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Matters related to the implementation of the Convention: Measures to reduce or eliminate releases from intentional production and use: DDT

DDT expert group and its report on the assessment of scientific, technical, environmental and economic information on the production and use of DDT and its alternatives for disease vector control

Note by the Secretariat

1. As is mentioned in the note by the Secretariat on the evaluation of the continued need for DDT for disease vector control and promotion of alternatives to DDT (UNEP/POPS/COP.9/5), the DDT expert group assessed the information on production and use of DDT and prepared a report for the consideration of the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants at its ninth meeting.

2. Annex I to the present note contains the report of the DDT expert group on the assessment of the production and use of DDT and its alternatives for disease vector control. Annex II to the present note sets out the list of current members of the DDT expert group. The terms of office of the members nominated by Parties will expire on 1 September 2019.

3. The present note, including its annexes, has not been formally edited.

* UNEP/POPS/COP.9/1.

Annex I

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

14 January 2019

Geneva, Switzerland

Stockholm Convention on Persistent Organic Pollutants

Abbreviations

a.i.	Active ingredient
BNNICD	Blue Nile National Institute for Communicable Diseases (Sudan)
BMGF	Bill & Melinda Gates Foundation
BOVA	Building-out vector-borne diseases network
COP	Conference of the Parties
CS	Capsule suspension
DDT	Dichloro-diphenyl-trichloroethane
DDE	Dichloro-diphenyl-dichloroethylene
GEF	Global Environment Facility
GVCR	Global Vector Control Response
GPIRM	Global Plan for Insecticide Resistance Management
ICIPE	International Centre of Insect Physiology and Ecology (Kenya)
I2I	Innovation to Impact
IRS	Indoor residual spraying
IRM	Insecticide resistance management
ITN	Insecticide treated nets
IVCC	Innovative Vector Control Consortium
IVM	Integrated vector management
LSM	Larval source management
MRTC	Malaria Research and Training Center (Mali)
MT	Metric Tonne (1,000 kg)
PBO	Piperonyl butoxide
PMI	President's Malaria Initiative
POPs	Persistent Organic Pollutants
SC	Suspension concentrate
SDG	Sustainable Development Goals
SIT	Sterile Insect Technique
UN	United Nations
UNEP	United Nations Environment Programme
VCAG	Vector Control Advisory Group
VCRC	Vector Control Research Centre (India)
VHEMBE	Venda Health Examination of Mothers, Babies and their Environment study
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme
WHO-PQ	World Health Organization Prequalification Team
WG	Water dispersible granule
WP	Wettable powder

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I. Introduction

1. The Stockholm Convention has listed dichloro-diphenyl-trichloroethane (DDT) in its Annex B with production and use of DDT for disease vector control in accordance with Part II of the annex, as an acceptable purpose. Such production and use, as provided in paragraph 2 of part II of Annex B, is restricted to World Health Organization recommendations and guidelines on the use of DDT and when locally safe, effective and affordable alternatives are not available to the particular Party. There is no time limitation on the availability of DDT under the Convention as an acceptable purpose for disease vector control.

2. Paragraph 6 of part II of Annex B of the Stockholm Convention on Persistent Organic Pollutants 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 World Health Organization, evaluate the continued need for dichloro-diphenyl-trichloroethane (DDT) for disease vector control on the basis of available scientific, technical, environmental and economic information".

3. According to its decision SC-3/2, the COP has ordinary meetings every two years, where it undertakes the evaluation of the continued need for DDT for disease vector control, as provided in the revised process for DDT reporting, assessment and evaluation contained in Annex I to that decision.

4. The process adapted by the above decision SC-3/2 for the reporting on and assessment and evaluation of the continued need for DDT for disease vector control has established an expert group to analyse the data gathered with the following Terms of Reference:

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.

5. In its evaluation of the continued need for DDT for disease vector control at its eighth meeting held in 2017, the COP concluded that countries that rely on indoor residual spraying for disease vector control may need DDT for that purpose in specific settings where locally safe, effective, affordable and environmentally sound alternatives are still lacking for a sustainable transition away from DDT (decision SC-8/2).

6. By the same above 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 with the objective of accelerating the identification and development of locally appropriate, cost-effective and safe alternatives.

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 to discuss the preliminary report that forms the framework for the expert group to report to the COP for its consideration during its ninth 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 every three years provide information to the Secretariat and WHO on the amount used, the conditions of such use and its relevance to the Party's disease management strategy. Information on production and use of DDT was provided by Parties for the period 2015 to 2017 and made available to the DDT expert group in its assessment for the ninth meeting of the COP. Furthermore, additional information obtained from producers and key-users are summarized in this section of the report.

A. Sources and amounts of DDT production and use

10. The Secretariat to the Stockholm Convention distributed the adopted DDT questionnaire to all Parties to provide information on production and use of DDT for disease vector control covering the 2015-2017 reporting cycle. DDT questionnaire responses discussed in this report refer to the 2015-2017 period, unless otherwise indicated. Parties that have been listed in the DDT Register have the obligation to report on their production and use of DDT. A total of 18 Parties out of 182 Parties to the Stockholm Convention responded to the DDT questionnaire. Among these respondents were 7 Parties out of the 17 that registered for acceptable use or production of DDT, indicating a response rate of 7/17, or 41% (Table 1). The countries in the DDT Register that did not respond to the questionnaire for 2015-2017, even after a reminder had been sent by the Secretariat, are: Botswana, Eswatini, Ethiopia, Eritrea, Madagascar, Marshall Islands, Namibia, Uganda, Venezuela and Zambia (Table 1). Four out of the 7 responding Parties (India, Mozambique, South Africa and Zimbabwe) reported use of DDT for disease vector control over the reporting period (2015-2017), and 3 (Mauritius, Senegal and Yemen) reported no use of DDT for the same. Zimbabwe was listed in the DDT Register in January 2018 and Morocco withdrew from the DDT Registry in December 2015.

11. Zambia and Eswatini had reported use of DDT in the reporting cycle 2009-2011. Gambia had also reported DDT use in 2009-2011, but did not notify the Register of acceptable purposes and did not submit the DDT questionnaire for 2015-2017.

12. The eleven Parties that are not listed in the DDT Register but that responded to the DDT questionnaire are: Afghanistan, Argentina, Australia, Belarus, Kyrgyz Republic, Monaco, Netherlands, Norway, Russian Federation, Sao Tomé and Slovak Republic.

13. From the Democratic People's Republic of Korea, no recent data are available on production or use of DDT since the publication in 2008 of its National Implementation Plan, which indicated production and use of DDT.

Table 1. Reporting status of Parties that are listed in the DDT Register* regarding the use of DDT during reporting cycle 2015-2017 based on country responses to the DDT questionnaire distributed to all Parties by the Secretariat to the Stockholm Convention.

Reporting status	Parties
Reported use of DDT	India, South Africa, Mozambique, Zimbabwe
Reported no use of DDT	Mauritius, Senegal, Yemen

Did not report	Botswana, Eswatini, Ethiopia, Eritrea, Madagascar, Marshall Islands, Namibia, Uganda, Venezuela, Zambia

* The DDT register lists Parties that have notified the Secretariat, in accordance with paragraph 1 of Part II of Annex B, of their intention to produce and/or use DDT for the acceptable purposes stipulated in the Convention.

(a) Global production

14. According to the information provided by Parties in the DDT questionnaire, India was the only producer during the reporting period 2015-17. This is in line with the previous reporting period, when India was also the only known DDT producer. All DDT was produced by HIL (formerly known as Hindustan Insecticides Limited) at two plants: Rasayani, Maharashtra (88% of total production) and HIL, Udyogmandal, Kerala (12% of total production)1. India reported figures of production that pooled 50% WP and 75% WP formulations of DDT. In India, DDT was formulated as 50% WP for in-country use, and as 75% WP for export. An 8% fraction of the produced amount in 2015-17 was exported from India.

Table 2. Global production of DDT reported by producing countries, 2015-2017, in Metric Tonnes of active ingredient (MT a.i.).

Producing country	2015	2016	2017
India	3,135	2,388	2,004

15. The production figures of different formulations were converted into the active ingredient (a.i.)2 content. Hence, the production of a.i. was 3,135 Metric Tonnes (MT) 3 in 2015, 2388 MT in 2016 and 2004 MT in 2017 (Table 2). Compared to data from the previous two reporting cycles, when production was more or less constant, a declining pattern is evident in 2016 and 2017 (Figure 1). Compared to the production level of 2015, production was 24% lower in 2016, and 36% lower in 2017.

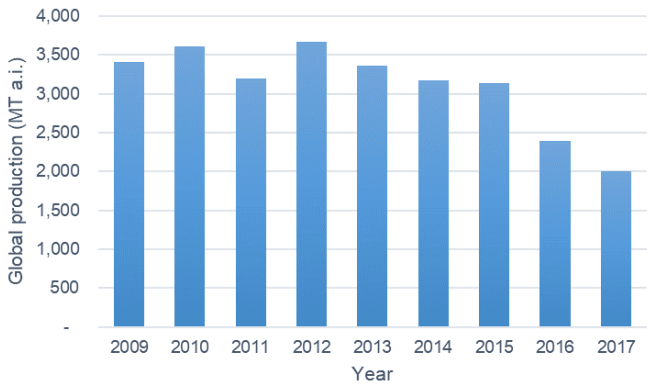

Figure 1. Trend in the global production of DDT, with India as only known producer ([1], this report).

(b) Export and import of DDT

16. According to the questionnaire data, India was the only country that exported DDT during the reporting period.

17. In India, DDT was exported directly from the production plant in Rasayani, Maharashtra. India reported export of 75% WP formulated product in quantities of 366 MT in 2015, 347 MT in 2016, and

[1] In India, production, export and use is reported by financial year (FY), but in the present report, figures are given by calendar year, not FY. Hence, 2015 refers to FY-2014/15, 2016 to FY-2015/16 and 2017 to FY-2016/17.

[2] Figures on a.i. were approximated on the assumption that 92% of a.i. was formulated as 50% WP and 8% of a.i. was formulated as 75% WP, based on the figures of use as 50% or 75% WP over the period 2015-17.

[3] 1 Metric Tonne = 1,000 kg

45 MT in 2017 (Table 3). India reported that export of DDT was to Mozambique, Myanmar, Namibia, South Africa and Zimbabwe. India presented only the total exported amounts; however, these amounts should have been specified per country of export. Myanmar withdrew from the DDT Register in February 2012 and, therefore, it remains unclear whether or for which purposes this country intends to the use DDT. South Africa reported no export of DDT; in previous years, South Africa reported exporting formulated DDT product to some other countries, mostly land-locked countries, in the African Region [2].

18. Two countries, South Africa and Zimbabwe, reported the import of DDT, as 75% WP formulation from HIL, India. South Africa imported 77.2 MT, and Zimbabwe 779.75 MT, of formulated product during the reporting period (Table 3). In addition, Australia reported that they imported minor samples of DDT (totalling less than 3 kg per year) for use as reference standards. The provided figures on export and import in Table 3 do not tally: the reported import from India (857 MT) is substantially larger than the reported export by India (758 MT). This gap could be due to reporting errors or due to differences in reporting periods between countries. Hence, the need for improved quality of data management and reporting at country level.

Table 3. Data on import and export of DDT (in Metric Tonnes) as reported in the DDT questionnaire.

			Amount of DDT 75% WP in MT				
Reported Export/import	From	To	2015	2016	2017	Total	Total in MT a.i.
Export	India	Zimbabwe, Mozambique, South Africa, Namibia, Myanmar	366.0	347.0	45.0	758.0	568.5
Import	India	South Africa	26.6	13.6	37.0	77.2	57.9
		Zimbabwe	133.0	321.9	324.9	779.8	584.9

(c) Stocks of DDT

19. Five countries have reported usable stocks of DDT (Table 4). Obsolete stocks of DDT are not solicited in the DDT questionnaire; Parties report on stockpiles and wastes in their national reports pursuant to Article 15 of the Convention [3].

20. India reported 538 MT of 50% WP formulated DDT product, stored in eight locations with 'storage capacity'. The Kyrgyz Republic reported 34.5 MT of DDT (formulation not given) stored at two sites 'inside 40t containers or under a roof'. Mauritius reported 5 MT of technical DDT, safely packed during a previous project to eliminate DDT from the island state. South Africa reported 21.4 MT of 75% WP DDT stored at two 'secure and locked store room with controlled access'. Zimbabwe reported 244.3 MT of 75% WW DDT distributed over five locations under storage conditions that are 'adequate for the quantities'.

Table 4. Stocks of DDT product (in Metric Tonnes) as reported by countries in the DDT questionnaire.

Country	Number of sites	Total amount MT	Formulation	Total MT a.i.
India	8	538.0	50% WP	269.0
Kyrgyz Republic	2	34.5	Not indicated	34.5
Mauritius	1	5.0	Technical grade	5.0
South Africa	2	21.4	75% WP	16.1
Zimbabwe	5	244.3	75%WP	183.2

(d) Repackaging and disposal of DDT stockpiles

21. According to a survey of UN Environment in 2016/17, recent efforts in several countries have led to the disposal of DDT, or to centralizing of DDT stocks awaiting disposal. PMI supported the collection and disposal of 115 Metric Tonnes of DDT from Ethiopia in 2015. The Directorate of Malaria Control in Pakistan centralized and stocked 400 Metric Tonnes of DDT, awaiting disposal [4]. Several GEF projects have supported the centralizing and disposal of DDT, with countries in Central Asia

being in the process of disposing their obsolete DDT stocks, and disposal efforts have been completed or are under way in Eritrea, Mozambique, Belize and Guatemala [4].

22. Despite these recent data on the disposal of DDT from various countries, UN Environment estimated that a total of 20,000 Metric Tonnes of DDT stockpiles might still exist worldwide. However, the actual amount is expected to be much higher due to limited sources of information and outdated data [4]. The Expert Group emphasized that countries with obsolete stocks of DDT should not decide to use those stocks again for any purpose.

B. Trends in DDT use for vector control

23. Four countries reported using DDT during the 2015-17 cycle: India, Mozambique, South Africa and Zimbabwe (Table 5).

24. As in previous reporting cycles, India was by far the largest global user of DDT. Nonetheless, India's average use in 2015-17 was 27% lower than the average use in the previous reporting period (2012-14). Moreover, within the period 2015-17, annual use in India also showed a declining trend, from 2,829 MT in 2015 to 1,900 MT in 2017. The main reasons for this decline are that India stopped using DDT for leishmaniasis control and partly shifted to pyrethroids for malaria control.

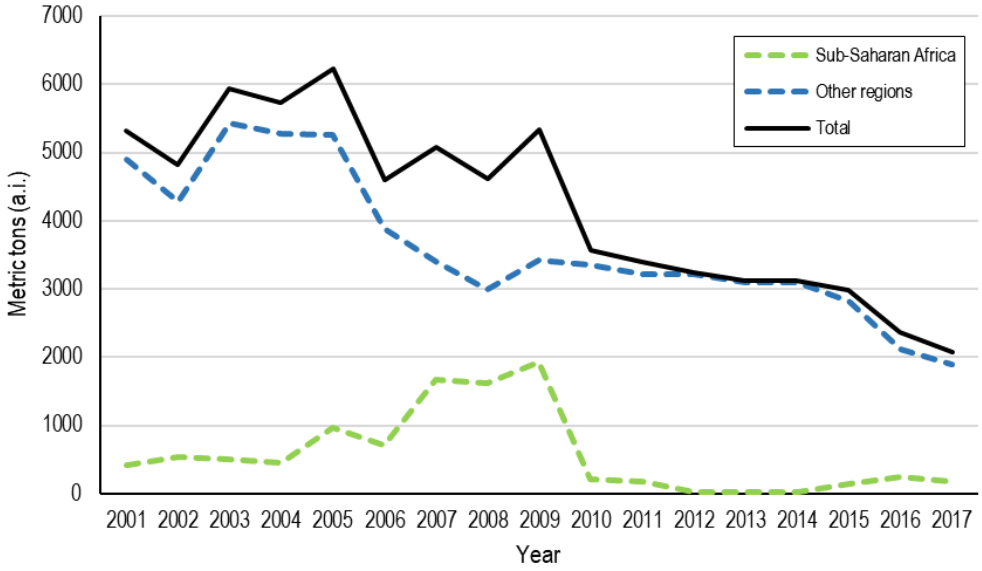

Figure 2. Historic trend in the reported use of DDT for disease vector control (after [3], supplemented with data from the latest DDT questionnaire).

25. Mozambique reported using 52 MT of DDT (75% WP product) in 2015, but reported zero use in 2016 and 2017. Previously, Mozambique stopped using DDT in 2012, but resumed DDT use in 2014 [3]. Hence, it is not clear whether the current pattern signifies a temporary stop or permanent termination of DDT use.

26. South Africa reported relatively small amounts of DDT use, with 19 MT in 2015, 14 MT in 2016 and 20 MT in 2017 (DDT 75% WP product). Zimbabwe, which did not report on DDT use in the previous reporting cycle, reported relatively large amounts of DDT use in 2015-17, with 133 MT in 2015, 322 MT in 2016, and 214 MT in 2017 (DDT 75% WP product). In total, these four countries used 7,421 MT of DDT active ingredient over the 3-year period 2015-17.

27. In addition to these four DDT-using countries, independent publications have indicated that three other countries, namely Botswana, Eswatini and Namibia, might have ongoing use of DDT for control or elimination of malaria [3, 5-7]. These countries did not respond to the DDT questionnaire. Furthermore, reports of DDT export from India to Myanmar indicate potential use. Myanmar withdrew from the DDT Register in February 2012.

28. Independent sources indicate that Zambia switched to other insecticides due to development of DDT resistance [8], and Zambia's DDT questionnaire response in 2012 stated that DDT was no longer used after 2010.

Table 5. Amount of DDT (in Metric Tonnes) used by countries, as reported in the DDT questionnaire.

	Amounts (MT)				Total product (MT)	Total a.i. (MT)
Country	2015	2016	2017	Formulation		
India	5,658.0	4,223.0	3,800.0	50% WP	13,681.0	6,840.5
Mozambique	51.7	-	-	75% WP	51.7	38.8
South Africa	18.6	13.9	20.2	75% WP	52.7	39.5
Zimbabwe	133.0	321.9	214.4	75% WP	669.3	502.0
Total	5,861.3	4,558.8	4,034.6		14,454.7	7,420.8

29. None of the countries that submitted the DDT questionnaire reported using DDT for purposes other than disease vector control.

30. In India, DDT was used for the control of malaria and visceral leishmaniasis. Six species of malaria vectors were targeted with DDT operations, covering 38%, 28% and 25% of the human population at risk in 2015, 2016 and 2017, respectively (Table 6). This declining trend in the at-risk population covered by DDT operations is consistent with the declining use of DDT for malaria control. In 2015, India targeted DDT against the sandfly Phlebotomus argentipes to protect 21% of the human population at risk of visceral leishmaniasis (compared to 78% as reported in 2014). In 2016, only 1% of the population at risk was protected with DDT, and in 2017, DDT was no longer applied against the leishmaniasis vector, shifting to a pyrethroid insecticide instead. This positive development is apparently in response to high levels of DDT resistance that have recently been detected in the sandfly vector populations [9, 10]. India's termination of DDT use for leishmaniasis vector control in 2017 was announced during COP-8.

31. Mozambique reported using DDT in 2015 to protect 5% of the human population at risk against malaria but, as stated above, did not use DDT in 2016 or 2017. South Africa used DDT to protect a constant proportion of 10% of the population at risk against malaria. Zimbabwe substantially increased its coverage of the human population at risk of malaria with DDT spray operations, from 26% in 2015, to 56% in 2016, and 53% in 2017; this indicates that malaria control in Zimbabwe relied, to a large extent, on the use of DDT.

Table 6. DDT used for disease control as reported by countries in the DDT questionnaire, indicated as the percentage of the total population at risk of malaria that was covered by IRS using DDT.

			% of at-risk population covered		
Country	Disease	Main vectors targeted as reported in the questionnaire*	2015	2016	2017
India	Malaria	*An. culicifacies, An. stephensi, An. fluviatilis, An. minimus, An. dirus, An.sundaicus*	38%	28%	25%
	Visceral leishmaniasis	*P. argentipes*	21%	1%	-
Mozambique	Malaria	*An. gambiae, An. funestus*	5%	-	-
South Africa	Malaria	*An. funestus*	10%	10%	10%
Zimbabwe	Malaria	*An. arabiensis, An. gambiae s.s., An. funestus s.s.*	26%	56%	53%

* Some of this information may not be accurate. For example, in India, it was noted by the Expert Group that *An. stephensi*, *An. dirus* and *An. sundaicus* are not targeted using DDT. In South Africa, additional vectors to the one indicated are also being targeted with DDT.

(a) Role of DDT in malaria elimination efforts

32. The Global Technical Strategy for Malaria 2016-2030, endorsed by the World Health Assembly in 2015, set goals for substantially lowering the global malaria burden [11]. A key milestone is the

elimination of malaria in at least 10 countries by 2020, with 21 countries (called E-2020 countries) identified as having the potential to reach this target[4].

33. A recent update on progress toward elimination shows that ten countries are on track, with less than 100 indigenous cases per year [12, 13]. In 2017, Algeria requested WHO certification of malaria-free status; in 2018, Paraguay and Uzbekistan were awarded WHO certification of elimination; and Argentina continues to work towards certification [14] (www.who.int). China has reduced indigenous cases of malaria from 5000 in 2010 to zero in 2017 [15], and terminated its use of DDT in 2003. Several other countries, including Bhutan, Costa Rica, Iran and Suriname have achieved remarkable reductions in indigenous cases, and have managed to do so without the use of DDT.

34. Among the E-2020 countries, three countries rely on the use of DDT in their elimination efforts: South Africa (based on the questionnaire response), and Botswana and Eswatini (indicated in separate publications [3], but not confirmed for the reporting period). The trends in indigenous malaria cases in these three countries show that they are off track of their elimination goals [12]. Data from southern Africa, especially South Africa and Zimbabwe, also shows that outdoor-biting and resting across several vector species, making them less amenable to control by IRS, is an important contributor to residual malaria transmission. The use of DDT in South Africa and neighbouring countries is considered necessary for the control and near-elimination of the malaria vector An. funestus, which in the recent past has proved to be highly resistant to the pyrethroids, resulting in control failure [16]; these countries use a strategy of spraying DDT and pyrethroids in a mosaic approach as a resistance management strategy, especially for the control of resistant An. funestus. New insecticide products may provide alternatives in this setting and are currently being evaluated in the field (see section IV D).

35. Countries that have managed to eliminate malaria require continued investment in the prevention of re-introduction of malaria so as to detect imported cases and avert local circulation of imported parasites. Mauritius, a country that eliminated malaria, has chosen to keep a small stock of DDT for emergency purposes.

36. None of the questionnaire responders refer to the use or potential use of DDT for control of vector-borne diseases other than malaria and leishmaniasis. Nevertheless, a potential shift in the use of DDT to other vector-borne diseases, including the Aedes vectors of arboviral diseases, should be monitored.

C. National and international policies, guidelines and regulatory measures on DDT use

37. National laws or regulations governing or restricting the purchase or use of DDT are reportedly in place in 14 out of 18 countries among those responding to the DDT questionnaire (including those countries that used DDT). Of the 14 countries with laws and regulations on DDT, all 14 indicated that these laws and regulations are fully enforced.5

38. For countries producing or using DDT, India and Zimbabwe reported that quality control on the product was done in the country, while Mozambique and South Africa indicated that this was not done in-country.

39. According to a retrospective analysis in the context of an effectiveness evaluation undertaken by the Stockholm Convention, the majority of Parties of the Stockholm Convention have legal measures in place that prohibit, or restrict, the production, import, export and use of DDT [3, 17]. Roughly half of the countries with legal measures in place established or amended them after 2001, the year of adoption of the Stockholm Convention.

40. In 2016, the Secretariat of the Stockholm Convention published a toolkit for the sound management of DDT for disease vector control, to provide a one-stop shop for information and resources regarding the lifecycle management of DDT - and other vector control insecticides [18]. The purpose of the toolkit was to assist those countries that still need DDT for disease vector control with their

[4] E-2020 countries: Algeria, Botswana, Cape Verde, Comoros, Eswatini, South Africa; Belize, Costa Rica, Ecuador, El Salvador, Mexico, Paraguay, Suriname; Islamic Republic of Iran, Saudi Arabia; South-East Asia: Bhutan, Nepal, Timor-Leste; China, Malaysia, Republic of Korea.

[5] These countries are: Argentina, Australia, Belarus, India, Kyrgyz Republic, Mauritius, Mozambique, the Netherlands, Norway, Russian Federation, Senegal, South Africa, Yemen and Zimbabwe.

legislation, regulations, registration, quality control, capacity and risk prevention in relation to DDT. The WHO's operational manual for indoor residual spraying was updated in 2015 [19].

41. The position statement by WHO on the use of DDT in malaria vector control (2011) highlights WHO's commitment to achieve sustainable malaria control in the context of the Stockholm Convention [20]. This statement provides guidance on the safe and effective use of DDT for malaria vector control; even though the statement is applied to disease vector control in the general sense, specific guidance on the use of DDT against vectors of diseases other than malaria is currently lacking.

(a) Safety issues related to DDT use

42. Assessment of the risks posed by the use of insecticides to public health is in most countries the responsibility of the Ministry of Health, according to the responses to the DDT questionnaire. In a few countries, an agency other than the health ministry was responsible for the health risks of insecticides, which highlights the importance in those countries for coordination on health risks with the health authorities.

43. Three out of 14 responding countries (Belarus, India and Mauritius) reported having a system in place to monitor exposure to DDT, one of which (India) is using DDT; however, it remains unknown what such a system entails. However, the 3 other DDT-using countries (Mozambique, South Africa and Zimbabwe) reported not having such a system in place. Seven out of 16 countries reported having developed a programme to raise awareness among communities and households on safety issues relating to DDT use in disease vector control; these countries included the 4 DDT-using countries.

44. A number of studies have recently been conducted on the exposure and health effects of DDT in those human populations covered by IRS operations that utilize DDT in the context of the Venda Health Examination of Mothers, Babies and their Environment (VHEMBE) study. The VHEMBE study is a cohort study among children and mothers in an area in South Africa. The results show i.a. that Serum p,p′-DDT/DDE levels in children exceeded their mothers' during the first two years of life [21], and may increase childhood infections (e.g. respiratory tract infections) in the sample of mostly prematurely-weaned infants [22], but DDT and DDE were not associated with significantly lower scores for a child's neurodevelopment [23].

45. Studies on the human health effects of DDT and its metabolites have been extensively reviewed in 2009 [24] and 2011 [25], but more recent studies have not been subjected to review. The 2011-review, which had been commissioned by WHO specifically in relation to DDT use for malaria control, concluded that evidence does not point to concern about levels of exposure for any of the health end-points that were assessed, in terms of relevant exposure scenarios for the general population in countries using IRS. For households where IRS was undertaken, the levels of DDT and DDE serum were generally below potential levels of concern for populations with the exception of some areas, where the exposures in treated residences were higher than potential levels of concern. Of particular concern are women of childbearing age who live in DDT IRS-treated dwellings and who may therefore transfer DDT and DDE to their foetus during pregnancy and/or to their infant via lactation [25]. Based on the WHO assessment, it has been recommended that efforts should be made to implement best practices to protect residents in DDT-treated households, as well as spray workers, from exposures arising from IRS [25].

III. Implementation of vector control products, methods and strategies

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

46. Recent progress in reducing global malaria incidence has been achieved predominantly through vector control, particularly by insecticide-treated nets (ITNs) and indoor residual spraying (IRS) [26]. The implementation of vector control is critically dependent on national capacity, guidelines and policies. WHO is in the process of publishing a comprehensive malaria vector control guidelines document, using guideline development methods as outlined by the Guidelines Review Committee.

47. According to DDT questionnaire responses, training facilities on insecticide use for disease vector control are operational, with training being conducted, in 11 out of 15 reporting countries; this includes the 4 countries that reported using DDT. Furthermore, 9 out of 15 responding countries reported that formal mechanisms exist for inter-sectoral collaboration in disease vector control, and 8 countries indicated that inter-sectoral collaboration has been implemented. A recent systematic review showed the importance of inter-sectoral collaboration to reduce vector-borne diseases [27]. A national entomology laboratory was reportedly being used for vector insecticide susceptibility testing in 9 out of

15 countries, and in 7 countries (which include the 4 DDT-using countries) this laboratory was internationally recognized. These data suggest that basic capacities and mechanisms were in place in DDT-using countries, while the countries that reported lacking these elements were those without endemic malaria.

48. During 2016 and 2017 WHO organized training workshops on the use of hand compression sprayers for IRS for control of visceral Leishmaniasis (in China), and malaria and visceral Leishmaniasis (in India).

49. Malaria control programmes in endemic countries have largely depended on external investment for vector control, with provision of supplies such as insecticide-treated nets, other insecticide products and spray equipment. But the recent expansion of vector control operations has not been accompanied by corresponding investment in local human resources, showing critical gaps in capacity for vector control in endemic countries [28]. Entomological and epidemiological surveillance are vital to the evidence-based selection and targeting of vector control interventions. Lack of technical capacity for vector surveillance and control will result in insecticide resistance development going unnoticed, or vector control operations not being adapted to changes in vector population composition or malaria incidence. The SADC Elimination 8 initiative has recently undertaken special efforts to enhance human capacity for vector surveillance through a fellowship programme.

50. According to WHO [11, 29], the need for evidence-based and surveillance-based vector control is becoming increasingly clear. With declining incidence of malaria in various countries, remaining areas of high transmission must be identified and targeted with appropriate interventions. There has also been a shift in several countries, particularly in sub-Saharan Africa, towards the use of newly available but more costly insecticides for IRS, necessitating a reduction in the coverage of operations and hence emphasizing the need for precise targeting; however, in Southern Africa, there are indications of expanding IRS operations. Changes in vector population dynamics, in response to large-scale use of insecticidal interventions and other contemporary trends, require that programmes timely detect insecticide resistance, determine vector species composition and assess the extent of outdoor transmission. Moreover, supplementary methods of vector control, such as larval source management, may be appropriate in specific settings, but the capacity for effective planning, application and monitoring of larval source management is still lacking in most malaria control programmes [11].

51. Consequently, to reach the milestones and targets set in the Global Technical Strategy for malaria (2016-2030) [11], the capacity and adaptive ability for vector control and vector surveillance is in need of strengthening in most malaria endemic countries, not just within research institutions and universities, but especially within the operational programmes [28]. Malaria control programmes also need the innovative ability to take on board new products and tools as these become locally available. Moreover, advocacy for vector control and vector surveillance should promote the career opportunities for vector biologists and public health entomologists in order to attract new human resources into vector control [29].

B. Insecticide resistance management

52. The vector control interventions that have reduced the global burden of malaria have relied to a large extent on insecticidal action [26], which inevitably exerts selective pressure upon vector populations that usually leads to the development of resistance. Insecticide-treated nets (ITNs) and IRS remain the only core interventions for malaria vector control, with larval source management as supplementary intervention [30]. Monitoring of insecticide resistance is of central importance to malaria vector control programmes in order to timely inform intervention policies. Countries should manage insecticide resistance by adopting strategies that mitigate the development of resistance within vector populations, or by modifying interventions in response to detected resistance , while coordinating with the agricultural sector on the management of resistance [31].

53. In general, the scale and intensity of insecticide resistance in malaria vectors are increasing [32-34]. Nevertheless, a recent WHO-coordinated cohort study in 5 countries established that ITNs, irrespective of insecticide resistance, continue to provide (partial) protection against the risk of infection [35].

54. According to the responses to the DDT questionnaire, 8 countries reported on the levels of resistance to DDT detected in anopheline species, showing variable levels of DDT resistance occurring across countries (Table 7). Data from Mozambique indicate DDT resistance in populations of An. gambiae s.l. in 2017, after full susceptibility was reported in the previous DDT questionnaire (2012-

2014). Mozambique stopped using DDT in 2016. In South Africa, the selection of DDT has been to prevent re-establishment of An. funestus from outside the country's borders, and South Africa coordinated with programmes in neighbouring countries (e.g. Mozambique, Zimbabwe) regarding the status of DDT susceptibility of this particular vector species. Resistance to DDT has been detected in the major malaria vector An. arabiensis in South Africa, but is very low-level and is not considered to be operationally significant currently.

55. Particularly high DDT resistance (with only 38% mortality level) was reported in 2017 for the malaria vector An. culicifacies from Jharkhand, India.

56. Seven out of 15 responding countries confirmed that there was a surveillance mechanism in place for monitoring resistance to DDT (and other insecticides). These countries all used the standard WHO insecticide susceptibility test, but Senegal used the WHO test together with the CDC bottle test. WHO's test procedures for insecticide resistance monitoring in malaria vectors were revised in 2016, and updated in 2018, to include additional tests for resistance intensity and thus to improve the value for decision making on vector control [36]. WHO is currently conducting a multi-centre study to validate discriminating concentrations for certain old compounds and establish discriminating concentrations for new compounds against malaria vectors and Aedes spp. Results from this study will be available in late 2019. A similar study for visceral leishmaniasis vectors is planned for 2019.

57. Countries also reported on resistance observed to other insecticides used in disease vector control, mostly in relation to malaria vectors (Table 8). Seven of the responding countries reported resistance to pyrethroids, 3 countries to carbamates, and 3 countries to organophosphates. Several of the responding countries with endemic malaria reported resistance to more than one class of insecticides, suggesting a challenge for managing insecticide resistance. Zimbabwe reported resistance (in unspecified vector species) to pyrethroids, carbamates as well as organophosphates, but out of three malaria vector species, two were reported to be susceptible to DDT (Table 7).

Table 7. Available information on vector susceptibility to DDT by country from the DDT questionnaire.

Country	Vector species	% mortality	Year	Location
India	*An. culicifacies*	38%	2017	Jharkhand
Kyrgyz Republic	*Anophelines spp.*	100%	2002	Unspecified
Mauritius	*An. arabiensis*	84-100%	2011	Wolmar, Bon Accueil, Notre Dame, Petit Raffray, Fond du Sac
	Aedes albopictus	93-100%	2011	Notre Dame, Cite La Cure, Pamplemousses, La Tapie
Mozambique	*An. gambiae s.l.*	89%	2017	Cuamba District
	An. gambiae s.l.	74%	2017	Nampula City
	An. gambiae s.l.	73%	2017	Monapo District
Senegal	*An. gambiae s.l.*	83%	2016	Velingara
	An. gambiae s.l.	53%	2016	Fatick
	An. gambiae s.l.	36%	2016	Mbour
	An. gambiae s.l.	56%	2016	Niakhar
South Africa	*An. arabiensis*	84%	2015	Mamfene, Northern KwaZulu-Natal Province
	An. pretoriensis	100%	2018	Hlablsa, Northern KwaZulu-Natal Province
Yemen	*An. arabiensis*	85%	2015	Kafl Shamer, Hajjah Governorate
	An. arabiensis	94%	2016	Wusab Asafel, Dhamar Governorate
Zimbabwe	*An. gambiae s.l.*	100%	2017	Chilonga, Chiredzi District
	An. funestus s.s.	100%	2014	Honde Valley, Mutasa
	An. arabiensis	91%	2015	Makakavhule, Beit Bridge

58. Venezuela, through their representation in the DDT Expert Group, reported the following information on vector susceptibility to DDT in 2017: An. darlingi 70% mortality, An. nuneztovari s.l. 90% mortality, and An. albitarsis s.l. 50% mortality.

59. Phlebotomus argentipes as the sole vector of visceral leishmaniasis in India has in the past been controlled through IRS using DDT. Recent studies, however, have demonstrated high DDT resistance,

but susceptibility to pyrethroids, in the sandfly vector [9, 10, 37]. From 2016, India shifted to using a pyrethroid, alpha-cypermethrin WP, in IRS for the elimination of visceral leishmaniasis.

Table 8. Insecticide resistance in *Anopheles* vectors to insecticide classes other than organochlorines (i.e. DDT) as reported by countries in the DDT questionnaire. 'R' indicates 'resistant', 'S' 'susceptible' and '-' not reported.

Country	Pyrethroids	Carbamates	Organo-phosphates	Vector species
India	R		R	*An. culicifacies, An. stephensi*
Kyrgyz Republic	S	S	S	Not specified
Mauritius	R	S	S	*An. arabiensis, Ae. albopictus, Cx. quinquefasciatus*
Mozambique	R	R	S	*An. gambiae s.l.* (PY, CA), *An. funestus s.l* (PY)
Sao Tomé	-	-	R	*An. gambiae*
Senegal	R	-	S	*An. gambiae s.l.*
Slovak Republic	S	S	S	Not specified
South Africa	R	R	S	*An. arabiensis*
Yemen	R	S	S	*An. arabiensis*
Zimbabwe	R	R	R	Not specified

60. Under the WHO Global plan for insecticide resistance management (GPIRM) in malaria vectors , a database has been established to keep track of the geographic distribution of insecticide resistance in malaria vectors (http://apps.who.int/malaria/maps/threats/). At the global level, DDT resistance in malaria vectors was frequently detected in all regions linked to recent or historical use of this chemical; DDT resistance may also confer cross-resistance to pyrethroids. Insecticide resistance can be managed using a range of strategies and technologies.

61. Table 9 shows the number of susceptibility tests on DDT conducted in countries with confirmed or probable use of DDT. The data indicate that large numbers of tests were conducted in Mozambique and India, followed by Zimbabwe and Namibia. Fewer tests results are available from Botswana, South Africa and Eswatini, and none from Gambia. Test results point to the presence of possible DDT resistance in all DDT-using countries, except in Namibia (based on 41 tests, which may not be very recent) and Eswatini (based on only 2 tests). Confirmed DDT resistance has been frequently reported from India, and less frequently from Mozambique and Zimbabwe. Details on vector species, test dates and mortality levels are available through the database.

Table 9. Number of tests of *Anopheles* malaria vectors using discriminating concentration bioassays of DDT taken between 2010-2014 or 2010-2017 (depending on the country); 'susceptible' indicates ≥98%, 'possible' 90-97%, and 'confirmed' <90% mortality in bioassay tests (Source: http://apps.who.int/malaria/maps/threats/).

Country	Susceptible	Possible	Confirmed	Total
Botswana[a]	12	2	0	14
Gambia[a,b]	0	0	0	0
Eswatini	2	0	0	2
India	16	2	83	101
Mozambique	114	10	7	131
Namibia[a]	41	0	0	41
South Africa	1	2	0	3
Zimbabwe	51	5	4	60

[a] Did not respond to the DDT questionnaire, but recent DDT use is implicated by independent publications

[b] No data available, but tests along the borders with Senegal indicate confirmed resistance

62. Resistance to pyrethroids was common and widespread in the main malaria vectors in all regions with malaria transmission in 2016 [38]. Available data show an increasing trend in pyrethroid resistance from 2010-2016 [38]. Pyrethroids are used for IRS but have until recently been the only insecticide class recommended for impregnation of bed nets.

63. In most malaria endemic countries, malaria vectors have demonstrated resistance to more than one class of insecticides; in 18 countries, resistance to all four available classes of insecticides has been reported, which presents a challenge for resistance management. In Africa, resistance to pyrethroids was present throughout most of the Region in 2016. There is evidence of resistance to carbamates in many African countries, particularly in West Africa, but a lower frequency of resistance was found to organophosphates.

64. There have been far fewer bioassays conducted on members of the An. funestus species group than for the An. gambiae species group in Africa, primarily because An. funestus s.l. are more difficult to collect and rear. Despite this, members of the An. funestus species group have exhibited an increase in the level of resistance to DDT and pyrethroids over the period 2010-2016, suggesting that this group presents a growing challenge to malaria vector control [38].

65. Data on resistance mechanisms show that metabolic detoxification systems are present in An. gambiae s.l. and An. funestus s.l. throughout Africa. Target site mutations are also widespread in Africa and Asia [38].

66. Insecticide resistance management is promoted by WHO as a strategy to delay the development of resistance, thus extending the useful life of available insecticide products. Strategies for resistance management include using insecticides with different modes of action in rotations or mixtures, or supplementing insecticides with non-insecticidal methods [39]. In practice, resistance management strategies may be limited by the availability and cost of alternative products; some of the alternative IRS products are substantially more costly than DDT or pyrethroids. WHO's Global Malaria Programme has supported countries in monitoring and managing insecticide resistance, and has developed a framework to assist countries in preparation of a national plan [40].

C. Implementation of integrated vector management

67. Integrated vector management (IVM) is promoted as the accepted approach to make vector control more effective, efficient and sustainable [41, 42]. An IVM strategy has been endorsed at the national level, by 7 out of 14 countries that responded to the DDT questionnaire, and this strategy is implemented throughout the country in 6 countries. These countries include 3 DDT-using countries; Zimbabwe reported that no IVM strategy is in place. Hence, it appears that IVM has been adopted as a strategy for disease vector control, at least in part, by many of the countries, but it remains unclear as to what extent these strategies incorporate the key elements of IVM.

68. One of the key elements of IVM is an integrated approach, implying the integration of vector control methods (chemical, non-chemical) and addressing several diseases, where appropriate [42]. Arguably, this key element has not fully materialized in malaria vector control, because only two

scalable vector control interventions have been identified that have a proven epidemiological impact on disease - insecticide-treated nets and IRS [30]. In 2013, larval source management (LSM) was added to the toolbox of interventions for malaria vector control, when WHO recommended LSM as a supplementary intervention for malaria control in specific settings where larval habitats are relatively 'few, fixed and findable' when used in conjunction with ITNs or IRS [43].

69. The toolbox of malaria vector control interventions needs urgent expansion, because in many countries and areas with high coverage of insecticide-treated nets or IRS, parasite transmission is not being completely interrupted, although they do reduce transmission substantially. This residual transmission is at least partly caused by malaria vectors that feed and/or rest outdoors. Other contributing factors may be partial effectiveness of ITNs and IRS due to insecticide resistance, or inadequate community compliance or quality or coverage of operations. A supplementary intervention such as LSM attacks vector species or subspecies irrespective of whether their feeding or resting takes place indoors or outdoors.

70. A report focussing on African countries suggests that most countries are still grappling with the challenges of implementing IVM, with limited capacity for entomological surveillance, minimal intersectoral collaboration on IVM, and minimal data available on the outcomes of IVM [44]. Most African countries have completed vector control needs assessment and action plan for IVM, and are applying IVM mainly to malaria control, without incorporating a multi-disease approach. Few countries have shown constructive operational developments along the key elements of IVM [45-47].

71. WHO has facilitated the development of a toolkit for IVM in the sub-Saharan Region [48]. This toolkit needs to be supported by appropriate training tools. Similar toolkits are planned or under development for use in the American, the South-East Asian Region and the Eastern Mediterranean Region of WHO.

72. WHO reported in 2017 that uptake of IVM at country level has been poor because the political buy-in required for reorientation and harmonization of programmes and approaches has been inadequate, which has been attributed to limited human capacity and a tradition of disease-specific programmes and structures [29, 49]. To advance the cause of IVM, WHO launched the Global Vector Control Response (GVCR) (2017–2030), which has been adopted by the World Health Assembly as resolution WHA 70.16. The GVCR builds on the concept of IVM while re-emphasizing the key elements through four pillars of action: Strengthen inter- and intra-sectoral action and collaboration; engage and mobilize communities; enhance vector surveillance; and scale up and integrate tools and approaches. These pillars of action, in turn, depend on enhanced vector control capacity, and increased research and innovation. The GVCR defined milestones and targets for the reduction in mortality, case incidence and epidemics of vector-borne diseases. A primary activity proposed in the GVCR is for countries to conduct or update their vector control needs assessment. WHO has published a framework for a national vector control needs assessment to help countries assess their baseline situation and track progress in accordance with the milestones and targets of the GVCR [50].

73. Despite these developments in vector control, the global response against malaria has stalled [5, 12]. The global malaria incidence rate dropped significantly post 2010, but the rate of decline then slowed down and even reversed in some regions post 2014. Mortality rates have followed a similar pattern [5]. The 10 highest burden countries in Africa suffered an estimated additional 3.5 million malaria cases in 2017 compared to 2016 [12]. The main culprit appears to be the funding gap, with US$ 2.7 billion invested in 2016, whereas an estimated US$ 6.5 billion is required annually to meet malaria control targets [11]. WHO forewarns that the current level of investment (both domestic and international) will bring near-certain increases in malaria cases and deaths [5]. To reverse these trends, a new '10+1' initiative has been launched to accelerate reduction of malaria deaths and cases in 11 countries with the highest malaria burden (www.who.int/malaria/news/2018/letter-partners-june/en/).

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

A. Cost-effectiveness of alternatives to DDT

74. Cost-effectiveness analyses of malaria vector control interventions are few, because they require a combination of cost analysis (costs can be highly variable) and data showing the epidemiological impact of the interventions [51]. In general, malaria interventions are considered to be highly cost-effective, with high returns on investment in public health [11]. Comparative cost effectiveness analysis

can assist countries in improving their efficiency of operations. A systematic review concluded that the median financial cost of protecting one person for one year was US$2.20 for insecticide-treated nets and US$6.70 for IRS [52]; the cost of IRS ranged from US$2.22-US$12.85. The cost of IRS is largely dependent on the selected insecticide product, which can range from US$1.80 for pyrethroids to US$23.50 for pirimiphos-methyl, per 250 m² spray surface [53]. Unpublished data from South Africa suggest that current costs of IRS are similar when using DDT or pyrethroids. Cost-effectiveness studies are lacking that compare the contemporary costs and the effective period of IRS (including cost of clean-up and disposal) for DDT with other available insecticide products; and the cost of IRS compared with other vector control tools such as ITNs. A cost analysis of LSM showed that this intervention compared favourably with those for IRS and ITNs, especially in areas where mosquito larval habitats are accessible and well defined [54]. A pragmatic approach would therefore be for programmes to do a comparative cost analysis of chosen products or interventions, assuming equal epidemiological impact; nevertheless, WHO emphasizes that demonstration of the epidemiological impact of vector control interventions is a key aspect in the new evaluation process for vector control products [55].

B. Availability and accessibility of alternative insecticides to DDT for indoor residual spraying

75. According to the questionnaire responses, IRS using insecticides other than DDT was used in most responding countries, with pyrethroids used against Chagas disease in Argentina, against visceral leishmaniasis in India, and with pyrethroids and/or organophosphates against malaria in India, Mauritius, Mozambique, Senegal, South Africa, Yemen and Zimbabwe. The use of some products was discontinued by responding countries. Kyrgyz Republic indicated IRS was discontinued in 2012 after elimination of malaria. South Africa indicated that alpha-cypermethrin and carbamates were no longer used for malaria control because of unacceptability to users and because of localized insecticide resistance. Zimbabwe indicated that unspecified carbamates were no longer used because of their short residual activity.

76. WHO has transformed its regulatory approval system for vector control products, and previous WHOPES recommendations have been converted to listings of prequalification. Hence, the mechanism of approval of vector control products is now harmonized with that of other health products. In 2017, the WHO Prequalification Team established a new group of scientific experts to formulate the mandate of the prequalification process and to guide assessments for prequalification of vector control products. The prequalified lists of vector control products have been published and are regularly updated [56].

77. Among the prequalified products recommended by WHO are 23 insecticide products for IRS, which include pyrethroids, organophosphates, carbamates and a neonicotinoid ; the residual periods of these products under field conditions have been published by WHO. Each these chemicals present a specific risk of adverse effects to human health and the environment. The list includes reformulated products of existing molecules with longer residual activity than earlier formulations. For example, K-Othrine Polyzone is a new formulation of the pyrethroid deltamethrin. As a WHO policy, DDT is recommended for use in malaria control, but no formulation of DDT has been prequalified because the sole producer of DDT (HIL) has not provided the required dossiers on ecological and toxicological effects and risk assessment data. Irrespective of non-availability of WHO-PQ prequalified DDT formulations, countries are free to produce DDT under their control and/or regulation of its use.

78. Two new IRS products (which are relatively costly) have recently become available: Actellic® 300CS (pirimiphos-methyl), that was used to protect 52 million people in Africa in 2017 , and SumiShield® 50WG, using the neonicotinoid Clothianidin, that was listed in 2017 [57]. The latter represents a new class of insecticide for vector control and is a welcome addition to the limited arsenal of insecticides available for the management of resistance. WHO has also evaluated Chlorfenapyr 240 SC, a halogenated pyrrole, for use in IRS, but the slow acting chemical requires different testing procedures and could not be approved through the prequalification process ; WHO reported that the manufacturer re-submitted the same product for evaluation under the new process for evaluation of its public health value; however, the availability of funds for such large-scale trials (needed in the process for bringing new products to market) remains a challenge.

79. There are several considerations for selecting a product for IRS among locally available and registered products, namely: mode of action (for resistance management), cost, effectiveness, residual activity period (in relation to the duration of transmission season), toxicity to non-target organisms, and acceptability by residents.

80. Another important consideration applies to the use of pyrethroids for IRS. Pyrethroids are the dominant and most affordable insecticide class used in vector control , and the heavy reliance on pyrethroids has caused widespread resistance [34, 58]. Pyrethroids have been the only insecticide class currently covered by a WHO recommendation for use in ITNs , and it is of vital importance that the effective use of pyrethroids in nets is preserved for as long as possible. Therefore, WHO recommends that pyrethroids should not be used for IRS in areas with high coverage of treated nets [31, 39]. In addition, coordination with the agricultural sector regarding the use of pyrethroids should be considered.

81. According to the responses to the DDT questionnaire, a resistance management strategy has reportedly been implemented in most countries that responded using alternative insecticides to DDT, namely: Argentina, India, Mauritius, Mozambique, Senegal, South Africa, Yemen and Zimbabwe.

C. Availability and accessibility of non-IRS chemical control methods

82. Insecticide-treated nets are the primary malaria vector control method globally (WMR). According to the information provided by the Parties that have responded to the DDT questionnaire, in 2015-2017, insecticide-treated nets were reportedly used in India, Mauritius, Mozambique, Senegal, Yemen and Zimbabwe, but not in South Africa.

83. Previous WHOPES recommendations on ITN products have been converted to listings of prequalification, in line with the restructuring of regulatory approval of vector control products at WHO [56]. Currently, 18 ITN products are listed among the prequalified vector control products: 6 alpha-cypermethrin products, 1 alpha-cypermethrin+chlorfenapyr product, 1 alpha-cypermethrin+PBO (i.e. synergist piperonyl butoxide) product, 5 deltamethrin products, 3 deltamethrin+PBO products, 1 permethrin product, and 1 permethrin+PBO product.

84. A number of ITN products have become available that contain the synergist piperonyl butoxide (PBO) which enhances the toxicity of the pyrethroid insecticides against resistant vectors. The PBO acts by inhibiting monooxygenase-based resistance mechanisms, that otherwise act to detoxify pyrethroids, thus completely or partially restoring susceptibility to pyrethroids, depending on the presence of other resistance mechanisms [59, 60]. In areas with pyrethroid resistance, the pyrethroid-PBO ITNs have recently demonstrated an added public health value compared to pyrethroid-only ITNs [59]. Based on these findings, pyrethroid-PBO ITNs have been given interim endorsement as a new WHO class of vector control products [59]. Pyrethroid-PBO ITNs prequalified by WHO are conditionally recommended for deployment instead of pyrethroid-only ITNs where the principal malaria vector(s) exhibit pyrethroid resistance that is: a) confirmed, b) of intermediate level[6], and c) conferred (at least in part) by a monooxygenase-based resistance mechanism, as determined by standard procedures [59].

85. A new dual-active ingredient ITN under evaluation for public health is Interceptor® G2, containing a combination of a pyrethroid insecticide and a non-pyrethroid active ingredient, chlorfenapyr [61, 62]. This is an important development in ITN technology as it is the first ITN using non-pyrethroids as active ingredient. Chlorfenapyr is a repurposed pyrrole insecticide from the agricultural sector, with a unique mode of action that has been shown to be effective against pyrethroid resistant mosquitoes [56, 63]. Two trials will be evaluating the public health impact of Interceptor® G2 in areas of pyrethroid resistance.

86. A further bi-treated ITN class consists of nets that contain pyrethroid and the insect growth regulator pyriproxyfen. Pyriproxyfen is effective against pyrethroid resistant vectors. It acts by reducing the fecundity of female mosquitoes that have survived exposure to the pyrethroid but have come into contact with pyriproxyfen [64]. There are several products using this technology. One of these, Royal Guard® LN is currently under WHO evaluation. Two cluster randomized trials are evaluating the efficacy of Royal Guard® LN in areas with highly pyrethroid resistant vectors. A trial in an area of intense pyrethroid resistance in Burkina Faso showed that children sleeping under a pyriproxyfen net had 12% lower incidence of malaria compared to those using standard pyrethroid nets [65].

87. Regarding other methods used for malaria vector control, the responses to the DDT questionnaire include the use of chemical larviciding in Mauritius and South Africa. India indicated that fenthion is no longer in use as a larvicide (since 2008) because of its adverse health effects.

88. Twenty larvicide products have been listed among the prequalified products recommended by WHO [56]. These products include 4 organophosphates, 4 chitin synthesis inhibitors, 3 juvenile

[6] Defined as 10–80% mosquito mortality in standard WHO susceptibility tests or CDC bottle bioassays.

hormone mimics, 6 spinosads, and 3 bacterial insecticide products. Moreover, WHO reported on the evaluation process for several new larvicide products [66-68]. Insecticidal paint products have also been used in some settings [69], but no such product has been formally tested or recommended by WHO.

D. Availability and accessibility of non-chemical control methods

89. According to the DDT questionnaire responses, 3 countries reported using the microbial larvicide Bacillus thuringiensis israelensis (Bti) for malaria control (India, Mauritius, Zimbabwe). India reported the use of environmental management for malaria control. The scale of use of these non-chemical methods of larval source management (LSM) remains unknown.

90. LSM, which includes habitat modification, habitat manipulation, larviciding and biological control, is recognized by WHO as a supplementary intervention to ITN and IRS for malaria control. In practice, LSM often involves the draining or filling of breeding sites, supplemented with larviciding of remaining anopheline habitats. Three bacterial larvicidal products have been prequalified by WHO, but these products are not readily available in many malaria endemic countries, either because they have not been registered, or because their use commonly depends on the importation of product from abroad. Conversely, the draining and filling of larval breeding habitats does not depend on products or equipment, and could be implemented locally by community members [70]. In specific settings there may be options for controlling vector breeding through engineering and water management [71, 72].

91. In the past, LSM has played an important role in malaria control and in the elimination of malaria vectors [73, 74]. In more recent studies, LSM used as a primary intervention reduced the prevalence of malaria in some cases but not in others [75]. LSM is not currently being promoted to the same extent as ITN and IRS because evidence on its contribution to malaria control is still considered insufficient, particularly in rural settings. Nevertheless, LSM is seen as a promising method in controlling residual transmission where applied in addition to ITN or IRS.

92. Housing improvement is another readily available supplementary method of vector control, with demonstrated epidemiological impact in certain situations [76-80]. In 2017, WHO issued a policy brief "Keeping the vector out" to emphasize the important role that housing conditions may have in the transmission of vector-borne diseases, and to showcase interventions and policies the housing sector can contribute to effective, integrated and intersectoral vector-borne diseases management; as a next step, evidence-based recommendations on housing and vector-borne diseases are needed [81]. The WHO Department of Public Health, Environmental and Social Determinants of Health, is developing housing and health guidelines which will also include a section on housing and vector-borne diseases. This would provide official WHO recommendations to stakeholders in the housing sector to be used as part of a toolbox of interventions for locally tailored approaches to vector control [81]. Housing improvement can involve communities in the closing or screening of eaves and windows [70, 82] using materials such as mesh netting that are available in most malaria-endemic countries.

93. Larvivorous fish have in the past been promoted for biological control of vector species larvae in breeding sites. However, a systematic review found weak evidence for an effect of high-stocking levels of fish on vector larval densities in water bodies, but the health benefits remained unknown [83].

E. New tools and research prospects for DDT alternatives

94. The assessment of new tools and approaches to vector control for their public health value is the mandate of the Vector Control Advisory Group (VCAG) of WHO. This group also provides guidance on what type of evidence is required for new tools to receive endorsement for policy recommendation from WHO. A list of interventions that are under assessment is regularly updated [84]. The assessments are based on published and unpublished data submitted by the innovator. Most of the interventions are at the proof-of-concept (entomological outcomes) or proof-of-principle (epidemiological outcomes) stage. Some recent submissions include the push-pull strategy for malaria control and peridomestic residual spraying for leishmaniasis control [62, 85]. To facilitate the process of submissions of new interventions under the recently transformed regulatory approval system, WHO created a single entry point for the evaluation of vector control products and associated guidance [86].

95. Innovation to Impact (I2I) is a comprehensive, global partnership, that was launched in 2013 by a large number of stakeholders, including industry, global evaluation and regulatory bodies, procurers, local and national representatives, and donors that convene through meetings (http://innovationtoimpact.org). I2I is a response to increased insecticide resistance in vectors and gaps in transmission control, aiming to improve the value chain for developing and delivering vector control

products in line with WHO's transformed regulatory approval process for vector control products. I2I's specific objectives are: to foster sustainable incentives to invest in innovation and promote effective products through the system; enable products to be efficiently brought to market while maintaining strong quality, safety and efficacy; and enhance and maintain product quality from manufacturer to end user.

96. The IVCC, as a 'catalyst for innovation', is working with private sector and research partners on developing new active ingredients, new vector control tools, and new types of interventions or paradigms for vector control (www.IVCC.com). Nine novel insecticide classes demonstrated promising insecticidal activity, three of which will be selected as candidates for full development, which takes at least 7 more years. New vector control tools include the recently-released products Actellic CS and K-Othrine Polyzone and a dual-active ingredient bed net. Insecticide-impregnated clothing and hammocks, slow-release insecticide emanators, and insect repellents are being evaluated, and the most effective of these are being tested in villages in Cambodia. However, a trial evaluating the effectiveness of topical repellents showed no impact on infection rates in humans, possibly due to problems with compliance [87].

97. Insecticide-treated durable wall lining, as a longer-lasting alternative to IRS, has demonstrated entomological impact [88]. Two commercial products using a pyrethroid and a non-pyrethroid are available on the market. One product is currently being studied in a cluster-randomized controlled trial in an area of pyrethroid-resistance in Tanzania, in comparison with ITNs [89]. Despite the potential effectiveness of durable wall lining in reducing malaria, concerns have been raised about feasibility and cost of producing and installing these polyethylene panels on the walls of houses; WHO currently does not recommend this tool for malaria control.

98. LSM is not new but is a potential supplementary method for malaria vector control in countries and programmes that requires further research on entomological and epidemiological outcomes in various urban and rural contexts. Several proof-of-principle trials are ongoing [82, 90].

99. Entomopathogenic fungi Metarhyzium anisopliae and Beauveria bassiana have demonstrated impact on malaria vectors, including vectors that are resistant to insecticides [91-94], and thus could serve in insecticide resistance management strategies. Outside the health sector, biopesticides based on these fungi have been successfully used in the control of outbreaks of locusts and other pests. Fungal biopesticide formulations targeting adult vectors (or larvae) have a high potential for complementing existing vector control measures, with various possible deployment strategies (e.g. spray, dissemination stations).

100. Innovation on methods of house improvement is actively promoted through the inter-disciplinary network BOVA (www.bovanetwork.org). Related to house improvement is the 'eave tube' technology which are plastic tubes with insecticide-coated mesh that is placed in the eaves of houses (closing the remaining eave gaps), thus killing entering mosquitoes upon contact with the insecticide. A trial assessing the epidemiological impact of eave tubes is nearing completion in 2019 [95].

101. Spatial repellents are volatile chemicals released into the air to change mosquito behaviour and thus interrupt human-vector contact [96]. An effect of transfluthrin or metofluthrin mosquito coils on malaria parasite prevalence was demonstrated in two randomized-controlled trials [97, 98]. No studies have yet demonstrated the effect of spatial repellents on clinical malaria [99], but one Phase-3 trial is nearing completion [84]. Spatial repellents are also a potentially useful tool for the control of outdoor transmission.

102. The push-pull system of vector control operates by simultaneous use of repellent and attractant volatile odorants and removal trapping [100]. Push-pull has demonstrated clear impact on entomological outcomes of malaria vectors in East Africa [101], and has potential benefits when used in addition to the core vector control interventions.

103. A mass-trapping technology has demonstrated entomological and epidemiological impact in Western Kenya [102].

104. Another vector control tool that is planned to go through proof-of-principle evaluation is the attractive targeted sugar bait technology, which is a technique to attract and kill adult mosquitoes by utilizing their sugar-feeding behaviour [85]. Three cluster randomised trials with epidemiological outcome are currently in preparation (Mali, Kenya and Zambia).

105. Endectocides, which are medicines that have insecticidal properties (most notably ivermectin) can be used to kill mosquito vectors by spiking their blood sources; two Phase-3 trials are currently being planned (Gambia, Guinea Bissau).

106. Biocontrol through use of Wolbachia spp. proteo-bacteria. This tool has been shown to protect Aedes aegypti mosquitoes from viral infections [103], and can also reduce the susceptibility of mosquitoes to other pathogens. In Mali, field and laboratory data showed that infection with a naturally occurring strain of Wolbachia had a strong adverse effect on sporozoites in malaria vectors [104].

107. Genetic modification for population reduction or replacement, and forms of vector sterilization including the sterile insect technique (SIT) are currently under evaluation for vector control [85, 105].

108. Larviciding via auto-dissemination is also being evaluated [106, 107].

109. In view of the need to expand the vector control toolbox for malaria control, a helpful systematic review evaluated the evidence for 21 malaria vector control tools, excluding ITN and IRS [99]. The evidence base was found to be most extensive for LSM and topical repellents. Evidence for LSM was, however, of low to moderate quality; nonetheless, larviciding is routinely applied in Europe and North America with good results for mosquito control. Relatively high quality of evidence is available for topical repellents for personal protection. However, currently available topical repellents have been shown to be ineffective as a public health intervention [87]. Five other vector control tools are supported by at least one trial with epidemiological outcomes: insecticide-treated clothing and blankets, insecticide-treated hammocks, insecticide-treated livestock, mosquito-proofed housing, and spatial repellents. These tools could be considered as additional options for supplementing ITN and IRS interventions. However, 14 other vector control tools have been identified for which epidemiological impact data are still lacking.

110. Considering that diverse settings and vector ecologies will influence the cost-effectiveness of control tools, it seems prudent for programmes and researchers to further invest in studies that can inform the translation of results from one setting to another and guide the prioritization and optimization of interventions in specific settings. Such studies should also identify contextual barriers, including cultural, institutional and socio-economic, for the upscaling of interventions proven effective in controlled trials.

111. According to the DDT questionnaire responses, research on locally appropriate alternatives to DDT has been reported from 8 out of 14 countries. Regarding the type of alternative interventions, 5 countries (2 of which use DDT) conduct research on using microbial insecticides, 5 countries (2 of which use DDT) conduct research on chemical larvicides, 4 countries (1 of which using DDT) conduct research on residual chemical insecticides, and 5 countries (1 of which using DDT) conduct research on larvivorous fish. This suggests that alternative interventions to DDT receive a certain (but unknown) amount of attention in research, including in DDT-using countries.

F. Implementation of the Road Map for development of DDT alternatives

112. The purpose of the Road Map is to provide a thematic guide and sketch the steps that are needed for the development and deployment of alternatives to DDT for the purpose of disease vector control to Parties to the Stockholm Convention and other global stakeholders. [4].The Road Map focuses on areas in which action is warranted, actors responsible for them and tentative timeframe towards strengthening the knowledge base for policy formulation and decision-making, enhancing country capacities for IVM, scaling up the development and deployment of non-chemical and chemical alternatives and eliminating of DDT stock-piles and waste. Some recent initiatives that contributes towards achieving the objectives of the Road Map include strengthening national capacities for innovative implementation of IVM involving 13 African countries, development of a global inventory of DDT stockpiles and contaminated sites and documentation of the highlights in the deployment of alternatives to DDT in Sri Lanka during its successful elimination of malaria.

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

A. Training tools and capacities for proper use of DDT alternatives

113. Regarding guidance on the core interventions ITN and IRS, various updates on guidance and manuals have become available in the past few years, in addition to guidance documents and manuals that have been previously published:

114. WHO has recently updated its guidelines on IRS [19], produced a framework for malaria elimination , issued recommendations on achieving and maintaining universal coverage with ITNs for malaria control , and updated its test procedures for insecticide resistance monitoring in malaria vectors [36]. Moreover, WHO issued a note on the risks of scaling back vector control in areas where transmission has been reduced: an evaluation has shown that even where substantial reductions in transmission have taken place, the discontinuation of vector control could risk a resurgence of malaria [108]. Furthermore, PMI has produced technical guidance on operational issues for ITN, IRS, entomological monitoring and insecticide resistance management [109].

115. Regarding the sound management of insecticides used for vector control, the DDT toolkit provides guidance on all lifecycle stages of DDT and other insecticides [18].

116. In the short term, capacity building on insecticide resistance monitoring and management will be of vital importance in countries and programmes implementing the core malaria vector control interventions - ITN and IRS. Also capacity for entomological surveillance to determine the causes and levels of outdoor transmission will be crucial in many countries.

117. Available manuals and guidelines on the core malaria vector control interventions - ITN and IRS - generally apply also to new products that have become available. An exception are the new ITN products using PBOs, for which separate guidance has been provided on conditions of use [59].

118. Various training courses on vector control are currently available, as summarized in a recent overview by WHO [110].

119. The interdisciplinary BOVA network to promote housing improvement could potentially expand into providing practical guidance and to assist in training and capacity building for countries and programmes on house improvement. The Roll Back Malaria (RBM) Vector Control Working Group (VCWG) has a LSM workstream, as well as a housing workstream amongst others. A number of other novel vector control interventions are at different stages in the development pipeline. As some of these tools will become available over the coming years, specific guidance and training will be needed to assist countries in the necessary capacity building to implement these should they choose to do so.

B. Available funding opportunities for transition from DDT to alternatives

120. It has been noted that to reach the first milestone of the Global Technical Strategy for malaria (2016-2030), the combined domestic and international annual spending on malaria control and elimination must increase from the current level of US$ 2.7 billion to US$ 6.4 billion by 2020. An additional 686 million would be required each year from 2016-2030 for malaria research and development, including for vector control [11]. External funding for vector control is stagnating [5], and the cost of selected insecticides, necessary for managing resistance development, increasingly limits the coverage of spray operations (particularly for IRS). The situation underscores the need for countries to secure more domestic funding sources for malaria vector control.

121. Unitaid supports the development of new tools for vector control in malaria. BMGF, Unitaid and other donors invested in IVCC in its development of new products and tools. The GEF is supporting several projects in relation to the phasing-out of DDT. In India, a US$ 10 million grant has been made available by the GEF to implement a project on development and promotion of alternatives to DDT. The GEF project on “Demonstration of Effectiveness of Diversified, Environmentally Sound and Sustainable Interventions, and Strengthening National Capacity for Innovative Implementation of Integrated Vector Management for Disease Prevention and Control” in the WHO AFRO Region is supporting field trials of alternatives to DDT in Botswana, Mozambique, Namibia, South Africa, Swaziland, Zambia, and Zimbabwe. The 9.55m USD project is currently collecting baseline data and plans field trials on three different alternatives until 2021; and is supporting capacity to facilitate compliance with Stockholm Convention requirements. In Central Asia, a US$ 15 million grant has been made available for the treatment of DDT wastes. Also, it was noted that the DDT producer HIL is funding research and development in India on alternative products for IRS.

C. Technology transfer and linkages with research and training institutions

122. At national level, linkages between research and operations have been weak, with universities and research institutions often working in isolation from or with limited interaction with operational programmes. Now that the need for evidence-based and surveillance-based vector control has been emphasized, and supplementary vector control interventions may be needed to address outdoor

transmission, it is imperative that the capacity for entomological surveillance, vector control and operational research is strengthened within disease control programmes by recruitment and training of vector biologists and public health entomologists, who should establish solid collaboration with research institutions and universities on joint operational research studies and evaluations [11, 28].

123. Also, it is vital for countries to develop career structures for vector control experts, vector biologists and public health entomologists, with life-long career opportunities including leadership positions to build a sustainable human resource capacity, either at country or sub-regional level. To facilitate this development, an evaluation of career structures should be undertaken as part of the vector control needs assessment [50]. Capacity for training and mentoring of entomologists and vector biologists exists within universities and colleges in some malaria-endemic countries, but other countries and (sub-)regions still lack this capacity and should look into the establishment of a unit with a degree programme on public health entomology.

VI. Actions taken by Parties or partners to reduce DDT reliance

124. Malaria endemic countries have continued to implement core malaria control interventions of diagnosis, case treatment, intermittent preventive treatment, distribution and universal coverage of ITN, and IRS in selected settings. These interventions have contributed to achieving national objectives for malaria control and elimination, and have thus reduced the need for DDT in vector control.

125. From the Parties having responded to the DDT questionnaire, Mozambique, South Africa and Zimbabwe reported on actions taken in the form of insecticide resistance monitoring with the aim of detecting resistance to DDT as part of their resistance management strategy. Although India has reduced DDT use for malaria and stopped it for leishmaniasis, there is a need for efficacy studies at field level because of evidence of high levels of DDT resistance in key vectors in some areas. The detection of DDT resistance in India in the sandfly vectors of visceral leishmaniasis has led to the replacement of DDT with pyrethroids for use in IRS.

126. Some countries responding to the DDT questionnaire reported larviciding as an alternative method to DDT, but the extent of implementation of this supplementary intervention is not known. IVM strategies are promoted through the Global Vector Control Response. Among the DDT-using countries responding to the DDT questionnaire, India, Mozambique and South Africa reported that an IVM strategy has been implemented. Pesticide management of DDT and alternative insecticides is a cause for concern. The last global survey on pesticide management reported major deficiencies in procedures and capacities at country level [111, 112]. An update of the 2010 global survey is expected soon.

127. In the wider context, the actions taken by countries towards achievement of several Sustainable Development Goals (SDGs) can directly or indirectly benefit the control of vector-borne diseases, thus reducing reliance on DDT. These SDGs include SDG-1 (No Poverty), SDG-3 (Good Health and Wellbeing), SDG-6 (Clean Water and Sanitation), SDG-11 (Sustainable Cities and Communities), SDG-13 (Climate Action), and SDG-17 (Partnerships for the Goals) [29, 113].

VII. Assessment summary

128. The response rate to the 2015-17 DDT questionnaire has been very poor. Only 7 out of the 17 Parties that are currently listed in the DDT Register have responded to the 2015-17 DDT questionnaire. Three Parties in the DDT Register which, according to information from other sources, including export information provided through the DDT questionnaire, have probable DDT use did not respond to the DDT questionnaire, namely Botswana, Eswatini, Namibia. The Parties that responded included the only known producing country, India, and four main DDT-using countries, India, Zimbabwe, South Africa and Mozambique.

129. DDT production was 3,135 Metric Tonnes (MT) of active ingredient in 2015, 2388 MT in 2016 and 2004 MT in 2017. Hence, a declining pattern is evident over the reporting period.

130. 92% of the amount of DDT produced in 2015-17 in India was used within the country and the remaining 8% was exported.

131. There were substantial inconsistencies in the exported and imported amounts. DDT was exported from India as 75% WP formulated product in quantities of 366 MT in 2015, 347 MT in 2016, and 45 MT in 2017. India exported to Mozambique, Myanmar, Namibia, South Africa and Zimbabwe;

Myanmar is no longer listed in the DDT Register. South Africa and Zimbabwe reported the import of DDT from India.

132. Five countries reported having usable stocks of DDT: India, Kyrgyz Republic, Mauritius, South Africa and Zimbabwe. Regarding obsolete stocks of DDT, a number of recent efforts have been taken to centralize or dispose of them. Separate data are being analysed by UNEP to provide a more comprehensive assessment on the remaining DDT stocks worldwide. Countries with obsolete stocks of DDT should not use those stocks again for any purpose.

133. Four countries reported the use of DDT in indoor residual spraying for vector-borne disease control during the reporting period 2015-2017. India remains by far the largest global user of DDT, but annual use in India showed a clear declining trend, from 2,829 MT in 2015 to 1,900 MT in 2017, a 33% decline. Mozambique reported using 52 MT (75% WP DDT) in 2015, but reported zero use in 2016 and 2017. South Africa reported relatively small amounts of DDT use (14-20 MT 75% WP DDT annually). Zimbabwe reported relatively large amounts of DDT use in 2015-17 (133-322 MT 75% WP DDT annually). In total, the four countries that reported on DDT use used 7,421 MT of DDT active ingredient over the 3-year period 2015-2017, which is 22% lower than the 9,477 MT use amount over the previous reporting period 2012-2014.

134. In India, DDT was used for the control of malaria and visceral leishmaniasis. In 2015, India targeted DDT against the sandfly vector of visceral leishmaniasis, but in 2017, DDT was no longer applied against the leishmaniasis vector, which was apparently in response to high levels of DDT resistance in the vectors. Mozambique, South Africa and Zimbabwe reported targeting DDT against malaria only.

135. The Global Technical Strategy for Malaria 2016-2030 set goals for malaria control and elimination. A number of countries have recently achieved elimination or near elimination without the use of DDT. Progress towards elimination in African countries has stalled, including in DDT-using countries, indicating the importance of outdoor transmission and insecticide resistance amongst other factors, lack of resources (human and financial) being of primary importance.

136. Recent studies in South Africa suggested a possible association between adverse health effects in children and prenatal exposure to DDT in the context of poverty and maternal low energy intake. However, a system to monitor human exposure to DDT is lacking in most DDT-using countries, according to the questionnaire responses.

137. National capacity for vector control remains mostly inadequate. The recent expansion of malaria vector control operations has not been accompanied by corresponding investment in local human resources. Evidence-based and surveillance-based vector control is needed to detect and respond to insecticide resistance and outdoor transmission, but the adaptive ability for vector control is in need of strengthening in malaria endemic countries.

138. The dependence on insecticidal methods for vector control has led to intensified and widespread insecticide resistance which could compromise effectiveness of available interventions. High DDT resistance in the main malaria vector is reported from India, and studies on the effectiveness of DDT IRS should be conducted to assist the evaluation of the continued need for DDT. Zimbabwe reported resistance to pyrethroids, carbamates and organophosphates, but malaria vector species remained mostly susceptible to DDT. Low-level resistance to DDT has been reported in one vector population in South Africa

139. A WHO global database showed that many insecticide susceptibility tests have been carried out in India, Mozambique and Zimbabwe, but fewer were conducted in other countries with confirmed or probable use of DDT. Resistance to pyrethroids is reaching alarming levels in many malarious countries, but WHO-coordinated studies suggest that insecticide-treated nets still offer protection against malaria. Insecticide resistance management is promoted to extend the useful life of available products and methods of vector control, but options are limited by the availability and cost of alternative products.

140. Integrated vector management (IVM) is the accepted approach to make vector control more effective, efficient and sustainable. However, many countries are still struggling to strengthen their human capacity needed for implementing IVM. Few countries have shown constructive operational developments along the key elements of IVM. Also, the toolbox of malaria vector control interventions needs urgent expansion. To advance the cause of IVM, WHO launched the Global Vector Control Response (2017–2030). Nevertheless, to reach the set targets, the investment in malaria control and elimination, including vector control, needs to be substantially increased over the coming years.

141. New alternative products to DDT for use in IRS are available, including one new active ingredient and one reformulated active ingredient to help manage resistance. Also, new insecticide-treated net products have been added to the available options, including pyrethroid-PBO ITNs for use in areas with pyrethroid resistance. A pyrethroid-chlorfenapyr ITN has been listed for prequalification and cluster-randomized trials are being conducted to verify efficacy against pyrethroid resistance vectors.

142. Two available alternative methods, larval source management and housing improvement are promising methods for controlling malaria, including residual transmission, when used complementary to insecticide-treated nets or IRS. These available methods must be actively promoted for testing through interdisciplinary networks, guidance and training.

143. A number of new classes of vector control tools are being developed and tested including their efficient entry to market. A systematic review evaluated the evidence for 21 malaria vector control tools, excluding ITN and IRS, identifying 7 tools supported by at least some epidemiological data. Fourteen other vector control tools have been identified for which epidemiological impact data are still lacking

144. Considering that diverse settings and vector ecologies will influence the cost-effectiveness of control tools, it seems prudent for programmes and researchers to further invest in studies that can inform the translation of results from one setting to another and guide the prioritization and optimization of interventions in specific settings. Such studies should also identify contextual barriers, including cultural, institutional and socio-economic, for the upscaling of interventions proven effective in controlled trials.

145. Various new guidance documents have been developed, and training opportunities exist on vector control, but a major challenge for vector-borne disease control programmes is the recruitment and training of vector biologists and public health entomologists, and the development of career structures for vector control experts, vector biologists and public health entomologists.

VIII. Conclusions and recommendations

146. 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 conclusions and recommendations:

147. Conclusion: The information submitted by Parties through the DDT questionnaire is the basis for the assessment of information on the continued need for DDT; however, the response rate to the DDT questionnaire has been very low (only 41% of the Parties listed in the DDT register have provided their completed questionnaire for the 2015-2017 reporting cycle). Further, concerns about poor data quality have also been noted; for example, the data on export and import do not match.

Recommendation: There are indications of DDT use in countries other than those listed in the DDT register, and therefore, it is reminded that Parties have the obligation to register once they start using DDT for the acceptable purpose in accordance with Part II of Annex B of the Convention.

Recommendation: To facilitate the evaluation of the continued need for DDT, it is critical that Parties, particularly those listed in the DDT Register, provide their completed responses to the DDT questionnaire. Special attention should be paid to the quality of reported data on production, use, storage, export and import. The Secretariat should liaise on a regular basis with the Parties listed in the DDT Register to facilitate their reporting on DDT, and work with Parties to identify the reasons for not responding in order to assist them in their reporting obligations. WHO should be encouraged to enhance reporting of IRS data on an annual basis as part of data collection for the World Malaria Report to support triangulation of the findings from the questionnaire.

Recommendation: Collaboration with the Basel Convention's reporting system related to imports and exports of obsolete DDT wastes for final disposal and the WHO's reporting system on public health pesticides in relation to DDT should be explored.

148. Conclusion: Efforts targeted towards sound disposal of obsolete DDT from various countries have shown results, but the amount of stockpiles remains substantive worldwide. Conservative estimates by UNEP point to a total global amount of 20,000 tonnes of DDT stockpiles, but the actual amount is expected to be much higher. There is a risk of expired stocks being misused and potentially leading to environmental contamination.

Recommendation: Continued funding from the Global Environment Facility and other donors is needed, as a priority, to support the centralizing and disposal of obsolete DDT stockpiles, prioritizing those countries where stockpiles pose immediate risks to human health and the environment.

149. Conclusion: A system to monitor human exposure to DDT is lacking in most DDT-using countries. Implementation of best practices is important to reduce exposure among spray workers and recipient households.

Recommendation: Countries that use DDT should establish a system for monitoring exposure among spray workers and recipient households to validate whether proper implementation of protective measures limits the exposure of spray workers and recipient households to within established thresholds, and to contribute to an understanding of the potential impact on health.

Recommendation: Countries should be encouraged to implement best practices to reduce the exposure among spray workers and recipient households.

150. Conclusion: DDT resistance in disease vectors is an important consideration for the continued use of DDT.

Recommendation: Parties should monitor for insecticide resistance in vector populations using standard WHO procedures.

Recommendation: Parties should formulate national plans for insecticide resistance monitoring and management based on established WHO guidelines.

151. Conclusion: National capacity for vector surveillance and vector control as needed for implementing Integrated Vector Management remains mostly inadequate.

Recommendation: To improve evidence-based and surveillance-based vector control operations, and to enable implementation of insecticide resistance management, national capacity for vector surveillance and control must be substantially improved in countries endemic for malaria.

Recommendation: UNEP and the Secretariat of the Stockholm Convention should continue to facilitate activities within the framework of the road map that strengthen capacity to transition away from the reliance on DDT for disease vector control.

152. Conclusion: There is an urgent need for the uptake of supplementary vector control methods in addition to core interventions.

Recommendation: Testing and phasing-in of readily available supplementary methods of disease vector control should be actively promoted through establishment and strengthening of interdisciplinary networks, guidance and capacity building.

153. Conclusion: There is an urgent need for new tools and technologies for disease vector control to be developed, tested and fast-tracked for deployment. Diverse settings and vector ecologies have an influence on the cost-effectiveness of control tools.

Recommendation: Increased funding should be provided for the development and evaluation of promising new tools and technologies for disease vector control.

Recommendation: Increased investment should be made for studies that can inform the translation of results from one setting to another and guide the prioritization and optimization of interventions in specific settings.

Recommendation: Funding for comparative cost-effectiveness studies of IRS with DDT and other core interventions for disease vector control is much needed.

154. Conclusion: DDT is indicated against DDT-susceptible target vector populations that are resistant to other classes of insecticide, pyrethroids in particular.

Recommendation: The use of DDT should be retained for malaria vector control where specifically indicated until such time as a suitable alternative (in terms of insecticidal efficacy and persistence on treated surfaces) is available and affordable.

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