision-making on the appropriate choice of insecticides. In their 2016 technical guidance report, the PMI recommend added focus on the development of long-term IRM strategies within the NMCPs for slowing down and mitigating the evolution of resistance in local vector populations. This strategy should also focus on moving the NMCPs towards Integrated Vector Management (IVM)(President's Malaria Initiative 2016).

59. Lastly, it is important to highlight that the need for resistance data and surveillance for non-malaria vectors is becoming increasing important as diseases such as Dengue, Chikungunya, Yellow Fever, Zika, Chagas, VL and cutaneous leishmaniasis (CL) continue to be public health issues around the world.

C. Implementation of integrated vector management

60. The WHO Global Strategic Framework for Integrated Vector Management defines IVM as *"a strategy to improve the efficacy, cost-effectiveness, ecological soundness and sustainability of disease vector control. IVM encourages a multi-disease control approach, integration with other disease control measures and the considered and systematic application of a range of interventions, often in combination and synergistically"*(World Health Organization 2004)

61. The IVM strategy comprises several key elements including:

(a) Insecticide policy and legislation;
(b) Collaboration within the health sector and with other sectors;
(c) Empowerment and involvement of local communities and other stakeholders through advocacy, social mobilization and regulatory control;
(d) Integration of non-chemical and chemical vector control methods;
(e) Evidence-based decision making guided by research, surveillance and evaluation;
(f) Capacity building of human resources and training for proper management of IVM;
(g) Rational utilization of resources – including targeting of IRS.

62. The IVM strategy, promoted since 2004, is widely acknowledged and the said target of most malaria endemic countries. However, the actual number of countries on track for IVM transition is uncertain. According to the 2012-2014 DDT questionnaires, 16 countries[q] reported having an IVM strategy at national level and 13 of those countries[r] reported having implemented it. However, according to a 2010 WHO survey, 62% of the member states (110 out of 142 countries) reported having an IVM policy in place(van den Berg et al. 2011). Notably, a large number of African NMCPs already incorporate some of the IVM key elements in their control activities(Beier et al. 2008). Reportedly, Zambia has fully embraced the IVM strategy and for the past 14 years IVM activities have been introduced, consolidated and expanded in a step-wise manner, in accordance with the WHO guidelines(Chanda et al. 2008). Documentation of IVM's impact in Zambia is recorded through routine monitoring and evaluation activities. These showed that in 2008, there was a significant reduction in in-patient malaria cases (55%) and deaths (60%) as compared to 2001/2002, however similar trends in reduction have been observed in other countries where IVM is still to be implemented and can therefore be attributed to vector control(Bhatt et al. 2015). In Zambia, the monitoring also detected resistance to DDT and pyrethroids in both *An. gambiae s.s.* and *An. funestus s.s.* leading to immediate discontinuation of DDT usage and concerns of the sustainability of the on-going control activities(Chanda et al. 2011; Chanda et al. 2013; Choi et al. 2014). In South Africa, IVM is currently

[q] India, El Salvador, Eritrea, Mexico, Mozambique, Myanmar, Senegal, Singapore, South Africa, Yemen, Zambia, Gabon, Mauritius, Morocco, Sri Lanka, Saint Lucia.

[r] India, El Salvador, Eritrea, Mexico, Mozambique, Senegal, Singapore, Zambia, Gabon, Mauritius, Morocco, Sri Lanka, Saint Lucia.

being rolled out as part of an enhanced control and surveillance approach at malaria foci (SA National department of Health policy document).

63. Many of the countries transitioning to IVM have obtained increased training on IVM principles and have held operational and structural arrangements within the Ministries of Health. However, recent surveys on the status of IVM implementation found that most of the countries that claim to implement IVM did not fully embrace the IVM principles, suggesting a need for further IVM training and introduction to the WHO Guidelines(World Health Organization 2003; UNEP 2011). The transition to IVM is faced by additional challenges, especially in low income countries, such as lack of policy frameworks to guide and promote the process as well as insufficient finances and operational difficulties(Corbel et al. 2012; Mutero et al. 2012). There is a need to ensure that IVM approaches are affordable and efficient in order for their implementation to make a lasting impact. NMCPs must strengthen inter-sectorial coordination for implementation of IVM strategies by involving all relevant sectors. Lastly, the NMCPs should include identification of locally tested alternatives to insecticides and cost-effectiveness assessments.

64. Vector borne diseases, representing 17% of the total burden of all infectious diseases, impede economic development. Vector surveillance and control works if well implemented. Strong political commitment and massive investments have led to major reductions in malaria, onchocerciasis and Chagas disease. However, the full impact of vector control has yet to be achieved due to inadequate delivery of interventions, limited investments leading to a lack of public health entomology capacity, poor coordination within and between sectors, weak or non-existent monitoring systems and few proven interventions (WHO Global Vector Control Response).

IV. Availability and accessibility of alternative products to reduce reliance on DDT for vector control

A. Recent developments

65. According to the questionnaires in the reporting cycle 2012-2014, 18 out of 30 countries reported using alternative products for vector control and conducting research into the development or testing of locally appropriate alternative interventions to DDT (see Appendix 2). The areas of research/testing are within microbial insecticides, chemical larvicides, larvivorous fish, residual chemical insecticides and genetic control approaches and the sterile insect technique (SIT). For example, India has: tested a new *Bti* strain (VCRC B 17) which is currently awaiting endorsement from the Central Insecticides Board & Registration Committee; introduced two IGRs (diflubenzuron and pyriproxyfen) in 2015; and studied different larvivorous fish and plant extracts for generating more scientific data. An SIT proof of principal study for the control of the major vector *An. arabiensis* is currently underway in South Africa (personal communication, Basil Brooke).

66. It is becoming increasingly important to acknowledge that vector control tools have become elements of *Aedes* and sandfly control, and therefore we have to consider not only *Anopheles* vector species but also strategies for promoting alternatives to DDT for other vector groups. For example, in March 2016, the WHO Vector Control Advisory Group (VCAG) reviewed five tools for vector control of *Aedes* mosquitoes as a response to the Zika virus outbreak. Based on the expert advice from the VCAG, the WHO recommended a pilot deployment of two of these tools (*Wolbachia*-based bio-control and OX513A transgenic mosquitoes) with rigorous monitoring and evaluation. The remaining three tools include: sterile insect technique; vector traps; and attractive toxic sugar baits. Furthermore, the WHO recommended promotion and use of existing tools such as: targeted residual spraying; space spraying; larval control; and personal protection measures(World Health Organization 2016c).

(a) Cost-effectiveness of alternatives to DDT

67. The costs and effectiveness of DDT are dependent on local settings and merit careful consideration concerning alternative products or methods. For vector control interventions, defining impact assessment and effectiveness requires care, since the epidemiology of vector-borne diseases is complex. In cases where a new intervention is being proposed, there may be inadequate resources or time to scientifically test the impact of a given vector control intervention using the entomological indicators. For these situations, a number of mathematical models have been developed to evaluate the predicted effectiveness of vector control interventions, including IRS with DDT and pyrethroids and the distribution of LLINs(Chitnis et al. 2010). These models are based on a number of peer-reviewed studies of malaria epidemiology and the effectiveness of the widely used IRS and LLINs interventions. In order to compare alternative vector control strategies to DDT using a cost-effective analysis, a common measure of impact assessment must be adopted. Simulation models have also been generated to analyze the cost-effectiveness of continued DDT usage compared to its rapid phase-out by

alternative combinations of IVM interventions(Pedercini et al. 2011). However, the evidence based assessment of cost-effectiveness for IRS and alternatives to IRS are currently insufficient for countries to make decisions towards sustainable transition away from DDT and the adoption of alternatives. The lack of expertise and updated cost-effectiveness studies has resulted in this lack of evidence.

68. Despite the abovementioned assessment, information on the applicability and cost-effectiveness of alternatives is generally limited, thus, not allowing countries to effectively design application of alternatives in local environmental, epidemiological and socio-economic settings. Furthermore, limited national capacity leads to inadequate analysis of available alternatives, insufficient consideration of alternatives in national policy and a lack of coherent and integrated approaches to vector control including the concept of IVM, which could help countries make evidence-based decisions on the use of pesticides, including DDT as mentioned in the above section 2.3. For example, a GEF funded initiative in Mexico and Central America reduced their reliance on pesticides, including DDT, by implementing alternative strategies against vector populations based mainly on environmental management and community participation. In 2015, GEF approved a similar project in India where bio- and botanical pesticides and other locally appropriate, cost-effective and sustainable alternatives to DDT will be introduced(GEF 2015a).

(b) Availability and accessibility of alternatives to DDT for indoor residual spraying

69. In 2015, the WHO released the second edition of their report *'Indoor residual spraying: an operation manual for IRS for malaria transmission control and elimination'*, to enhance existing knowledge and skills and to assist malaria programs to design, implement and sustain high quality IRS programs(World Health Organization 2015b). This manual provides guidance on good practice for planning and implementation of quality spraying programme for malaria vector control with emphasis on safe handling of insecticide.

70. The 5th meeting of the COP requested the Persistent Organic Pollutants Review Committee (POPRC) to assess the alternatives to DDT in accordance with the general guidance on considerations related to alternatives and substitutes. In 2012, the POPRC assessed the then 11 WHO recommended alternatives to DDT and reported that 10 insecticides were considered not likely to meet all the Annex D criteria for persistence, bioaccumulation, toxicity, and long range environmental transport in a preliminary screening assessment. However, the POPRC considered that bifenthrin might meet all Annex D criteria but remained undetermined due to equivocal or insufficient data in a preliminary screening assessment(Persistent Organic Pollutants Review Committee 2012).

71. As of today, the WHO recommends 12 active substances of insecticides(World Health Organization 2015e) (total of 21 formulated products), including DDT, for use in IRS in malaria control programs. The recommended IRS products fall within five different classes of insecticides with products available in all five classes. However, it should be noted that four of these classes collectively target only two neurological sites within insects, namely the sodium ion channels and acetylcholinesterase. The alternative classes of insecticides to DDT are the organophosphates, pyrethroids and carbamates. However, the choice of any of these alternatives depends on the susceptibility of vector populations, the length of the disease transmission season, the type of surfaces to be sprayed, the commercial availability and the ability of the governments to procure and handle the insecticide. Importantly, most of the recommended alternatives to DDT do not have the desired residual persistency of more than six months and therefore require more than one round of application per year.

72. The first choice for most countries when they consider IRS is to use one of the different formulations of the pyrethroid class of insecticides because of their low cost, low toxicity to mammals, effectiveness and community compliance. For example, India is using pyrethroids for IRS for both mosquitoes and sandflies, and the Indian government is currently reviewing the effect of this on sandfly control. In terms of mosquitoes, a recent study from India showed a higher effectiveness of pyrethroids coils compared to IRS with DDT in terms of deterrence-reduction in house entry, irritancy and excito-repellency, blood-feeding inhibition and effect on mosquito fecundity(Ogoma et al. 2014). However, as mentioned earlier, the observed increase in pyrethroid resistance in many locations has necessitated the use of carbamates (such as bendiocarb) and organophosphates for IRS, in order to preserve the effectiveness of LLINs. The introduction of insecticides of another class should always be preceded by appropriate susceptibility assessment. Research is also being carried out to re-purpose existing chemicals for use in insecticide based vector control, as for example clothianidin-based IRS products or new LLINs based on compounds such as pyriproxyfen(World Health Organization 2016d).

73. Microencapsulated insecticides are used in insecticide paint (IP) formulations[s] where they are embedded in the paint matrix and gradually released on the surface of the dried paint. This method is applied for IRS and can be applied on both interior and exterior surfaces, it has a prolonged residual effect and can offer simultaneous protection across a wide range of vector-borne diseases (malaria, Chagas, leishmaniasis, dengue, chikungunya, Zika, lymphatic filariasis, etc.). Furthermore, IP can easily be applied by untrained persons, hence eliminating the need for specialized personnel and extensive logistic planning. IPs' residual effect has been estimated to last for 12-32 months depending on the vector species, however, it should be noted that longer persistence might negatively affect resistance management. The industry has initiated production and market development of IP in West Africa and India, making IP available to the increasingly consumer-driven market for disease-prevention. However, the use of IP needs to be monitored and controlled to prevent environmental hazards and human health impacts from unsafe production, application and disposal, and to facilitate resistance management. More evidence of the effectiveness of IP with regards to disease reduction and possible resistance development is needed. (Schiøler et al. 2016)

74. The Innovative Vector Control Consortium (IVCC), a product development partnership, has developed Microencapsulated pirimiphos-methyl CS (Actellic 300 CS), a long lasting (6-9 months) alternative insecticide for IRS, and K-Othrine Polyzone, a new formulation of an existing pyrethroid that extends the residual impact(Innovative Vector Control Consortium 2016) - both have been recommended by the WHO(World Health Organization 2015e). In addition, a recent study conducted in Sarawak, Malaysia, demonstrated long-lasting effect of deltamethrin-WG against *An. maculatus*(Rohani et al. 2014). Research in Morocco has found that IRS with α-cypermethrin was an effective and cost-effective approach for the prevention of CL(Faraj et al. 2016).

75. The cost-effectiveness of DDT and alternatives for IRS must also be considered. In Appendix 3 and 4, the prices for DDT and alternatives are listed. The prices vary depending on how the price is calculated e.g. per house per six months or cost per sachet. At the Seventh Meeting of the COP to the Stockholm Convention in May 2015 the following prices were listed: unit costs to spray 250m^2 are approximately $1.80 for pyrethroids, $6.00 for DDT, $13.00 for bendiocarb, and $23.50 for the primiphos-methyl CS(Stockholm Convention 2015b). The final cost assessment should of course include the required number of spraying rounds per year in a given setting.

76. In 2016, UNITAID announced that they are investing $65.1 million through the IVCC over the next four years to create a market for IRS products that will reduce prices of new insecticides (not specified) from $23.5 to $15[t] by 2020(UNITAID 2016). Furthermore, from 2016 UNITAID is funding a subsidy mechanism to assist the PMI in purchasing new insecticides for IRS for $8.50 per bottle in the first year(UNITAID 2016). Due to the high cost of current alternatives to DDT an approach with increasingly targeted (focal) use of IRS is seen as a way of reducing cost and improving quality of spray operations. However, targeted IRS will often require high quality and updated epidemiological and entomological information. For example, in low transmission countries IRS is often conducted in places where there is no malaria but spray programs have insufficient data to withdraw spraying for fear of leaving populations unprotected.

(c) Chemical control

77. A number of organizations, such as the IVCC, have on-going research projects to develop novel insecticides to overcome resistance and reduce application costs of insecticides, as well as to develop information systems and tools that allow effective use of insecticides. The IVCC has announced that they are developing LLINs with alternative insecticide classes, which are anticipated to be available in 2017. By 2015, they selected three active ingredients that moved into the final development stage of testing which may take up to seven years(Innovative Vector Control Consortium 2016). In addition, durable wall linings using high-density polypropylene fabric that contains a proprietary combination of two non-pyrethroid insecticides is being evaluated and results are expected in early 2017(President's Malaria Initiative 2016).

78. According to WHOPES, several products for LLINs, IRS and mosquito larviciding are currently being tested (World Health Organization 2016d). As part of the Global Malaria Action Plan(Roll Back Malaria Partnership 2016a) of the Roll Back Malaria Partnership, universal coverage of LLINs (defined as one net for every two persons) is recommended for all populations at risk of malaria living in areas with indoor biting vectors. To mitigate the current increasing trend in vector resistance to pyrethroids and improve the effectiveness timeframe of the LLINs, eight new LLIN products have been submitted by various companies to WHOPES for laboratory and field evaluation

[s] Insecticide Paint formulations have not been evaluated by the WHO as of yet (personal communication; WHO).

[t] UNITAID and IVCC did not specify what the price covers in terms of area, etc.

prior to market launch. New generation LLINs (e.g. Olyset duo and Interceptor G2) are under development and they may prove effective against pyrethroid resistant vectors. The updated list of LLINs recommended by the WHO (World Health Organization 2016f) as of 2016, include 16 nets(World Health Organization 2016g) and seven products for treatment of nets for malaria vector control. In 2015, the WHO published a report *'Conditions for use of long-lasting insecticidal nets treated with pyrethroid and piperonyl butoxide'*(World Health Organization 2015a) in which they recommend use of Olyset Plus and PermaNet 3.0 as LLINs with this insecticide combination. A series of demonstration projects for alternative vector control methods coordinated by WHO/EMRO have tested: 1) the comparison of pyrethroid IRS, LLINs and environmental management for protection against cutaneous leishmaniasis in Morocco; and 2) the combined use of LLINs and IRS with bendiocarb, compared to LLINs alone in the WHO/AFRO region. These projects attempted to advance the evidence base on the combination of IRS and LLINs and alternative vector control approaches as an attempt to interrupt transmission. Unfortunately, the evidence has so far been inconclusive with some trials showing significant added impact(West et al. 2014) whilst others show no evidence of additional protection in spite of the combination of insecticides(Corbel et al. 2012). WHO guidelines for combining IRS and LLINs were issued in 2014(World Health Organization 2014e). As recent studies indicate, the effectiveness of this combination will depend on the behavior of vectors (Reddy et al. 2011; Smithuis et al. 2013) and acceptance from the human population(Bradley et al. 2012).

79. Chemical larviciding with organophosphates such as Temephos is used by a few countries in very specific settings to control anopheline larvae. This includes the urban malaria scheme implemented in several Indian cities, where granules formulation of Temephos is used to control *An. stephensis* as well as *Aedes* mosquitoes. WHO has stated that larviciding is likely to be cost-effective for malaria control only in settings where breeding sites of *Anopheles spp.* are "few, fixed and findable". Anti-larval activities with chemical and non-chemical methods should be explored as a supplementary measure to IRS and LLINs, provided there is evidence that this is a cost-effective, sustainable and operationally feasible measure(World Health Organization 2012f). A novel approach within larviciding is 'auto-dissemination', which was originally developed for container-breeding *Aedes* mosquitoes. Through this method the female mosquito picks up traces of the juvenile hormone mimic pyriproxyfen while resting inside a container and carries it to the breeding sites, where she deposits sufficient toxicants to the water resulting in inhibition of mosquito development from pupae to adult stage. Pyriproxyfen also decreases the lifespan and fecundity of the adult female mosquito. Due to the early stage of development, it is uncertain if auto-dissemination will work against *Anopheles*(Lwetoijera et al. 2014; Mbare et al. 2014). For resistance management purposes, if an organophosphate is used for larviciding, a different class of insecticide should be used for adult control.

80. The use of IGR has been incorporated in an integrated approach to malaria and dengue vector control, but more studies are required to assess the impact. The WHOPES recommends 14 different compounds and formulations for control of mosquito larvae(World Health Organization 2016h). In 2015, the PMI stated that they will not prioritize their resources to support mosquito larvae control due to lack of sufficient evidence of efficacy. However, in a pre-elimination context, they would consider supporting larviciding(President's Malaria Initiative 2016).

81. Other technologies, which are being developed by commercial groups include treated clothing and shelter material, attractive toxic sugar bait traps, and spatial repellents(President's Malaria Initiative 2016).

(d) Non-chemical control

82. Management of urban environments and domestic settings aimed at reducing vector propagation needs to be linked with a focus on specific areas that are conducive for the generation of vector habitats such as poor solid waste management, domestic water storage habits, and construction sites. This needs to be high on the agenda for urban planners and urban health authorities. The new SDGs may facilitate such focus, discussions and interventions as health has become a more integrated part of the urban and environmental agenda. It is important to emphasize that many of the most novel non-chemical alternatives to DDT and other insecticides have still only been tested within a research set-up and therefore still need to be proven feasible in a large scale *in vivo* setting.

83. Larval source management, which includes environmental management, microbiocides and biological control, aims to suppress vector population size and subsequently human-vector contact. Before the introduction of DDT, engineering and environment-based interventions contributed to the prevention of malaria, especially in Asia(Konradsen et al. 2004). Studies indicate that environmental management approaches can be cost-effective components to add to integrated control programs, if there are sufficient resources and technical capacity to plan, implement and evaluate the

intervention(Konradsen et al. 2004; Pedercini et al. 2011). Most of these methods have been documented to be effective in reducing malaria transmission in those specific settings where conditions were appropriate for their use(Killeen et al. 2002; Keiser et al. 2005; Fillinger et al. 2011). The Roll Back Malaria larval source management work-stream 2012 has supported case study reports on larval source management in urban areas in Mauritius(Roll Back Malaria Larval Source Management Work Stream 2012 2012b), Sudan(Roll Back Malaria Larval Source Management Work Stream 2012 2012d), India(Roll Back Malaria Larval Source Management Work Stream 2012 2012c) and Tanzania(Roll Back Malaria Larval Source Management Work Stream 2012 2012a). Environmental management for larval vector control may be most feasible in urban areas or in particular agricultural settings where the management of water can be controlled through engineering approaches or infrastructural investments.

84. There are several new bio-insecticides and bio-pesticides with different modes of action used for mosquito larval management, such as entomopathogenic fungi from the Hyphomycetes (*Beauveria bassiana* and *Metarhizium anisopliae*). These fungi have an advantage over the current fast-acting insecticides by disrupting feeding and killing the mosquito later in the life-cycle, but before it is infectious, thereby reducing the selection pressure and potential development of resistance seen in chemical insecticides. Application of entomopathogenic fungi can be done through spraying of resting areas such as clay pots and eave screens(Stockholm Convention 2015b). Furthermore, endosymbiotic bacteria (*Wolbachia pipientis*) fipronil, spinosad, imidacloprid, novaluron, and methoprene could serve as good alternatives for mosquito control, particularly when they are directed towards the aquatic larval stages. Additionally, 41 essential oils have been reported to effectively repel *Aedes, Anopheles* and *Culex*(Zhu et al. 2016).

85. Another strategy has been the use of microbiocides, including the bacterial larvicides *Bacillus thuringiensis israelensis* (Bti) and *Bacillus sphaericus* (BSph) or their combinations(World Health Organization 2016e). A pilot study in Kenya has demonstrated the effectiveness of Bti in reducing malaria morbidity(Fillinger et al. 2009) which studies from Gambia(Majambere et al. 2007), Burkina Faso(Dambach et al. 2014), and Ghana(Nartey et al. 2013) support. A study to assess the effectiveness of a community-based microbial larviciding intervention in Tanzania found the intervention to be effective in reducing the prevalence of malaria infection in urban Dar es Salaam with the highest effectiveness during dry seasons(Maheu-Giroux et al. 2013).

86. For at least 35 years, the WHO has promoted the use of larvivorous fish as an environmentally friendly alternative to insecticide-based interventions for malaria control. Biological larval control using larvivorous fish is feasible in certain ecotypes and settings and is propagated in India as a supportive intervention to control vector breeding. An additional benefit from the use of larvivorous fish is the ability by certain species, in particular *Gambusia affinis*, to reduce DDT contamination in the water and sediment as well as in edible fish of rural ponds(Dua et al. 1999). Lastly, *Toxorhynchites* larvae are predators of *Aedes* larvae and have therefore been proposed as a potential biocontrol agent against *Ae. aegypti* and *Ae. albopictus*(Lin et al. 2016).

87. A systematic review has highlighted that, despite low quality evidence, the direction and consistency of effects indicate that housing is an important risk factor for malaria(Tusting et al. 2015). Dedicated housing and homestead improvements, for example insect screens on windows and doors aimed at reducing indoor vector densities, and interventions to make the homestead environment less conducive for vector breeding have been shown to reduce vector-borne diseases in particular settings(Atieli et al. 2009; Kirby et al. 2009; Bradley et al. 2013). However, the evidence of housing modifications needs further documentation(Anderson et al. 2014)..

(e) New paradigms and research prospects on alternative products and strategies for vector control.

88. In June 2016, the IVCC received a $75 million grant from the Bill & Melinda Gates Foundation (BMGF). Over the next five years, this grant will contribute to the development costs of three new insecticides currently in pre-development and other related tools and solutions. The total costs are shared with industry and other funders. In addition, the IVCC has announced that they are directing their activities towards assuring delivery of products, including regulatory approval, improvement of market dynamics and vector control. They highlight that even though their vector control solutions are mainly focused on malaria transmission, the portfolio also has significant potential for dengue, Zika, chikungunya, filariasis and yellow fever transmission(IVCC 2016b). The IVCC, BMGF, WHO and TDR have issued calls on research ideas and tools relevant for outdoor transmission and grants have already been given. The UNEP/GEF, UNIDO, WHO, TDR, UNTAID, BMGF, USAID, DFID, Wellcome Trust, and the EU continue to be some of the other key donors that fund vector control research and product development.

89. Several research groups have focused on the possibility of using modified mosquito releases to reduce vector populations or to render them incapable of transmitting the pathogens for malaria and dengue. Examples of these are genetically modified mosquitoes and *Wolbachia* infected *Ae. aegypti*(Oliva et al. 2014). A study highlighted that recent developments have allowed for efficient mass-rearing and irradiation for male release, and that *Wolbachia* combined with irradiation is an effective control approach that promise a safe and sustainable suppression of mosquito vectors(Lees et al. 2015). The evidence of such technologies for impact on disease is still lacking, but studies indicate that they have considerable potential, especially the self-sustaining strategies compared to the self-limiting strategies(Alphey 2014).

90. The green synthesis of nanoparticles has emerged as a very active area of research, with several studies conducted to investigate how these can help to control malaria and dengue vectors. For example, a study showed that very low doses (1 ppm) of lemongrass-synthesized gold nanoparticles controlled these vectors by boosting early instar mosquito larvae predation by copepods (*Mesocyclops aspericornis*) in an aquatic environment(Benelli 2015).

91. New paradigm vector control methods are being reviewed and guided by the VCAG and the IVCC committee, ESAC 3. Examples of such paradigms are: new generation LLINs and IRS insecticides that may restore effectiveness against pyrethroid resistant mosquitoes[u]; spatial repellents; insecticide treated eaves screening; and lethal mosquito attractants(World Health Organization 2014b). Some of these approaches are still being pilot tested while others have reached the stage of large-scale trials; hence none have currently been sufficiently evaluated for policy recommendation.

92. South Africa is currently rolling out a malaria foci clearing program, which is designed to prioritize localities that are still experiencing local transmission. This program is a critical component of South Africa's malaria elimination campaign and includes procedures for rapid notification and subsequent case investigation followed by enhanced surveillance and control. The foci clearing program will likely lead to a reduction in insecticide use as IRS operations become more targeted. In addition, a project to assess the dynamics of malaria transmission in two of South Africa's malaria endemic provinces is underway. Data to date show that at least four Anopheles species are transmitting malaria within South Africa - three of which contain components of their populations that tend to feed and rest outdoors. These data are expected to inform the incorporation of vector control technologies that target outdoor-resting vectors, including larval source management (personal communication, Basil Brooke).

93. As mentioned earlier in this report, the International Centers for Excellence in Malaria Research has established evidence in hyperdemic areas that malaria transmission and vectors are highly spatially and temporally heterogeneous. In addition, most vectors exhibit a mix of behaviors suggesting that local programs will have to address control of multiple species as well as the control of single species that presents multiple behaviors. As a consequence, the International Centers for Excellence in Malaria Research are calling for a paradigm shift towards new combinations of sampling, surveillance and control tools in order to understand how behavioral adaptions impact elimination efforts(Conn et al. 2015).

(f) Implementation of the Road Map for development of alternatives to DDT

94. In 2013, the COP invited UNEP to develop a road map for the development of alternatives to DDT in collaboration with the WHO, the DDT expert group and the Secretariat. The road map was presented to the COP at its seventh meeting in 2015 in document UNEP/POPS/COP.7/INF/6. The road map was developed with financial support from the Government of Switzerland.

95. The road map defines a plan of global, regional and national activities to strengthen the development and implementation of locally safe, effective, affordable and environmentally sound alternatives to DDT in vector control. It identifies key actors responsible for implementing the road map and explains their respective roles. It includes a status report, elaborating on recent developments in the production, trade, use and consumption of DDT, global policies and strategies for vector control, as well as the status of vector control tools. The purpose of the road map is to provide a thematic guide and sketch the steps that are needed to achieve the goal of making the development and deployment of alternatives to DDT a priority. In general, it provides a framework for action and does not have a specific phase-out date. It consists of three key elements:

(a) Establishment of overall road map management and reporting procedures;

[u] These new tools are still under evaluation, thus evidence to support efficacy against pyrethroid resistance must be demonstrated and operational issues must also receive equal focus (personal communication; WHO).

(b) Implementation of the road map through strengthening of the knowledge base for policy formulation and decision-making and of national and local capacities, development and deployment of chemical alternatives, and up-scaling of application of non-chemical alternatives, and

(c) Elimination of stockpiles and waste, and updating of inventories.

96. These elements were set to begin implementation starting from May 2015 and onwards. More information about the road map is available at the Stockholm Convention website(Stockholm Convention 2015b) under 'Information documents' and UNEP/POPS/COP.7/INF/6.

V. Capacity to transition from DDT to alternatives for vector control

A. Training tools and capacities for proper use of alternative insecticides and non-chemical methods for vector control

97. In September 2014, the IVCC and the US Armed Forces Pest Management held a joint workshop that focused on public health pesticide application technology tools with the objective to improve the quality and efficiency of current vector control practices. The outcome was an identification of new opportunities to improve application technologies including: use of constant flow valves and erosion resistant tips on sprayers in all IRS programs; introduction of compression sprayers that minimize pesticide waste and human error; and embracing the potential for new larval source management techniques and next generation technology such as unmanned, smart spray systems(Knapp et al. 2015). Such tools can ensure the proper use of insecticides and non-chemical methods for vector control in the most efficient way depending on the local setting, but improved implementation is needed.

98. The Public Health Pesticide Program (IR-4 PHP), administrated by the State University of New Jersey, has developed a Public Health Pesticides Database that provides information on pesticide chemistry and toxicology and the efficacy of various chemical tools including repellents, attractants, and toxins against specific pests(IR-4 2014).

99. A Disease Data Management System (DDMS) on malaria control has been developed by the IVCC and Liverpool School of Tropical Medicine. The tool is a computer package that collates data on disease incidence, vector populations (including density and insecticide resistance) and intervention activities and presents this information in a web-based, real-time geographical format. The system has been successfully implemented in Bihar, India, and will expand to seven African countries. It was recently expanded to include VL for initial implementation in India(IVCC 2016a). This tool assists malaria and dengue control programs with data integration and management, thereby facilitating a transition from DDT to other alternatives.

100. The US Center for Disease Control and Prevention has compiled a comprehensive website with resources such as guidelines, publications, online training seminars, online lectures, etc. on vector control and integrated pest management(Centers for Disease Control and Prevention 2016).

101. The FAO/WHO International Code of Conduct on Pesticides Management from 2013 provides standards of conduct and serves as a point of reference in relation to sound pesticide life cycle management practices, in particular for government authorities and the pesticide industry(FAO 2013).

102. In 2015, the PMI released a second edition of their *'Best Management Practices (BMP) for IRS in vector control interventions'* that expands upon the first edition from 2010[153]. This manual aims at establishing a uniform approach for environmental assessment of pesticide use in IRS, and to provide acceptable safety standards and practices for the handling, storage, transportation and use of IRS pesticides. It also includes a separate chapter on *'DDT Special Considerations'*. The new additions to the manual include: best practices for water transport of pesticides; an expanded section on gender equality; guidance for the use of the PMI innovative Mobil Soak Pits for disposal of biodegradable waste in remote areas with targeted spraying; and seven assessment checklists for field inspection and reporting to guide environmental compliance(Chandonait 2015).

103. To facilitate the implementation of IVM for disease vector control, the WHO has developed several guidelines available for disease endemic countries including:

(a) Guidelines for vector control needs assessment(World Health Organization 2003);

(b) Guidelines for procurement of public health pesticides(World Health Organization 2012d);

(c) Core structure for training curriculum on Integrated Vector Management(World Health Organization 2012a);

(d) Handbook for Integrated Vector Management(World Health Organization 2012e);

(e) Guidance on policy development for Integrated Vector Management(World Health Organization 2012c), and

(f) Monitoring and Evaluation Indicators for Integrated Vector Management(World Health Organization 2012g).

104. Furthermore, the WHO has developed a *'Guidance note on capacity building in malaria entomology and vector control'*(World Health Organization 2013b) and a guideline for testing new LLINs to substantiate claims of efficacy in areas of high insecticide resistance(World Health Organization 2014a). Lastly, WHO has comprehensive guidelines to vector control of vector-borne diseases such as the *Global Technical Strategy for Malaria 2016-2030*(World Health Organization 2016b) and their *Dengue guidelines for diagnosis, treatment, prevention and control*(World Health Organization 2009).

105. The Roll Back Malaria Partnership has published a Toolbox that is divided into seven main categories of the programming cycle for malaria control including: Policies and Strategies; Assessing and Planning; Resourcing and Mobilization; Implementation of Interventions; Implementation Systems; Monitoring and Evaluation; and Advocacy, and Communication. Under each category, detailed information and advice is offered to guide training of personnel and implementation of activities(Roll Back Malaria Partnership 2016c).

106. A 2010 survey of public health pesticide registration and management practices in WHO member states showed that only 23 of 109 countries have certified training in vector control for those who are responsible for decision-making and implementation of vector control activities, and only 16 out of 109 countries have training in sound management of public health pesticides for the same group of people(World Health Organization 2011b). Information on the capacity of human resources within vector control at international and national levels is difficult to identify and may not exist in most settings. However, it is essential to have this information when discussing the issue of capacity and it is therefore important to conduct needs assessments of available human resources. For instance, the increasing role of private pest and vector control companies in urban settings offer a range of possibilities for making use of their capacities while also ensuring that they adhere to government policies to reduce insecticide resistance. Furthermore, it is relevant to emphasize the need for large scale trials and cost/feasibility assessments to understand capacity requirements and socio-economic impacts of alternatives.

107. An area that is lacking coordination of capacities is the collaboration between the agricultural, environmental and the public health sector, commonly called Integrated Vector and Pest Management. There is a great need to work together to address the development of vector insecticide resistant strains, to coordinate regulatory and legislative policies on registration, import and use of pesticides, and to regulate and monitor the trade and market for these chemicals.

B. Available funding opportunities for transition from DDT to alternatives

108. The focus upon and continued investments in alternatives to DDT has been emphasized following the initiation of the Road Map for development of alternatives to DDT. The UNEP/GEF partnership supports an international effort to promote alternatives to DDT. GEF has so far supported a total of 15 projects through direct or indirect investments by more than $76million(Sow et al. 2014). Many of these projects are now completed and many are in the pipeline for approval. Among the already approved projects are GEF funded projects in: India of about $50million (including co-financing) to *'Development and promotion of non-POP alternatives to DDT'*, Guatemala of about $6 million (including co-financing) for*'Environmentally sound management and disposal of PCB-containing equipment and disposal of DDT wastes and upgrade of technical expertise'*, and in Bangladesh/Nepal of about $4.38 million (including co-financing) to *'Demonstrate cost-effective and sustainable alternatives for DDT in vector borne disease control in the Indian sub-continent'*(Global Environment Facility 2016).

109. Furthermore, as mentioned in chapter 3, the IVCC received substantial funding in 2016 from BMGF to support the continued development of new insecticides. IVCC and the PMI also received $65 million from UNITAID to subsidize prices on alternative IRS insecticides to facilitate the transition from DDT to alternatives and to mitigate insecticide resistance by lowering the price on expensive insecticides. These and other funding opportunities are available for countries to strengthen systems for disease vector control with alternatives to DDT.

110. The Roll Back Malaria Partnership has developed an online tool, The Malaria Funding Data Platform, to facilitate analysis of funding flows within malaria, which can help identify financing gaps and priorities(Roll Back Malaria Partnership 2016b). This tool is useful to navigate the increasingly

comprehensive public/private nature of funding in malaria, and to create an overview of the resource mobilization that is happening within and between the various stakeholders in the partnership.

C. Technology transfer and linkages with research and training institutions relevant for vector control

111. Career development opportunities, job retention and regular training for vector control officers/entomologists to senior level decision-makers should be made available in order to develop and maintain a cadre of trained and experienced staff to address local disease problems. Collaboration between national vector-borne disease control programs, universities and other research organizations is much needed. As of January 2014, 50% of the posts as public health entomologist in India were vacant as career opportunities within government organizations were perceived as limited (person communication - Dr. Sharma, India). This highlights the fact that human resources at international, national and local level is absolutely central to the successful control of malaria and other vector-borne diseases.

112. In the 2012-2014 reporting cycle, 16 out of the 30 responding countries indicated that they have training facilities for insecticide use and that they have established intersectoral collaboration in disease vector control. Eighteen out of the 30 responding countries reported that they have an entomology laboratory being used in the country for vector resistance testing, however only nine of the laboratories are internationally recognized. Ideally, every NMCP should have a professional entomologist to offer vector surveillance and allied operational research oversight. Such a person should be qualified at least at the MSc level and should be employed as a high-level professional.

113. Lastly, information on the capacity of universities and colleges to train the next generation of entomologists and public health professionals in the field of vector-borne disease control is important to facilitate an assessment of the capacity to train and conduct research within this area. It could be very relevant to review the need for establishment of a medical entomology unit and of curricular to see if the integration of alternatives to insecticides (including DDT) is being promoted. Furthermore, assessing the level of priority that the field of vector-borne disease control receives in general is important.

VI. Actions taken by Parties/Partners to reduce reliance on DDT use for vector control

114. A number of initiatives have been set up by WHO and partners to improve vector control including judicious use of all approved insecticides (including DDT). These initiatives include advocating for universal coverage with LLINs, promoting effective diagnosis and treatment of all malaria cases, promoting IVM as a sustainable approach to disease prevention, promoting effective insecticide resistance management, and allowing countries to use DDT as long as there is no viable alternative for IRS. New paradigms and tools for vector control are under investigation and development as mentioned in chapter four.

115. Collaboration with sectors such as agriculture, environment, and energy could ensure that their activities do not result in increased vector densities and disease transmission. Although successful experiences involving resource mobilization in public health programs such as HIV/AIDS exist, effective mobilization for disease vector control and in particular, search for alternatives to DDT, is still a challenge in many countries. Since 2004, the main financial supporters of malaria control programs have been the GFATM, WHO, BMGF, the US and UK governments, USAID, PMI, and the World Bank. Most of these donors coordinate their activities through the Roll Back Malaria Partnership and the WHO. The most recent WHO global malaria report 2015 indicates that resources have been allocated to support the up-scaling of vector control interventions over the past few years. Maintaining these gains and moving forward with elimination is a challenge in the face of donor fatigue and competing needs.

VII. Assessment summary

116. Reducing disease burden is a primary objective of the Sustainable Development Goals related to socioeconomic and agricultural development, urbanization, forced displacement and climate change. Every year, vector borne diseases account for more than 17% of the global burden of infectious diseases. Control of these diseases depends upon suppression of vector populations using insecticides and other methods. A number of countries consider DDT an important element of their vector borne disease control and elimination efforts. Under the Stockholm Convention, DDT use is restricted to appropriate disease vector control.

117. Thirty countries, out of 178 Parties to the Stockholm Convention responded to the 2012-14 DDT questionnaire administered by the Secretariat. Currently 17 Parties are listed in the DDT Register; of those only 10 have responded out of which three reported use of DDT for disease vector control. However, information provided by exporters indicated that at least five other countries in addition to these have imported DDT during the reporting period. The assessment of the continued need for DDT is limited by the poor response rate by Parties and poor quality and inconsistency of information provided through the DDT questionnaire and other information channels.

118. Global annual DDT production remained mostly unchanged compared to the 2009-11 reporting cycle, approximately 3300 MT of active ingredient. In the current reporting cycle, India was the only producer of DDT, 91% of which was for domestic use; and the remainder was exported. Of the three Parties reporting use of DDT, a modest decline was reported in India, a substantial reduction in South Africa and a 10 fold increase in Mozambique. In India, the use of DDT has substantially shifted from malaria to leishmaniasis control. None of the 30 responding Parties reported using DDT for purposes other than disease vector control.

119. 26 out of 30 responding Parties reported the existence of national laws and regulations on DDT. Among the four remaining countries, one reported using DDT for vector control. India has developed and implemented a plan for sound management of pesticide products used in indoor residual spraying.

1. The ongoing disposal of obsolete DDT stocks was coordinated by several organizations. However, the inventory of DDT stockpiles is far from complete and therefore remains a global challenge for safe management and disposal. Information in the DDT questionnaire and that contained in the road map for the development of alternatives to DDT as endorsed by the COP 7 and other sources of information show significant discrepancies in stock quantities. This road map is seeking to accelerate the management of stockpiles and also the promotion of alternatives within its framework.

120. Effective vector control and disease elimination are threatened by inadequate human capacity and infrastructure in vector control programmes, the spread of insecticide resistance, outdoor biting by malaria vectors, and poor coordination between the relevant ministries, research institutions and other stakeholders. Many vector control programmes are heavily dependent on external funding which undermines their long-term sustainability.

121. Adoption of Integrated Vector Management (IVM) and insecticide resistance management into control programmes are progressing slowly. Insecticide resistance in vector populations is widespread and is increasing. Training tools and guidelines are available for use of alternative insecticides and non-chemical methods. A draft strategic Global Vector Control Response 2017 – 2030 being developed by WHO, which will be considered for endorsement by World Health Assembly in May 2017, will highlight the importance of vector control in line with SDG 3.3.

122. The use of alternative chemicals for IRS is constrained by factors such as insecticide resistance, cost, efficacy, toxicity and duration of insecticidal effect. An alternative approach to the large scale use of DDT may include the targeted use of IRS with more costly insecticides in low transmission settings; this approach requires robust surveillance. Several countries have moved towards targeted IRS, thereby reducing the amounts of insecticides used.

123. There are a number of existing and potential alternatives to DDT. Long-lasting Insecticidal Nets (LLIN) for malaria vector control are highly effective in certain ecological and community settings. Larval source management (LSM) is an effective supplemental intervention in particular settings. Appropriate house improvements and insecticide-treated curtains have been shown to reduce exposure to malaria vectors. Personal protection methods with niche applications include use of topical repellents, insecticide treated clothing and blankets/hammocks.

124. In addition, there is an extensive research and development pipeline of novel vector control tools relying on a variety of approaches, including new molecule and repurposed chemicals; bacterial, physical and genetic manipulation of vectors; vector baiting and trapping techniques; new generation LLINs including the use of synergists to restore susceptibility to pyrethroids; insect growth regulators; and fungal IRS. However, none of these new vector control approaches are currently backed by sufficient evidence of epidemiological efficacy, safe use and efficient operational delivery to be considered for public health interventions. In some cases, insufficient funding has led to slow development of new tools.

VIII. Recommendations

125. The DDT expert group reaffirms that there is a continued need for DDT for indoor residual spraying (IRS) in specific settings for disease vector control where locally safe, effective and affordable alternatives are still lacking, and agreed to the following recommendations:

(a) Reporting on DDT by Parties should be significantly improved to undertake adequate assessments under the Convention, particularly the mechanism for reporting on use, import and export, and stockpiles of DDT, including the use of other chemical for IRS;

(b) Coordination between the entities that collect relevant information on DDT including the Basel, Rotterdam and Stockholm Conventions, UNEP monitoring programme and the WHO's reporting system on public health pesticides should be further enhanced;

(c) Further support for the identification and safe disposal of obsolete DDT stockpiles should be strengthened with the aim of complete removal of the obsolete stocks;

(d) Use of DDT for leishmaniasis vector control should only be considered if safe, effective and affordable alternatives to DDT are not available;

(e) Countries should seek WHO guidance before considering DDT for the control of vectors of arboviruses;

(f) To ensure judicious use of resources, including DDT, countries in low or medium transmission settings should endeavour to adopt a targeted approach to IRS which must be based on an adequate surveillance system;

(g) National capacity for research, resistance monitoring and implementation should be increased for pilot testing and up-scaling of existing alternatives to DDT by relevant national and international bodies within the framework of the proposed WHO Global Vector Control Response (GVCR) and the road map for the development of alternatives to DDT;

(h) There is an urgent need for funding at the global level for research and development into new vector control tools, aiming to generate evidence that would meet the requirements for policy recommendations on alternatives to DDT by WHO;

(i) The Secretariat of the Stockholm Convention should continue to facilitate activities on strengthening capacity to transition away from the reliance on DDT for disease vector control.

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Appendix I to the report: Assessment of indicated DDT resistance in malaria vectors[v]

Country	Species/complex tested[w]	Year
Afghanistan	*An. stephensi* & An. superpictus**	2010-2014
Angola	*An. coustani & An. gambiae s.l.**	2010-2015
Benin	*An. coluzzii & An. gambiae s.l.**	2010-2014
Burkina Faso	*An. arabiensis* & An. coluzzii & An. gambiae s.l.**	2010-2014
Burundi	*An. gambiae s.l.**	2014
Cambodia	*An. dirus* & An. minimus**	2014
Cameroon	*An. gambiae s.s.**	2010-2014
Central African Republic	*An. gambiae s.l.**	2014
Chad	*An. gambiae s.l.**	2011-2014
China	*An. sinesis* & An. vagus*	2010-2012
Colombia	*An. albimanus* & An. darling**	2011-2014
Congo	*An. gambiae s.l.**	2013-2014
Cote D'Ivoire	*An. coluzzii & An. gambiae s.l. & s.s.**	2010-2013
Democratic Republic of Congo	*An. gambiae s.l.**	2010-2015
Equatorial Guinea	*An. coluzzii*	2010-2014
Eritrea	*An. funestus & An. gambiae s.l.*	2010-2014
Ethiopia	*An. arabiensis* & An. gambiae s.l.*	2010-2014
Ghana	*An. gambiae s.l.**	2010-2014
Guinea	*An. gambiae s.l.**	2012-2014
India	*An. culicifacies s.l.* & An. fluviatilis**	2010-2015
Iran	*An. stephensi* & An. culicifacies**	2010-2012
Kenya	*An. arabiensis* & An. gambiae s.l.* & An. funestus**	2010-2015
Lao People's Democratic Republic	*An. dirus* & An. minimus**	2013-2014
Liberia	*An. gambiae s.l.**	2010-2014
Madagascar	*An. gambiae s.l.* & An. funestus* & An. mascarensis*	2010-2015
Mali	*An. gambiae s.l.**	2010-2014
Myanmar	*An. dirus* & An. minimus**	2011-2014
Nepal	*An. annularis* & An. fluviatilis**	2014
Niger	*An. coluzzii*	2013
Nigeria	*An. coluzzii & An. gambiae s.l.**	2010-2014
Pakistan	*An. stephensi* & An. culicifacies**	2011-2013
Philippines	*An. flavirostris* & An. maculatus s.l.**	2011-2015
Rwanda	*An. chrysti & An. coustani & An. gambiae s.l.**	2010-2015
Senegal	*An. arabiensis* & An. gambiae s.l.**	2010-2014
Somalia	*An. arabiensis* & An. funestus**	2010-2013
Sri Lanka	*An. culicifacies* & An. subpictus**	2010-2013
Sudan	*An. arabiensis**	2010-2014
Togo	*An. gambiae s.l.**	2011-2013
Uganda	*An. funestus* & An. gambiae s.l. & s.s.**	2011-2014
United Republic of Tanzania	*An. arabiensis* & An. gambiae s.l.**	2010-2015
Yemen	*An. arabiensis* & An. culicifacies**	2010-2014
Zambia	*An. funestus* & An. gambiae s.l. & s.s.**	2010-2014

**Major Anopheles species in the respective countries.*

[v] Compiled data from WHO World Malaria Report 2015. Resistance level (% mortality) and test location were not mentioned in the report. Therefore, the information in this appendix should only be treated as an indication of resistance to DDT in the mentioned species and countries.

[w] Insecticide susceptibility bioassays (reported resistance to at least one insecticide for any vector at any locality).

Appendix II to the report: Alternatives to DDT as reported by 18 out of 30 countries during reporting cycle 2012-2014

Country	Larvicides & biological control		Indoor Residual Spraying		Insecticide-treated nets		Others	
	Disease	**Product**	***Disease***	**Product**	***Disease***	**Product**	***Disease***	**Product**
Argentina	*Dengue*	Bti, Temephos	*Chagas, Malaria*	Permethrin, Beta-cypermethrin, Deltamethrin			*Dengue, Chagas*	Environmental management, housing construction
El Salvador	*Malaria*	Larvivorous fish, Temephos	*Malaria, Chagas, Leishmaniasis*	Deltamethrin	*Malaria*	Deltamethrin		
Eritrea	*Malaria*	Bti, BSph, Temephos	*Malaria*	Bendiocarb, Lambdacyhalothrin	*Malaria*	Deltamethrin		
India	*Malaria* *Other vector borne diseases*	Bti Larvivorous fish	*Malaria, VL*	Malathion, Synthetic pyrethroids: Deltamethrin, Cyfluthrin, Lambdacyhalothrin, Alphacypermethrin, Bifentrin	*Malaria*	LLINs	*Malaria*	IVM with larvivorous fish, environmental management
Madagascar			*Malaria*	Chlorpyriphos				
Maldives	*Dengue, Chikungunya*	Bti	*Dengue, Chikungunya*	Deltamethrin	*Dengue, Chikungunya*	Malathion		
Mauritius	*Malaria, Dengue, Chikungunya*	Bti, Temephos	*Malaria, Dengue, Chikungunya*	Alphacypermethrin			*Dengue, Chikungunya*	Fogging: Deltamethrin, Beta-cyfluthrin
Morocco	*Malaria*	Temephos	*Leishmaniasis*	Alphacypermethrin, Permethrin	*Leishmaniasis*	Deltamethrin		
Mozambique			*Malaria*	Deltamethrin				
Myanmar	*Dengue*	Larvivorous fish (Gambusi Affinis, Poecilia reticulate), Bti (H-14), BSph, Temephos	*Malaria*	Alphacypermethrin, Malathion	*Malaria*	Deltamethrin	*Dengue*	Deltamethrin, Malathion
Pakistan	*Dengue*	Bti	*Malaria,*	Deltamethrin,				

			Dengue, Leishmaniasis	Permethrin				
Peru			*Dengue, Malaria, Chagas, Leishmaniasis, Bartonelosis* *Pest*	Alphacypermethrin, Temephos, Cypermetrin, Deltamethrin Carbaryl				
Senegal			*Malaria*	Bendiocarb, Pirimiphos-methyl				
Singapore*	*Dengue, Chikungunya*	Triflumuron, Flufenoxuron, Pyriproxyfen, Bti, BSph, Temephos	*Dengue, Chikungunya*	Pyrethroids, Carbamates, Neonicotinoids				
South Africa	*Malaria*	Temephos	*Malaria*	Alphacypermethrin, Deltamethrin				
St. Lucia	*Dengue, Chikungunya, Malaria*	Bti, BSph, Poecilia reticulate					*Dengue, Chikungunya, Malaria*	Malathion
Zambia	*Malaria*	Pyriproxyfen GR	*Malaria*	Pirimiphos-methyl EC	*Malaria*	Permethrin, PBO, Deltamethrin, Alphacypermethrin		
Yemen	*Malaria*	Lambdacyhalothrin, Bendiocarb	*Malaria*	Deltamethrin	*Malaria* *Dengue and Hekoonjuana*	Alphacypermethrin Nets: Icon Sengenta and Rocket Mobidco		

Bti: Bacillus thuringiensis israelensis

Bs: Bacillus sphaericus

*: Singapore has reported use of 83 different combinations of insecticides/pesticides with various active ingredient formulations and %w/w. This table only includes the main classes that they use. For a detailed list contact the Secretariat.

Appendix III to the report: Cost-effectiveness of DDT and alternative insecticides for IRS in 2007

Cost comparison of the WHO recommended insecticides for IRS, excluding operational costs and freight and other external costs*

Insecticide	Dosage (g/m^2)	Approximate duration of residual effect on mud surfaces (months)	Number of spraying rounds per 6 months	Total dosage per 6 months (g/m^2)	Formulation	Approximate amount of formulated product required per house per 6 months (kg)	Approximate cost of formulated product[73] (US$ per kg)	Cost per house per 6 months (US$)	Cost ratio (DDT = 1)
DDT	2	6	1	2	75% WP	0.5	3.0	1.6	1.0
Deltamethrin	0.025	3	2	0.05	2.5% WP	0.4	4.0	1.6	1.0
Malathion	2	2	3	6	50% WP	2.4	3.4	8.2	5.1
Lambda-cyhalothrin	0.03	3	2	0.06	10% WP	0.1	72.0	8.6	5.4
Bendiocarb	0.4	2	3	1.2	80% WP	0.3	46.0	13.8	8.6
Fenitrothion	2	3	2	4	40% WP	2.0	7.4	14.8	9.3
Propoxur	2	3	2	4	80% WP	1.0	18.8	18.8	11.8

* DDT, dichlorodiphenyltrichloroethane; WP, water-dispensable powder.

From: Dichlorodiphenyltrichloroethane (DDT) for Indoor Residual Spraying in Africa: How Can It Be Used for Malaria Control?
Defining and Defeating the Intolerable Burden of Malaria III: Progress and Perspectives: Supplement to Volume 77(6) of *American Journal of Tropical Medicine and Hygiene.*
Breman JG, Alilio MS, White NJ, editors. Northbrook (IL): American Society of Tropical Medicine and Hygiene; 2007 Dec.

Appendix IV to the report: Costs, advantages and disadvantages of IRS-recommended chemical classes

Source: the President's Malaria Initiative Technical Guidance (2016). Available from: https://www.pmi.gov/docs/default-source/default-document-library/tools-curricula/pmi-technical-guidance-(march-2016).pdf

Table 1. Advantages and Disadvantages of IRS-Recommended Chemical Classes

Chemical class	Advantages	Disadvantages	Cost/sachet or sachet equivalent
Pyrethroids	• Low toxicity • Low cost • >7 months duration for longer-lasting formulations	Resistance	$2-3
Carbamates	• Medium toxicity Profile • Less resistance	• High cost • < 4 month duration	$11*
Organo-phosphates	• Less resistance • CS formulation >6 months duration	• Higher relative toxicity • Higher costs	$23.50 for CS formulation
Organochlorines (DDT)	• Low cost • >7 months duration	• Management costs • Resistance • Supply	$4 to $6.70

*The number of structures sprayed per bottle/sachet is approximately equivalent for all insecticides, however, the short residual life of current WHOPES-recommended carbamate formulations means that in areas of year-round transmission, two rounds of spraying are required, effectively doubling the price of carbamates.

Annex II

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