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Report of the Persistent Organic Pollutants Review Committee on the work of its thirteenth meeting

Addendum

Risk management evaluation on dicofol

At its thirteenth meeting, by its decision POPRC-13/1, the Persistent Organic Pollutants Review Committee adopted a risk management evaluation on dicofol on the basis of the draft contained in the note by the Secretariat (UNEP/POPS/POPRC.13/2), as revised during the meeting. The text of the risk management evaluation as adopted is set out in the annex to the present addendum. It has not been formally edited.

Annex

DICOFOL

RISK MANAGEMENT EVALUATION

18 October 2017

Contents

Executive Summary

1. At its twelfth meeting the Persistent Organic Pollutants Review Committee (POPRC) reviewed and adopted a revised draft risk profile on dicofol. The POPRC concluded that dicofol is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects such that global action is warranted. A risk management evaluation is therefore required that includes an analysis of possible control measures for dicofol in accordance with Annex F to the Convention. Parties and observers were invited to submit to the Secretariat the information specified in Annex F before 9 December 2016.

2. Responses regarding the information specified in Annex F of the Stockholm Convention have been provided by Austria, Canada, Columbia, India, Japan, Monaco, Serbia (Parties) and by International POPs Elimination Network (IPEN) and Pesticide Action Network (PAN) (observers). The risk management evaluation is primarily based on these responses and on selected additional relevant literature.

3. Dicofol is an organochlorine pesticide, used to control mites on a variety of crops. Dicofol was introduced commercially in 1955. Intended uses of dicofol cover fruits, vegetables, ornamentals, field crops, cotton, tea, and Christmas tree plantations. Between 2000 and 2007, global production of dicofol was estimated to have been 2,700-5,500 t (tonnes) per year but production has declined sharply since then as a number of countries have phased out production and usage, including Benin, Brazil, Canada, Columbia, Member States of the European Union, Guinea, Indonesia, Japan, Mauritania, Oman, Saudi Arabia, Sri Lanka, Switzerland and United State of America. Production of dicofol now takes place in a small number of countries, predominantly at a single plant in India, and reportedly at a plant in Israel. Dicofol is also authorized for specific uses in Mexico. Until recently, China was one of the major global producers of technical DDT and dicofol, producing approximately 97,000 t of technical DDT between 1988 and 2002, from which approximately 40,000 t dicofol was manufactured. In 2014, the last remaining technical dicofol producer in China ceased production of technical dicofol. Dicofol is produced predominantly in India in a closed system in batches; production in 2015-2016 was 93 t. The expiry date for the production and use of DDT as a closed-system site-limited intermediate in the production of dicofol was extended until May 2024 (UNEP/POPS/COP.7/4/Rev.1).

4. Currently applied control measures cover a broad spectrum of possible control measures including the prohibition and restriction of production, use, import and export; the replacement of dicofol by chemical and/or non-chemical alternatives; the establishment of exposure limits in workplaces; the environmentally sound management of obsolete stock and; the clean-up of contaminated sites.

5. The successful prohibition on the production, sale and use of dicofol by a wide number of countries within different geographies and climatic conditions and on different crops indicates that viable chemical and non-chemical alternatives do exist; however, the available information is not sufficient to demonstrate that this is true in all cases. A restriction on production and use is less effective at protecting the environment and human health than a full prohibition but could reduce the total quantity of dicofol used and potential exposure under certain scenarios. While there has been a decline in the production and use of dicofol, it has been manufactured in significant quantities, with a diverse set of potential applications and end users. This represents a challenge for the identification, collection and safe destruction of obsolete stock of dicofol. While the identification of dicofol may have been improved through appropriate labelling to identify contents in some locations, studies suggest an awareness campaign and concerted efforts working with farming communities and other end users is needed to help manage the collection and safe destruction of stock to prevent environmental releases. Maximum environmental concentrations for water have been developed by the European Union as an example of measures to protect the environment. Furthermore, it would be possible to limit some occupational exposure by imposing restrictions on the nature of manufacture (e.g. specifying closed-systems only) and worker activities (e.g. ensuring use of correct personal protective equipment in all global geographic areas). However, it is suggested that, in developing countries in particular, highly hazardous pesticides may pose significant risks to human health or the environment, because risk reduction measures such as the use of personal protective equipment or maintenance and calibration of pesticide application equipment are not easily implemented or are not effective (FAO).[1]

6. A large number of countries have already transitioned away from the use of dicofol after prohibition, and that for a major user of dicofol it has been possible to phase-out its use completely

[1] http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/code/hhp/en/.

when managed with the correct transitional arrangements. No specific examples of critical uses were provided by the Parties or observers submitting information as part of the Annex F survey; nor have any critical uses otherwise been identified.

7. A range of chemical and non-chemical alternatives to dicofol are available and accessible in various geographical regions. The alternatives, considered as technically feasible, include over 25 chemical pesticides, biological controls (pathogens and predators), botanical preparations (plant extracts), and agroecological practices (such as are used in agroecology, organics and integrated pest management or IPM). The range of alternatives reflects the various pest-crop combinations for which dicofol is or has been applied, in regions with very different climatic conditions and crops. All the alternatives described are considered to be technically feasible, available and accessible in a range of countries. However, the available information (primarily from Annex F submissions) is not currently sufficient to conclude that these alternatives are economically feasible in all cases where dicofol is still used. Equally, there is no information to suggest that alternatives cannot be feasibly implemented in all cases. This emphasizes the need for further assessment under the local conditions and consideration of the specific agroecosystems and agricultural practices used, giving priority to ecosystem-based approaches to pest control.

8. Non-chemical alternative processes and products, and more specifically agroecological and integrated pest management practices, have proven to be efficient as an alternative to dicofol in a number of countries (including India, China, and Australia) and for a number of crops, such as cotton, tea, citrus, and apples. However, the existing evidence is not sufficient to demonstrate that this is true for all uses.

9. In accordance with paragraph 9 of Article 8 of the Convention the POPRC recommends to the Conference of the Parties to the Stockholm Convention to consider listing dicofol and specifying the related control measures under the Stockholm Convention in Annex A without specific exemptions.

1 Introduction

10. In May 2013, the European Union and its Member States, being Parties to the Stockholm Convention, submitted to the ninth meeting of the Persistent Organic Pollutants Review Committee (POPRC) a proposal to list dicofol in Annex A, B and/or C of the Convention (UNEP/POPS/POPRC.9/3). The proposal was further evaluated by the Committee at its tenth and eleventh meetings in Rome in October 2014 and October 2015.

11. Having examined the proposal, the Committee adopted a decision (POPRC-10/3) that dicofol meets the criteria of Annex D to the Convention and established an intersessional working group to review the proposal further and prepare a draft risk profile.

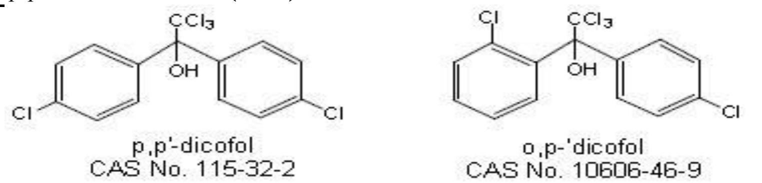
12. At the twelfth meeting of the POPRC in September 2016 the Committee, having reviewed the risk profile on dicofol, decided (decision POPRC-12/1) in accordance with paragraph 7(a) of Article 8 of the Convention, that dicofol is likely as a result of its long range environmental transport to lead to significant adverse human health and environmental effects such that global action is warranted. The Committee also established an intersessional working group to prepare a risk management evaluation that includes an analysis of possible control measures for dicofol.

13. Parties and observers were invited to submit to the Secretariat the information specified in Annex F before 9 December 2016. The submitted information and other relevant information are considered in this document.

1.1 Chemical identity of dicofol

14. Dicofol is an organochlorine pesticide comprising two isomers: *p,p'*-dicofol and *o,p'*-dicofol. The technical product (95% pure) is a brown viscous oil and is composed of 80-85% *p,p'*-dicofol and 15-20% *o,p'*-dicofol with up to 18 reported impurities. The purer form is generally >95% dicofol containing less than 0.1% dichlorodiphenyltrichloroethane (DDT) and related compounds (ΣDDT, i.e. DDT, DDE and DDD) (WHO 1996). Table 1.1 provides an overview of the key information used for the identification of dicofol.

Table 1.1
Information pertaining to the chemical identity of dicofol

Common name IUPAC Chem. Abstracts	<u>Dicofol</u> 2,2,2-trichloro-1,1-bis(4-chlorophenyl)ethanol Benzenemethanol, 4-chloro-α-(4-chlorophenyl)-α-(trichloromethyl)- 4-chloro-alpha-(4-chlorophenyl)-α-(trichloromethyl)benzene-methanol 1,1-bis(4'-chlorophenyl)2,2,2-trichloroethanol
Other names	1,1-bis(4-chlorophenyl)-2,2,2-trichloroethanol and 1-(2-chlorophenyl)-1-(4- chlorophenyl)-2,2,2-trichloroethanol (*p,p′*- and *o,p′*-isomer)
Molecular formula	$C_{14}H_9Cl_5O$
Molecular weight	370.49
CAS registry number	dicofol; *p,p′*-dicofol 115-32-2 *o,p′*-dicofol 10606-46-9
Trade names	1,1-bis(chlorophenyl)-2,2,2-trichloroethanol; 4-chloro-α-(4-chlorophenyl)-α-(trichloromethyl)-; Acarin; AK-20 HC free; Benzenemethanol; Carbax; Cekudifol; CPCA; Decofol; Dicaron; Dichlorokelthane; Dicomite; Difol; DTMC; ENT 23648; FW293; Hilfol; Hilfol 18.5 EC; Kelthane; Kelthanethanol; Kelthane A; Kelthane (DOT); Kelthane Dust Base; Kelthane 35; Milbol; Mitigan; *p,p'*-dicofol; NA2761 (DOT); NCI-C00486
Structural formulas of the isomers	

1.2 Production and uses

Production

15. Dicofol can be manufactured by the hydroxylation of DDT (van de Plassche *et al.* 2003), or directly, without isolation of DDT by the reaction of chloral (trichloroacetaldehyde) with monochlorobenzene in the presence of oleum (SO_3 and H_2SO_4) followed by dehydrochlorination, chlorination and hydrolysis. Between 2000 and 2007, global production of dicofol was estimated to have been 2,700 - 5,500t per year (OSPAR, 2002; Hoferkamp et al. 2010) but production has declined sharply since 2007 as a number of counties have since initiated phase-outs of their production and usage.

16. Production of dicofol is now limited to companies in a small number of countries. In India this includes one manufacturer (Hindustan Insecticides Limited (HIL)), while a second has registered with the Central Insecticide Board for the production of dicofol[2](Indofil Industries Limited) but is not currently producing (Communication from India, 2017). Additionally, in Israel the company Adama[3] (formerly Makhteshim Agan) has a registered product containing dicofol (Acarin T 285). Based on the information provided through Annex F responses, production is now predominantly limited to the facility based in India, although no further information on the production facility based in Israel has been identified. In 2015-2016 production at the facility based in India was 93 t (India, 2016) with dicofol produced in a closed system as a batch process. The expiry date for the production and use of DDT as a closed-system site-limited intermediate in the production of dicofol has been extended until May 2024 by decision SC-7/1 (UNEP/POPS/COP.7/36).

17. China was previously one of the major producers of technical DDT and dicofol. It was estimated that 97,000 t of technical DDT was produced between 1988 and 2002, with approximately 54,000 t used to manufacture dicofol (40,000 t of dicofol produced) (Qiu *et al*. 2005). In 2014, it was reported that the last remaining technical dicofol producer in China ceased production.

18. Brazil manufactured around 90t of dicofol per annum up to 2010 but has ceased production completely in 2014. Remaining stock in Brazil was expected to have been fully used/destroyed by 2015 (Brazil, 2016). Until 2006 Spain was the major manufacturer and consumer (90 t in 2006) of dicofol in Europe, produced only by Montecinca, S.A. in Barcelona, Spain under contract to Dow Agro Sciences (van de Plassche et al. 2003). Additionally dicofol-based products were also formulated

[2] www.cibrc.nic.in/biopesticides.doc.
[3] http://www.pcpb.or.ke/cropproductsviewform.php.

in a plant in Italy (OSPAR, 2008). Dicofol is no longer produced in EU Member States. Production in the USA was estimated at 160 t/y for the years 1999 to 2004 (Hoferkamp *et al.* 2010).

Uses

19. Dicofol is an organochlorine pesticide, used in many countries to control mites on a variety of crops. Dicofol was introduced commercially in 1955 (WHO 1996). The substance has been used primarily in East and Southeast Asia, the Mediterranean coast, as well as in Northern and Central America (Li *et al.* 2014a). Intended uses of dicofol cover fruits, vegetables, ornamentals such as orchids, field crops, cotton, tea, Christmas tree plantations, and non-agricultural outdoor buildings and structures (US EPA 1998, Li *et al.* 2014a). In Mexico, there are 17 registrations for dicofol (potential uses). It is authorized for the application on aubergine, chili, strawberry, lime, apple, orange, pear, watermelon, mandarin, grapefruit, vine, citrus fruits, ornamental plants and nursery gardens (Mexico, 2015). In Brazil dicofol was used as an acaricide for cotton, citrus and apple crops. However, all use of dicofol as a pesticide was banned in 2015 (Brazil, 2016).

20. Li *et al.* (2014a) estimated, based on a combination of literature surveys, field surveys and personal communications, a total of 28,200t of dicofol was used globally in a 13 year period from 2000 to 2012, mainly in Asia (21,719 t; 77% of global usage), followed by North America (1,817 t), Europe (1,745 t), Latin America (1,538 t), Africa (1,434 t) and Oceania (13 t). China was the main user of dicofol during this time (69% of global total).

21. However, between 2000 and 2012 the estimated dicofol usage decreased by 75% in China (from 2,013 t to 530t), 69% in India (from 145 t to 43 t) and 90% in the USA (from 323 t to 33 t) with most use occurring in California, Florida, and Georgia for that time frame. The decrease of estimated global use from 2000 (3,350 t) to 2012 (730 t) was approximately 80%. In Europe dicofol usage was estimated to have decreased from 317t to 32 t between 2000 and 2009 (Li *et al.* 2014a). According to estimated emission data published by van der Gon *et al.* (2007), the major consuming countries in Europe in 2000 were Spain, Italy, Turkey, Romania, and France. Dicofol has been used in Ukraine, but the current situation is unclear (UNECE, 2010).

22. It is expected that the observed decline in global dicofol usage over the period 2000-2012 has continued since this study period; therefore, it is estimated that the current global dicofol use is well below 1,000 t/y.

1.3 Conclusions of the Review Committee regarding Annex E information

23. At its tenth meeting in October 2014, the Committee concluded that dicofol fulfilled the screening criteria specified in Annex D (POPRC-10/3). The Committee also decided to establish an ad-hoc working group to review the proposal further and prepare a draft risk profile in accordance with Annex E of the Convention.

24. At its eleventh meeting in October 2015 the Committee considered the draft risk profile for dicofol (UNEP/POPS/POPRC.11/3), comments and responses relating to the draft risk profile (UNEP/POPS/POPRC.11/INF/8) and additional information on dicofol (UNEP/POPS/POPRC.11/INF/15) and agreed to defer its decision on the draft risk profile for dicofol to the twelfth meeting of the Committee (decision POPRC-11/2).

25. At its twelfth meeting in September 2016, the Committee adopted the risk profile for dicofol (UNEP/POPS/POPRC.12/11/Add.1) and decided (decision POPRC-12/1) in accordance with paragraph 7(a) of Article 8 of the Convention, that dicofol is likely as a result of its long range environmental transport to lead to significant adverse human health and environmental effects such that global action is warranted; established an intersessional working group to prepare a risk management evaluation that includes an analysis of possible control measures for dicofol in accordance with Annex F to the Convention; and invited Parties and observers to submit to the Secretariat the information specified in Annex F before 9 December 2016.

1.4 Data sources

1.4.1 Overview of data submitted by Parties and observers

26. This risk management evaluation is primarily based on information that has been provided by Parties to the Convention and observers. Responses regarding the information specified in Annex F of the Stockholm Convention (risk management) have been provided by the following countries and observers:

(a) Parties: Austria, Canada, Colombia, India, Japan, Monaco, Serbia;

(b) Observers: Pesticide Action Network (PAN) and International POPs Elimination Network (IPEN).

1.4.2. *Other data sources*

27. Additional references, including those previously cited in the risk profile on dicofol (UNEP/POPS/POPRC.12/11/Add.1), and others, are listed under "References".

1.5 Status of the chemical under International Conventions

28. Dicofol is subject to a number of agreements, regulations and action plans:

(a) In December 2009 dicofol was proposed to be added to Annex I (prohibition of production and use) of the Aarhus Protocol on Persistent Organic Pollutants (POPs) under the Convention on Long-Range Transboundary Air Pollution (LRTAP). The POPs Task Force (except for one expert) concluded that dicofol met the indicative numerical values of the Executive Body decision 1998/2. However, no finalised action for dicofol under the LRTAP POPs Protocol was taken pending further consideration under the Stockholm Convention. In December 2013, the Executive Body of LRTAP decided to defer any discussion of dicofol until after COP7 of the Stockholm Convention in 2015[4] (USA, 2015);

(b) The Oslo and Paris Conventions (OSPAR) Commission included dicofol in the List of Chemicals for Priority Action (by 2004);

(c) In 2012, the Chemical Review Committee of the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade considered if dicofol met the requirements of the Convention. The Committee had before it two notifications and supporting documentation on dicofol submitted by the European Union and Japan. The Committee decided that, as only one of these notifications of final regulatory action from one prior informed consent region had met the criteria set out in Annex II, at the current time dicofol could not be recommended for inclusion in Annex III to the Convention;

(d) Since 2009 the specific exemptions for DDT listed in Annex B of the Stockholm Convention as an intermediate in the production process of dicofol have expired and no new registrations may be made with respect to such exemptions. However, after a request from India (UNEP/POPS/COP.7/INF/3), the expiry date for the production and use of DDT as a closed-system site-limited intermediate that is chemically transformed in the manufacture of other chemicals that, taking into consideration the criteria in paragraph 1 of Annex D, do not exhibit the characteristics of persistent organic pollutants has been extended from June 2014 to May 2024, upon notification to the Secretariat. In March 2014, India submitted a notification to the Secretariat relating to the production and use of 150 t DDT. To date, this is the only submission of notification to the Secretariat. The exemption for use of DDT as a closed-system site-limited intermediate to produce dicofol expired for Brazil in 2014 and China withdrew their exemption for this use the same year.[5]

1.6 Any national or regional control actions taken

29. In several countries or international organizations commercial dicofol must meet standards with respect to:

(a) The minimum content of the *p,p'*-isomer;

(b) The maximum content of DDT and related substances (DDTr).

30. The following (inter)national regulations exist:

(a) FAO/WHO Specification 123/TC/S/F (1992) requires the amount of DDTr in technical dicofol (by weight) to be less than 0.1%;

(b) The limit of 0.1% of DDTr is or was in place in the USA (US EPA, 1998), Canada, Japan, Brazil, Australia and Argentina (Van der Gon, 2006). Information from other countries is not available;

(c) As discussed in previous sections, many countries have passed national legislation to prohibit or restrict the production and/or use of dicofol. For example, in the UK, the approval of the marketing of dicofol was revoked on 31 May 2000 but approval for storage and use was valid until

[4] http://www.unece.org/fileadmin/DAM/env/documents/2013/air/eb/ECE_EB.AIR_122_E.pdf.

[5] http://chm.pops.int/Implementation/Exemptions/Closedsystemsitelimited/tabid/453/Default.aspx.

31 May 2002 (OSPAR, 2002). Most registrations in Europe were revoked during the late 1990s (OSPAR, 2008);

(d) The permitted use of dicofol for plant protection products in the EU expired by 2010 at the latest according to Commission Decision 2008/764/EC[6] . In addition, all non-agricultural uses are prohibited according to the Biocidal Products Regulation No (EC) 528/2012;[7]

(e) Dicofol is included in EU Directive 2013/39/EU[8] as a priority hazardous substance in the field of water policy. This sets environmental quality standards for dicofol, for inland surface waters (1.3×10^{-3} µg/l); other surface waters (3.2×10^{-5} µg/l); and biota (33 µg/kg wet weight). Additionally, because dicofol is a priority hazardous substance there is an obligation under the water framework directive for cessation of all discharges to the environment, which goes beyond the EQS target thresholds;

(f) EU Regulation (EC) No 396/2005 (as amended by Commission Regulation (EU) No 899/2012) specifies maximum residue levels of dicofol in or on food and feed of plant and animal origin (see Table 2.2; Section 2.2.1). This Regulation also specifies requirements of Member States to conduct sampling to adequately monitor compliance with these MRLs (see 2.5.2).

31. It is known that KELTHANE® (a trade name product containing dicofol), previously produced in Spain by Dow Agro Sciences was purified on-site to meet the 0.1% DDTr limit (van de Plassche *et al*. 2003). Only limited information is available regarding the compliance of dicofol producers with these stringent specifications. The content of DDTr in commercial dicofol made by other producers is unknown. A content of 3.5% DDTr of dicofol produced by a company in India has been reported (van de Plassche *et al*. 2003). Levels in Turkey have been found between 0.3% and 14.3% (Turgut *et al*. 2009). In China, it has been reported that dicofol products with high levels of DDT impurities were available on the market after 2003. Qiu *et al*. (2005) reported an average ΣDDT content of 24.4% measured in 23 commercially available dicofol formulations.

32. In December 2011, the USEPA issued an order for the cancellation of the technical registration of dicofol at the request of the registrant (Makhteshim Agan of North America, Inc). The cancellation was effective on 14 December 2011, and the existing stocks provision allowed the registrant to reformulate it into end-use products and sell it until 31 October 2013. Sale and distribution by others was allowed until 31 December 2013, and use was prohibited after 31 October 2016 (USA, 2016).

33. In Canada, in December 2011, dicofol was de-registered as a pesticide under the Pest Control Products Act (PCPA). Sales of dicofol were voluntarily discontinued in Canada in December 2008 and, as per the mandatory process set out by the Pest Management Regulatory Agency, remaining stocks were to be used by 31 December 2011. Since this deadline, dicofol products can no longer be sold or used in Canada (Canada, 2016).

34. In Colombia, the import, production, commercialization and use of dicofol is banned.

35. The use of dicofol has been banned in Benin, Brazil, Colombia, the 28 member states of the EU, Guinea, Japan, Mauritania, Oman, Saudi Arabia, and Switzerland (PAN and IPEN.2016) as well as Indonesia and Sri Lanka . Furthermore it has been voluntarily cancelled in Canada and the USA.

36. India (2016) indicated that 'All the control parameters such as the control of discharges or emissions, and prohibition of reuse and recycling of wastes, are observed during production. The system adopted in HIL is free from fugitive emissions. Monitoring measures are in place to assess possible releases' for dicofol produced in a closed system in controlled batches by HIL. No results of the monitoring were provided.

2 Summary information relevant to the risk management evaluation

2.1 Identification of possible control measures

37. Identification of potential control measures should address the potential direct exposure of humans to dicofol (in occupational settings during manufacture, use, harvesting of crops, and washing of work clothing) and also indirect exposure from residual levels in food and as a result of exposure via the environment, where dicofol has the potential for long range transport, persistence, and bioaccumulation. Consideration should also be given to the potential for negative environmental effects. Annex F of the Convention also states that, in identifying suitable control measures,

[6] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008D0764.

[7] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=OJ:L:2012:167:TOC.

[8] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:226:0001:0017:EN:PDF.

consideration should be given to relevant information on the socio-economic aspects associated with the control measures identified to allow the Conference of the Parties to take the most appropriate course of action.

38. Based on the nature of dicofol production and use, the following control measures are potentially available: (1) Prohibition of production, use, import and export; (2) Use restriction including termination of processes which could lead to unintentional release of the chemical (such as specific use conditions and restrictions, through training, and better labelling); (3) Clean-up of contaminated sites; (4) Environmentally sound management of obsolete stock; (5) Establishment of exposure limits in workplaces; and (6) Establishment of maximum residue limits in water, soil, sediment and/or food.

2.2 Efficacy and efficiency of possible control measures in meeting risk reduction goals

2.2.1 Technical feasibility

Prohibition of production, use, import and export

39. Prohibition of the production, use, import and export of dicofol has already been successfully implemented by many countries, with further details provided in section 1 of this dossier. Information provided through the Annex F survey has highlighted a range of chemical alternatives which are already actively in use, including the ten alternatives provided by Canada (Canada, 2016) and three alternatives provided by India (India, 2016). A range of non-chemical alternatives have also been identified by PAN and IPEN (2016).

40. To date three Parties made notifications to the Secretariat for exempted uses of DDT for manufacture of dicofol. As of the 1 June and 13 September 2014 respectively, China and Brazil withdrew their request to make use of these exemptions signaling an end to the production of dicofol. Prior to this date in 1997, China issued a ban on the use of dicofol on tea plants (UNEP/POPs/POPRC.12/11/Add.1). Based on the Stockholm Convention exemptions for the use of DDT, data from Van der Plassche *et al.* (2003), and company data from the Adama (formerly Makhteshim Agan) website (http://www.adama.com/mexico/es/), it is believed that the production (India and Israel), sale and use of dicofol now only occurs in a small number of countries globally (primarily India, Israel and Mexico).

41. The successful prohibition of the production, sale and use of dicofol by a number of nations, from a variety of geographical and climatic regions that grow a diverse range of crops indicates that viable chemical and non-chemical alternatives do exist and are in use. The specific alternatives to dicofol that are available are further discussed in Section 2.3. However, useful context on the process of phase-out and the potential technical obstacles is presented here.

42. Chen and Kwan (2013) reports on a six year project in China, aimed at developing alternatives to dicofol and facilitating the phase-out of dicofol production and use by closing two facilities that produced dicofol through an open-system process. Closure of these sites ceased the production of 1,350 t of DDT-containing wastes annually, and protected workers from the exposure to dicofol and DDT during the production process. Affected workers from these production facilities were consulted in the early stages of the process for the provision of settlement packages and re-training to avoid economic impacts. The project also aimed to train and educate farmers to develop alternative practices largely based around integrated pest management (IPM) utilizing a mixture of non-chemical practices alongside chemical alternatives to dicofol. The final report for the study presented by Chen and Kwan (2013) stated that adoption of these techniques has been largely successful, with use of dicofol as a chemical pesticide no longer needed by the agricultural sector in China.

43. Eyhorn (2007) reports a study (Maikaal bioRe sustainability study) working with organic cotton in India. In this study Eyhorn (2007) noted that the economic margins for the farmers were particularly tight, meaning that many farmers had a reliance on specific pesticides and were reluctant to change farming practices due to fear of failing crops and economic impacts resulting from such failures. For others these difficult economic conditions meant that they were more willing to experiment with new approaches as the existing approach using dicofol was equally difficult to maintain. Eyhorn (2007) worked with 60 farmers using conventional chemical approaches and 60 farmers using organic agroecological approaches, based on non-chemical techniques and additional manure spreading. After two years, review of the study outputs demonstrated that crop yields and output from both sets of farmers were broadly similar; labor requirements were also broadly similar, with additional economic savings for the organic farmers from not using chemical alternatives. Eyhorn states that due to 10-20% lower production costs and a 20% price premium for organic products,

average gross margins from organic cotton fields were, depending on the year, 30-40% higher than in the conventional production system. Organic farms achieved a 10-20% higher income than conventional farms. However, Eyhorn (2007) did note a drop in crop yields for the first year of the study by 10 – 50% while new practices were installed. On that basis, the study found that the longer term economic position was good with cost neutral / cost savings, and gross margins 30-40% higher than in the conventional production system where the market provides a premium for organic products, but 'initially mainly wealthier farmers and farmers who were leaders in their communities adopted organic farming while marginal farmers hesitated to take the risk of conversion' due to the costs of the transitional year. The study noted that managing the economic constraints of the conversion period emerged as an important entrance barrier to organic farming, especially for small and resource-poor farmers, however in the long-term, smallholders were likely to be better off in the organic farming system due to lower production costs and stabilised incomes, which help reduce vulnerability to drought and market price fluctuations (Eyhorn, 2007).

44. Wang *et al*. (2015) provide a perspective on the technical feasibility of prohibition and switch to alternatives. Wang *et al*. noted that many farmers in China continued to make use of specific pesticides (including dicofol) even when restrictions were implemented and safer alternatives were available. Based on a survey of 472 Chinese farmers on farming practices and their perspectives on the use of chemicals, Wang *et al.* (2015) highlighted that, again due to economic constraints and fear of failing crops, many farmers were reluctant to change from their preferred choice of pesticides to untested alternatives. Farmers also relied heavily on the guidance of pesticide retailers for advice on the best alternatives. The study by Chen and Kwan (2013) highlighted the need to work with farmers, with training and education being particularly important for technical feasibility of changing farming practices. Wang *et al*. (2015) also highlighted the need to work with pesticide retailers to ensure that the pesticide restrictions were upheld and that the best guidance is available in selection of pesticides.

45. Prohibition would represent the most effective means to protect human health and the environment from the risks associated with dicofol. Data reviewed and presented within this dossier suggests that many nations with different crops and from different geographies and climatic regions have already successfully implemented transitions to alternative chemicals or non-chemical alternative options available. Data provided through the Annex F survey suggests that a number of chemical alternatives are already widely available, although data on price and efficacy was not sufficient to provide critical review. Review of transition to non-chemical alternatives suggests that this may prove a highly successful option should a prohibition be implemented. However the studies reviewed have also highlighted the possibility of socio-economic impacts in the short term and need for a transitional phase to minimize these impacts.

Restriction of production, use, import and export; Termination of processes which could lead to unintentional release of the chemical; Establishment of exposure limits in workplaces

46. Information on the restriction of uses for dicofol to protect human health and the environment are very limited. Data from China stated that the use of dicofol on tea plants was banned in 1997, while uses on other crops were allowed to continue until 2014 when production in China ceased (UNEP/POPs/POPRC.12/11/Add.1). The USA addendum to the Registration Eligibility Decision (RED) for dicofol in 2006 provides further details on measures to protect worker safety in farming communities in the USA. As part of the RED dossier development for pesticide eligibility, 'restricted entry intervals' (REI) are developed. These REI indicate a safe period of time after treatment during which workers should not return to the treated area. As a default the REI is set to 12 hours, however after review of additional toxicological information it was necessary to review the toxicological end-points and amend the REIs for some commodities. For cotton and alfalfa which are harvested mechanically the use of 12 hour REIs was allowed to be retained. However for fruit crops such as citrus, grapes, strawberries, and tomatoes, as well as pecans, mint, and cucumber which may be harvested manually, the REIs were extended to between 20 days (Bermuda grass) and 87 days (citrus fruits). The REIs also refer to product labelling and setting of inhalation exposure limits. It is possible to grant farmers early access to treated areas provided the limits are not exceeded and the worker does not touch or by action is touched by pesticide residues (USEPA, 2006).

47. Standard occupational exposure limits (OEL) for the use of dicofol have not been identified. However industry-developed occupational exposure limits are reported by Cropcare (2001) and Rohm and Haas (Reported in Cornell, 1993) as an 8-hour time weighted average of 0.1 mg/m^3, and short term exposure limit of 0.3 mg/m^3. The OELs reported are based on atmospheric concentrations, while both references highlight that absorption through dermal contact with atmospheric concentrations is a key mechanism for exposure. Nigg et al (1991) provide some further data on occupational exposure based on analysis of urine from workers mixing and spraying dicofol to treat citrus crops. The ten day study analyzed samples for the dicofol metabolite dichlorobenzilic acid (DCBA) as a means of

assessing exposure to dicofol. Excretion rates for DCBA over test period of use were in the range of 19-42 µg/day. This was used to correlate an estimated dermal exposure of dicofol ranging between 2.7 and 13 mg/day.

48. The US EPA (2006) RED document highlights what personal protective equipment (PPE) should be used when working with dicofol-based products. For both liquid emulsion based products and wettable powders where engineering controls are not in use, workers should wear long-sleeved shirts and trousers, chemical-resistant footwear plus socks, and respirator. For certain activities, a chemical resistant apron is required. Additionally if overhead exposures would be expected, then chemical-resistant headgear is needed. However, it is suggested that, in developing countries, highly hazardous pesticides may pose significant risks to human health or the environment, because risk reduction measures such as the use of personal protective equipment or maintenance and calibration of pesticide application equipment are not easily implemented or are not effective (FAO). A number of studies indicate that the level of use and awareness of PPE in certain developing countries is insufficient to ensure the safety of farm workers using hazardous pesticides (Banerjee *et al.*, 2014; Gesesew *et al.*, 2016; Neupane *et al.*, 2014).

49. Potential for exposure and impacts on human health during the manufacture of dicofol depend upon the manufacturing process. Chen and Kwan (2013) highlighted the increased risks to workers from production processes using the open-system and the need to move to closed-system production processes. The OELs presented by Rohm and Haas (reported in Cornell, 1993) and Cropcare (2001) highlight the dangers of potential atmospheric concentration build up and exposure, particularly through dermal contact with atmospheric vapors. The Chen and Kwan (2013) study notes that the two remaining open-system production plants in China closed in 2009. India's request for the continuation of the exemption for use of DDT as an intermediate in the manufacture of dicofol indicates that it occurs in a closed-system process at HIL (UNEP/POPS/COP.7/INF/3) and states:

"Dicofol is produced in a closed system in batches. Through condensation of chloral and monochlorobenzene (MCB), DDT is produced which is further dehydrochlorinated to DDE followed by tetrachloro through chlorination. Tetrachloro further hydrolyzed by an acidic medium to produce dicofol. Non transformed manufacture wastes ethylene dichloride (EDC) is recovered from the final product for re-use through distillation. Whole manufacturing process is done in closed system where after every step transformed materials are transferred through closed lines and reaction process occurs in closed vessel".

50. Li *et. al*. (2014b), however, reports a study, working on the manufacture of dicofol in the closed system process that released PCDD/PCDF. In this study high concentration of PCDD/PCDF have been found to be produced from a closed system dicofol manufacturing process. Dioxins and furans were not only found in waste water and waste acid, but also in the dicofol products itself.

51. It is unclear from publicly available literature whether Adama Insecticides Limited in Israel (formerly Makhteshim Agan) is still actively manufacturing dicofol and whether this process is open or closed.

52. Based on the information reviewed, the restrictions on the production and use of dicofol could take two forms. Firstly, to protect manufacturing workers, occupational exposure could be reduced by phasing-out all remaining
open-production facilities to use closed-systems only. This would limit the risk of exposure during manufacture. Secondly during agricultural use of dicofol the use of the correct PPE and suitable REIs could help to better protect farm workers, particularly during application and the manual harvest of some crops. The issue of exposure via food or through the environment is more complex, and possible restrictions could limit the use of dicofol to specific crop-pest combinations, however there is insufficient evidence to conclude how effective this would be. A restriction on production and use would be less effective than a prohibition but would reduce the total quantity of dicofol used and potential exposure under certain scenarios.

Environmentally sound management of obsolete stock; Clean-up of contaminated sites

53. Although global production and use of dicofol has undergone significant reductions, there may potentially be stock of dicofol remaining in a number of locations across the globe. Additionally, the continued manufacture and sale of dicofol is still ongoing in a limited number of countries.

54. The management of obsolete stock of dicofol presents a challenging issue due to the complexity of the supply chain and end users. Dicofol products have been designed both for use on crops within larger scale operations, and for use on ornamentals such as orchids and rosebushes. Product size can also vary significantly from as small as 1 litre containers (AK-20 HC Free, produced

by Adama)[9] to 200 kg containers (Hindustan Insecticide limited website).[10] This makes the identification, collection, and secure destruction of dicofol stocks particularly challenging due to the disperse nature and the locations of remaining stock. The International POPs Elimination Project (IPEP) (Saoke, 2005) provides an overview of work conducted in Africa to locate and manage obsolete stock of pesticides in a secure fashion. The study report found the presence of dicofol based products at two sites in Nairobi with a total quantity of 255 l of dicofol (as active ingredient). A further quantity of 0.4 kg of dicofol (total quantity of active ingredient) was also found at a site in the Rift Valley, Nakuru. This highlights the need for education campaigns and concerted efforts to help work with farmers and other consumers to reclaim obsolete products for safe management. It also highlights a potential risk for the mismanagement of obsolete stock and potential release to environment either intentionally or unintentionally from the loss of containment during storage or handling.

55. One option for secure disposal of dicofol products, as with many other persistent organic pollutant compounds, is through thermal destruction. Thermal destruction of dicofol does not pose a technical problem, however access to appropriate destruction facilities is limited in some countries. Torres (2008) also provides details of an alternate means of destruction. This involves the use of supercritical water oxidation (SCWO) and subcritical water oxidation (SBWO). The use of SCWO and SBWO is useful where the maximum organic content is limited to 20%. The process works through the use of oxidant products, such as hydrogen peroxide, oxygen, nitrite, nitrate, and water at temperatures and pressures above the critical point of water (374°C and 218 atmospheres) and in subcritical conditions (370°C and 262 atmospheres) to treat waste. Under these conditions, organic materials become very soluble in water and are then oxidized to produce carbon dioxide, water, and salts or inorganic acids.

56. Contaminated sites, particularly at former manufacturing sites, remain a concern. Chen and Kwan (2013) discuss the identification of two contaminated sites of former manufacture where dicofol was produced using open systems. The Great Wall Pesticide and Chemical Group site at Zhanjiakau in the Hebei province of China was remediated by Veolia in 2012, while the second site at Shandong owned by the Da Cheng Company still awaits remediation. Liu et al (2015), provide details of a soil sampling study at a former dicofol manufacture site in Shandong. Dicofol was detected in soil cores in concentrations ranging from 0.5 to 1440 mg/kg, with the highest concentrations found in the middle of the production facility area. This was despite the fact that the original surface had been a concrete floor approximately 0.5 m thick. Soil cores were taken from surface level to a depth of 5 m, with the highest dicofol concentrations found in the 2.5-3 m range. While the study does not provide details of the cost of remediation, comparison to similar remediation of contaminated soils (involving excavation and thermal treatment) quoted within the RME for PCP (UNEP/POPS/POPRC.10/2) provides estimates of around 3.2 million USD for a former contaminated production site for PCP in Haverton, USA and 3.7 million USD (converted from NZ dollars) for a similar former site of production in New Zealand.

57. Dicofol has been produced and formulated by a number of operators in a wide set of geographies spanning most continents. Chen and Kwan (2013) highlighted the significance of dicofol manufacture for the emissions to environment of dicofol, and contamination of soil, sediment and biota. Furthermore, Qiu *et al*. (2005) commented on atmospheric concentrations of DDT over the Taihu Lake, near Shanghai, which were identified as being linked with the manufacture of dicofol at a plant on the north side of the lake. The monitoring and remediation of contaminated sites is a significant undertaking which will in turn likely have high associated costs.

58. To summarize, while there has been a decline in the production and use of dicofol, it has been manufactured in significant quantities, with a diverse set of potential applications, end users and labelling. This represents a challenge for the identification, collection and safe destruction of obsolete stock of dicofol. An awareness campaign and concerted efforts working with farming communities and other end users would likely be needed to help effectively manage the collection and safe destruction of obsolete stock to prevent mismanaged loss to the environment.

Establishment of maximum residue limits in water, soil, sediment or food

59. There is only limited data on the setting of maximum environmental levels for dicofol. The EU Directive on Environmental Quality Standards (EQS) (2013/39/EU) sets both maximum annual average concentrations for surface waters and maximum concentrations in aquatic biota. For surface waters these values are 1.3 ng/l (reported within the EQS Directive as $1.3 x10^{-3}$ µg/l) for inland waters and 0.032 ng/l (reported as $3.2 x10^{-5}$ µg/l) for all other surface waters. The maximum concentrate for

[9] http://www.adama.com/mexico/es/portafolio-de-soluciones/manejo-de-plagas/ak-20.html.

[10] http://hil.prosix.in/dicofol.php.

biota within the aquatic compartment is 0.033 mg/kg (reported in the EQS Directive as 33 µg/kg) wet weight. As a means of comparison, research by Loos (2012) provided limits of quantification for surface waters as low as 0.005 µg/l. The dossier, developed as the evidence base for creation of critical thresholds under the EQS Directive also provides data on a wide range of predicted environmental concentrations (PEC) for Europe. The PEC values quoted in the dossier (EC Dicofol EQS dossier, 2011) range from 0.097 µg/l as a measured concentration by James *et al*. (2009) to 115 µg/l as a modelled concentration by Daginnus *et al*. (2009).

60. While EQS set environmental standards for protection of the environment, it is also possible to set maximum residue levels (MRLs) for food (based on good agricultural practice) which should be set at levels to protect human health from dietary exposure. MRLs are developed on a country and crop specific basis and so globally will vary for a number of reasons. To help provide a harmonised approach to the MRLs in use, globally work has been completed under the Codex Alimentarius Commission supported by the WHO, the FAO and national governments to development of international MRL values reported within the CODEX international food standards. Table 2.1 provides the agreed MRL (referred to as CXL by CODEX) values for dicofol within the CODEX. Where development of MRLs varies, and in some cases are yet to be developed, the CODEX provides a valuable tool to allow protection of human health. This is particularly important for developing countries that may not have a national MRL. Further examples of MRLs that have been developed include for example the EU regulation on pesticide residues in food and feed (EU 899/2012) (Austria, 2016), which sets maximum allowable concentrations for dicofol in a variety of food and feed goods. In Australia, all pesticides registered for use have MRLs for all domestic production set under the Agricultural and Veterinary Chemicals Code Instrument No. 4 (MRL Standard) established in 2012. Table 2.2 provides details of the MRLs set under EU and Australian regulations for comparison of some working limits that have been set. Additionally, the US Food and Drug Administration (US FDA), under CPG Sec. 575.100 action levels for unavoidable pesticide residues in food and feed commodities for a variety of different pesticides. Under the US FDA, the action level for dicofol within animal feed is 0.5 mg/kg (reported as 0.5 ppm) (US FDA, 2016).

61. Data available to help establish maximum residual levels of dicofol in water, soil, sediment or food is limited. Further data on development of environmental limits for the natural environment would be needed to draw more complete conclusions.

Table 2.1
CODEX maximum residue limits (CXLs) for dicofol[11]

	Maximum residue limit (mg/kg)
Spices, Fruits and berries	0.1
Spices, Roots and Rhizomes	0.1
Spices and Seeds	0.05
Tea, Green, Black (black, fermented and dried)	40

Table 2.2
Maximum residual concentration for dicofol in food (all values as mg/kg)

	European Union (Regulation (EU)No 899/2012)* Thresholds based on limits for dicofol	**Australian Agricultural and Veterinary Chemicals Code Instrument No. 4 (MRL Standard) 2012** Limits for dicofol for all domestic uses**
Cereals	0.01	–
Citrus	0.02	0.5
Fruits	–	5 (excludes strawberry)
Pomes	0.02	0.2
Stonefruit	0.02	1
Berries	0.02	1 (strawberry)
Tomatoes	0.02	1

[11] http://www.fao.org/fao-who-codexalimentarius/standards/pestres/pesticide-detail/en/?p_id=26

	European Union (Regulation (EU)No 899/2012)* Thresholds based on limits for dicofol	Australian Agricultural and Veterinary Chemicals Code Instrument No. 4 (MRL Standard) 2012** Limits for dicofol for all domestic uses
Pulses	0.02	0.5
Fungi	0.02	–
Cucumber, Gherkin	–	2
Brassicas	0.02	5
Leafy vegetables	0.02	5
Meat products	0.02	–
Nuts	0.05	5 (almonds)
Seeds / oil seeds	0.05	0.1 (cotton seed)
Tea	0.05	5
Hops	–	5

* http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:226:0001:0017:EN:PDF
** https://www.legislation.gov.au/Details/F2014C00970

62. Additionally, data from the EU, USA and Australia also provide guidelines for limits set on residual concentrations in food and feed. These limits can provide some guidance on the work completed by a number of nations to identify and set safe limits. The risk profile for dicofol provided additional data on acceptable daily intakes (ADI) developed in Australia (Australian Government, 2016); the EU (JMPR, 2011) and USA (US EPA, 1998) as 0.001 mg/kg bw, 0.002 mg/kg bw and 0.0004 mg/kg bw respectively. Additionally, Australia has established an ADI value for dicofol of 0.001 mg/kg bw (Australian Government, 2016).

2.2.2 *Identification of critical uses*

63. Dicofol has been used as pesticide for the treatment of mites in a wide range of crops and also on ornamentals such as orchids and rose bushes. However, a number of prohibitions have now been established by many countries across the globe growing different crops in different geographies and climatic conditions, with transition to alternative options (both chemical and non-chemical) adopted by many nations. Insufficient data has been found both from the Annex F survey and a wider supporting literature search on whether there are any uses that can be defined as critical. None have been identified by Parties or observers or through the review of literature.

64. Possible critical uses for which there may not be an alternative available in country will arise where there are specific crop-pest combinations where a chemical and/or non-chemical alternative is not yet available. There is also the possibility that there may be cases where there are technical obstacles which make transition to alternative options more difficult. For example, an initial reduction in crop yields during transition to alternate methods for pest control in cotton fields in India, as reported by Eyhorn *et al*. (2007). However, studies such as those by Eyhorn (2007) and Chen and Kwan (2006) demonstrated that it was possible to remove dicofol from these applications when a transition processes was put in place to overcome a number of technical and practical obstacles.

65. The evidence reviewed suggests that chemical and/or non-chemical alternatives are technically feasible for dicofol. The identification of critical uses based on crop/pest combinations for dicofol may therefore relate to transitional issues for replacement by alternative approaches, such as technology transfer and financial management. This could be managed with technical and financial assistance under the auspices of the Convention with a time-limited exemption for transition.

2.2.3 *Costs and benefits of implementing control measures*

Prohibition on use

66. Prohibition of the production, use, import and export of dicofol would represent the most effective measure for protection of both the environment and human health under the Stockholm Convention. This would cease all current and potential future releases of dicofol, while existing environmental concentrations would decline over time. The risk profile on dicofol

(UNEP/POPS/POPRC.12/11/add.1) provides detailed information on the toxicological and environmental effects that can be attributed to exposure of dicofol at doses which cause effects. The prohibition of dicofol would remove these risks and related economic costs for addressing health and environmental effects linked to releases and exposure.

67. Possible costs related to the prohibition of dicofol and the associated use of chemical and non-chemical alternatives include: (1) Implementation costs for governments and authorities; (2) Cost impacts on the two companies that still manufacture dicofol; (3) Possible cost impacts on farmers using dicofol (for use of alternatives and possible initial changes in productivity in terms of quantity or quality); (4) Cost impacts on society for agricultural products grown using dicofol, costs for management of obsolete pesticides and remediation of contaminated sites, and waste disposal costs; and (5) Cost impacts on environment and health due to dicofol use. No data has been identified / provided to calculate the scale of these possible costs.

68. There is only limited information providing a cost impact assessment for the comparison of pesticide prices and transition from dicofol to other chemical alternatives. Van der Gon (2006) of TNO, provides such a study for the European geographic area based on data from 2002. This study is also included within the UNECE (2010) exploration of management options. The UNECE dossier states:

"*TNO has established that prices of alternative substances are ranging from one to five times the price of dicofol. TNO estimated the costs for replacing dicofol to range from 90 Euro to 665 Euro per kilogram dicofol replaced, depending on the price of the compounds used as a substitute. In practice in most cases the most economical options will be selected. Only in very typical situation more expensive alternatives have to be used. This means that the overall costs of substitution will be near the lowest estimates. For this projection the costs are estimated to be 100 Euro per tonne replaced*".

It is of note that dicofol is no longer used within the European Union.

69. Other case studies presented by Chen and Kwan (2013) and Eyhorn (2007) provide further insights for Asia around the potential economic costs and benefits of prohibition. Chen and Kwan (2013) makes it clear that the production facilities manufacturing dicofol employed a sizeable workforce. The transition arrangements in the study involved the need for settlement packages and retraining of workers to minimize the economic impacts on this target group. Additionally, considerable effort was made to work with farmers through training programmes and transition to alternative practices linked to IPM. The co-financed GEF project cost 17.6 million US dollars over a six year period. However, it should be recognized that China was a major global producer of technical DDT and dicofol, and the related cost of the GEF project can be expected to mirror the scale of the industry. Recent figures from the production facility in India estimate annual production during 2015 – 2016 at only 93t (India, 2016). Eyhorn (2007) highlighted the economic constraints that face farming communities in India, and hesitance to move to unfamiliar alternatives.

70. Prohibition on the production, use, import and export of dicofol has already been completed by many nations around the globe with different crops, geographies and climatic conditions, demonstrating that it is technically feasible. In the longer term no significant economic impact has been identified (at least for those countries with prohibitions). However the transitional costs and impacts may mean that short term effects (such as reduced crop yields, training costs for farm workers to adopt new approaches and economic impacts for workers within pesticide manufacturing industries) are possible and this should be considered as part of the POPs Review Committee assessment and technical assistance programme of the Convention.

Restriction on use

71. A restriction on the production, use, import and export on dicofol would be less effective than a full prohibition but would limit the potential release and exposure of dicofol under certain scenarios. In developing what kind of restriction could be needed it is necessary to establish the key criteria for the manufacture and use of dicofol and also to identify critical uses that would form part of the restriction. The evidence reviewed and presented within this dossier has highlighted that in particular the open-system production of dicofol represents a high risk, both from direct exposure of workers and also the generation of wastes contaminated with both dicofol and DDT. Information provided by India (India, 2016) states that the facility operated by Hindustan Insecticides Limited is a closed-system only. It is unclear whether the production facility in Israel operated by Adama (formerly Makhteshim Agan) is closed or open.

72. Guidelines prepared by the US EPA (2006) highlighted the need for specific PPE when working with dicofol during manufacture or use and included of longer REI values for protection of farm workers entering treated areas for some commodities. These REI values ranged from

20 – 87 days, varying dependent on different crops and farming activities. REIs are intended to protect farm workers, particularly those working with crops where harvesting is completed manually. There is no evidence that the identified PPE and REIs are in use for all global farming communities and urban users. Restrictions could potentially be used to protect these workers with the use of dicofol limited to only crops that are harvested mechanically such as cotton and alfalfa. It should be noted that while REI values limit the risks to workers from direct exposure, they may do little to limit environmental exposure in use and manufacturing sites and may not limit long range transport of dicofol.

73. Finally a time-limited restriction to use dicofol only for those crop/pest complexes identified as critical could limit the use of dicofol. However in attempting to identify critical uses, there is insufficient information, and no specific examples of critical uses were provided by Parties or observers as part of the Annex F survey.

74. A restriction on the use of dicofol for specific crops would likely entail similar activities and cost impacts as a prohibition, as detailed in the previous section.

75. To summarize, a restriction on the production, use, import and export of dicofol would be less effective at protecting the environment and human health than a full prohibition. It could be possible to limit the use of dicofol to only key critical uses, which would limit potential exposure while also limiting economic impacts where technically feasible options are unavailable for specific crop/pest combinations. However, no critical uses have been identified. Furthermore, it would be technically possible to limit occupational exposure by imposing restrictions on the nature of manufacture (e.g. specifying closed-systems only) and worker activities (e.g. recommending use of correct PPE in all global geographic areas. A number of studies suggest that PPE is not easily implemented in developing countries, and may not be effective, is currently not worn by a large number of small-scale pesticide users in hot climates, and that many governments have not been able to enforce its use (NPASP, 2012; Banerjee *et al*., 2014; Neupane *et al*., 2014). It is, however, important to highlight that information on the scale of economic costs due to a restriction on dicofol have not been identified.

2.3 Information on alternatives (products and processes)

2.3.1 Overview of alternatives

76. Based on the responses provided to the Annex F request for information, the supporting information from Canada, PAN and IPEN, and additional literature references, a range of alternatives to dicofol have been identified. Dicofol has been used across a broad range of crop types, as well as ornamentals, in an equally broad set of geographical regions (see section 1), and different types of alternatives are available, including chemical alternatives, biological controls, botanical preparations, agroecological practices such as those used in agroecology, organic farming and IPM.

77. In the response to the Annex F information request, Canada and India report on potential alternative chemical pesticides to dicofol. Ten pesticides are registered in Canada for the control of mites and reference to the approved uses is made. India reports on four alternative chemical pesticides.

78. PAN and IPEN have provided information on non-chemical alternatives to dicofol, i.e. biological control systems, botanical preparations and agricultural practices. Specific information on agroecological practices and IPM as alternative processes to the use of dicofol is provided for the following crops: cotton, tea, citrus and ornamental crops.

79. Additional information on all these potential chemical and non-chemical alternatives to dicofol is also available from the literature and covers a range of crops and geographical regions, demonstrating that alternatives do exist and are already in active use. This section of the risk management evaluation provides an overview of the main chemical and non-chemical alternatives, including their properties, technical application and potential for use as alternatives to dicofol.

2.3.2 Chemical alternatives

80. Over 25 chemical alternatives to dicofol are available for specific crop-pest combinations. Some of the chemical alternatives have been evaluated as part of the assessment of alternatives to endosulfan (UNEP/POPS/POPRC.8/INF/13). This section provides a breakdown of the key alternatives, identified based on the information provided by Parties and observers as part of the Annex F responses and upon the frequency with which alternatives were identified in the literature. These sections include an analysis of their technical feasibility (highlighting the potential strengths and weaknesses), costs, efficacy, risks, availability and accessibility.

81. Any transition to alternative substances must be mindful of the health and environmental hazard profiles of the alternatives under consideration. Simply replacing persistent organic pollutants with other hazardous chemicals should therefore be avoided and safer alternatives should be pursued.

To ensure that a potential alternative leads to the protection of human health and the environment, the chemical being considered should be assessed to determine whether it is safer than persistent organic pollutants, contains characteristics of persistent organic pollutants, or has other undesirable hazardous characteristics.

Abamectin

82. Abamectin (CAS-No 71751-41-2) is a mixture of avermectin B1a (min 80%) and avermectin B1b (max 20%). The avermectins are compounds derived from the soil bacterium *Streptomyces avermitilis*. Abamectin is a natural fermentation product of this bacterium and acts as an acaricide, nematicide and insecticide for use in a wide variety of crops. Abamectin is used to control insect and mite pests of a range of agronomic, fruit, vegetable and ornamental crops. Abamectin is used to control insect, tick and mite pests of a range of fruit, vegetable and ornamental crops.

83. India (2016) reported that abamectin (abamectin technical) is a potential alternative to dicofol within their nation.

84. According to Manners (2013), abamectin is registered (or with minor use permit) in Australia for ornamental use against two spotted spider mite, *Tetranychus urticae*. Occasional abamectin resistance has been detected at high levels in Australian horticulture.

85. Rodrigues and Pena (2012) applied and assessed abamectin for the control of the red palm mite (*Raoiella indica* Hirst) on coconuts in Florida. Using spray treatments in field trials, abamectin was effective in reducing the mite population, compared to the untreated control, especially at 8 and 14 days after treatment. No statistical differences were observed among all treatments applied (i.e. etoxazole, abamectin and sulphur), including abamectin at 42 and 55 days after treatment, suggesting the chemicals no longer have an effect on mites at 42 days or more after treatment.

86. Lasota and Dybas (1990) stated that abamectin is highly unstable to light and has been shown to photodegrade rapidly on plant and soil surfaces and in water following agricultural applications. Abamectin was also found to be degraded readily by soil microorganisms. Abamectin residues in or on crops are very low, typically less than 0.025 ppm, resulting in minimal exposure to humans from harvesting or consumption of treated crops. In addition, abamectin does not persist or accumulate in the environment. Its instability as well as its low water solubility and tight binding to soil, limit abamectin's bioavailability in non-target organisms and, furthermore, prevent it from leaching into groundwater or entering the aquatic environment. Abamectin can have adverse impacts on pollinators and biological control organisms (Khan *et al*., 2015; Broughton *et al*., 2013; Jin *et al*., 2014). Abamectin was found to decrease the longevity of forager worker bees (Aljedani and Almehmadi, 2016). A summary of the Global Harmonized System (GHS) classification of hazards for abamectin is provided within Table 2.3.

Propargite

87. India (2016) reported that propargite (CAS-No 2312-35-8) is a potential alternative to dicofol within their nation, and is marketed under the tradename Propargite 57% EC. Propargite is registered (or with minor use permit) in Australia for ornamental use against the two-spotted spider mite, *Tetranychus urticae*. There is occasional detection of low levels of resistance in Australian cotton and roses to propargite (Manners, 2013).

88. Propargite can be used to control phytophagous mites on a variety of crops, including vines, fruit trees, tomatoes, vegetables, ornamentals, cotton and maize.

89. Propargite generally has been shown to have low acute toxicity via the oral and dermal routes of exposure. However, it is considered to be severely irritating to both the skin and eyes, and dermal sensitisation effects have been observed. Propargite poses a potential for adverse effects on reproduction in birds and mammals. Risk to aquatic organisms and plants is generally lower than the risk for birds and mammals (US EPA, 2001). In a laboratory study, Rhodes et al. (2013) have associated exposure to propargite with an increased risk of Parkinson’s disease. According to the US EPA (2001), propargite is classified as a likely human carcinogen based on the appearance of intestinal tumours in test animals. In 1999, US EPA revoked tolerances for the use of propargite on apricots, apples, peaches, pears, plums, figs, cranberries, strawberries, green beans, and lima beans since those uses were believed to pose an unacceptable carcinogenicity dietary risk. A summary of the GHS classification of hazards for propargite is also included in Table 2.3.

Bifenzate

90. Bifenazate (CAS-No 149877-41-8) is an acaricide effective against a wide range of phytophagous mites and used in a range of crops and ornamentals in Canada, USA and Australia.

91. Bifenazate is registered in Canada for the control of mites. Bifenazate is the active ingredient in the end-use products Acramite 50 WS and Floramite SC. Acramite 50 WS is used to control European red mite, two-spotted spider mite and McDaniel mite (apples only) on apples and grapes, while Floramite SC is used to control two-spotted spider mite and Lewis mite on greenhouse ornamentals, including in shadehouses and interiorscapes.

92. In the response to the Annex F information request, Canada indicated that bifenazate is both available and accessible in Canada, has been evaluated for its human health and environmental safety, and is currently registered and used in Canada; hence, it is considered to be technically feasible in Canada.

93. Based on an evaluation of available scientific information, under the approved conditions of use, Canada (2016) states that bifenazate has societal value and does not present an unacceptable risk to human health or the environment.

94. According to Dutcher *et al*. (2009), bifenazate is an effective chemical control for pecan leaf scorch mite in the USA. In field trials bifenazate was tested as a possible replacement for dicofol. Dutcher *et al*. indicated that the cost of control with bifenazate may be justified when based on literature values of the potential yield reductions associated with a lack of mite control in pecan. A summary of the GHS classification of hazards for bifenazate is provided in Table 2.3.

Fenbutatin Oxide

95. Fenbutatin oxide (CAS-No 13356-08-6) is an organotin compound. Fenbutatin oxide is registered in Canada for the control of mites. Fenbutatin oxide is an insecticide used to control mites in greenhouse food (tomatoes, cucumbers) and ornamental crops and for outdoor uses on ornamental nursery stock. The end-use products, formulated as wettable powders, can be applied in the greenhouse by conventional hydraulic handheld sprayers and outdoors with low volume ground boom equipment and backpack sprayers.

96. In the response to the Annex F information request, Canada indicated that fenbutatin oxide, is both available and accessible in Canada, has been evaluated for its human health and environmental safety, and is currently registered and used in Canada; hence, it is considered to be technically feasible in Canada. Fenbutatin oxide is unlikely to affect human health provided that risk reduction measures are implemented, such as protective equipment for handlers, advisory label statements on potential spray drift and run off, buffer zones for aquatic and terrestrial habitats. Fenbutatin oxide is toxic to aquatic organisms (Canada, 2016).

97. Based on a hazard assessment of alternatives to dicofol, including fenbutatin oxide, Sánchez *et al*., 2010 stated that compared to dicofol, fenbutatitn oxide is “better for humans but in most cases worse for the environment, aquatic life specifically being an issue”. Fenbutatin oxide is relatively immobile and persistent in the environment, with no apparent major route of dissipation. It is practically non-toxic to birds on an acute basis, but extremely toxic to both freshwater and estuarine aquatic organisms. In mice, fenbutatin oxide caused a significant decrease in epididymal sperm count, sperm motility, sperm viability and sperm function (Reddy et al, 2006).

98. According to Manners (2013), fenbutatin oxide is registered (or with minor use permit) in Australia for ornamental use against the two-spotted spider mite, *Tetranychus urticae*. Fenbutatin oxide has sporadic high level resistance. High level resistance develops easily, but is unstable and reverts over time. A summary of the GHS classification of hazards for fenbutatin oxide is provided in Table 2.3.

Pyridaben

99. Pyridaben (CAS-No 96489-71-3) is an insecticide and acaricide. It is used to control mites and whiteflies on ornamental plants, flowers and foliage (non-food) crops in green houses, and to control mites on apples, pears and almonds.

100. Pyridaben is registered in Canada for the control of mites. Pyridaben oxide is registered for greenhouse food and non-food crops, terrestrial food/feed crops and ornamentals. Registered pyridaben end-use products are formulated as wettable powder, to be applied using field sprayers or hand-held spray equipment.

101. In the response to the Annex F information request, Canada indicated that pyridaben is both available and accessible in Canada, has been evaluated for its human health and environmental safety, and is currently registered and used in Canada; hence, it is considered to be technically feasible in Canada.

102. Rodrigues and Peña (2012) applied and assessed pyridaben for the control of the red palm mite (*Raoiella indica* Hirst) on coconuts in Florida. Using spray treatments in field trials, pyridaben was effective in reducing the mite population, compared to the untreated control.

103. Based on a hazard assessment of alternatives to dicofol, including pyridaben, Sánchez *et al*. (2010), stated that aquatic toxicity, bioconcentration and environmental fate of pyridaben are similar to synthetic pyrethroids used in agriculture. The main distinguishing feature is that pyridaben is more photo-labile than most pyrethroids i.e. pyridaben can be photochemically degraded. Laboratory studies show that pyridaben is acutely toxic to fish and invertebrates, with invertebrates being more sensitive than fish to pyridaben (Rand and Clark, 2000). Sánchez *et al*. (2010), state that chemical inhibitor agents of mitochondrial electron transport are as dangerous as dicofol to the environment and/or humans. In mice, pyridaben can induce DNA damage and chromatin abnormalities in sperm (Ebadi *et al*, 2013). A summary of the GHS classification of hazards for pyridaben is provided in Table 2.3.

Tebufenpyrad

104. Tebufenpyrad is registered (with minor use permitted) in Australia for ornamental use against two spotted spider mites (Manners, 2013). High resistance to tebufenpyrad was confirmed in Australia (Manners, 2013). Tebufenpyrad shows genotoxic activity in human cells in vitro (Graillot *et al*., 2012).

Other chemical alternatives

105. Apart from the chemical alternatives described above, a range of other chemical alternatives to dicofol are identified in the literature and based on the responses to Annex F information request (Canada and India). The alternatives are used on a range of crops and in various geographical regions. Some of the alternatives meet the FAO/WHO criteria for a Highly Hazardous Pesticide.[12] Table 2.3 provides an overview of the chemical alternatives to dicofol as reported in the Annex F response, including those described above.

106. The alternatives reported by Canada are available and accessible in Canada and have been evaluated for their human health and environmental safety. They are considered to be technically feasible by Canada.

Table 2.3
Overview of chemical alternatives reported in responses to the Annex F information request and a summary of the GHS classification of hazards

Chemical alternative to dicofol	Reported as an alternative by Parties and Observers (Annex F Survey)	Global Harmonized System (GHS)[13] hazard classifications
Abamectin	India (Abamectin technical)	H300 - Fatal if swallowed; H330 - Fatal if inhaled; H361d - Suspected of damaging the unborn child; H372 - causes damage to organs through prolonged or repeated exposure; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.
Acequinocyl	Canada	H317 - May cause an allergic skin reaction; H370 (lung) (inhalation) - Causes damage to organs; H373 (blood system) - May cause damage to organs; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.
Bifenzate	Canada	H317 - May cause an allergic skin reaction; H373 - May cause damage to organs; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.
Cyflumetofen	Canada	H300 - Fatal if swallowed; H331 - Toxic if inhaled; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.
Etoxazole	Canada	H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.
Fenazaquin	India (Magister 10% EC)	H301 - Toxic if swallowed; H332 - Harmful if inhaled; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.

[12] http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/code/hhp/en/.

[13] GHS hazard classifications based on Annex VI of the European Union Regulation on Classification, Labelling and Packaging of hazardous substances and mixtures.

Chemical alternative to dicofol	Reported as an alternative by Parties and Observers (Annex F Survey)	Global Harmonized System (GHS)[13] hazard classifications
Fenbutatin oxide	Canada	H315 - Causes skin irritation; H319 - Serious eye irritation; H330 - Fatal if inhaled; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.
Fenpyroximate	Canada	H301 - Toxic if swallowed; H317 - May cause an allergic skin reaction; H330 - Fatal if inhaled; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.
Formetanate hydrochloride	Canada	H300 - Fatal if swallowed; H317 - May cause an allergic skin reaction; H330 - Fatal if inhaled; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting ects.
Propargite	India (Propargite 57% EC)	H315 - Causes skin irritation; H318 - Causes serious eye damage; H331 - Toxic if inhaled; H351 - Suspected of causing cancer; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.
Pyridaben	Canada	H301 - Toxic if swallowed; H331 - Toxic if inhaled; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.
Spirodiclofen	Canada	317 - May cause an allergic skin reaction; H351 - Suspected of causing cancer; H410 - Very toxic to aquatic life with long lasting effects[14].
Spiromesifen	Canada	H332 - Harmful if inhaled; H410 - Very toxic to aquatic life
Tebufenpyrad	India	H301 - Toxic if swallowed; H317 - May cause an allergic skin reaction; H332 - Harmful if inhaled; H373 (gastro-intestinal tract) (oral) - May cause damage to organs; H400 - Very toxic to aquatic life; H410 - very toxic to aquatic life with long lasting effects.

2.3.3 *Non-chemical alternatives*

107. In line with the evaluation of alternatives to endosulfan (decision POPRC-8/6: Assessment of alternatives to endosulfan), PAN and IPEN, in their response to the Annex F information request, suggested that, for pest control, priority should be given to ecosystem-based approaches. The Conference of the Parties by decision SC-6/8 (UNEP/POPS/COP.6/33) encouraged Parties when choosing alternatives to give priority to ecosystem based approaches to pest control. Furthermore, ICCM4 recommended that when phasing out highly hazardous pesticides (which include POPs), emphasis should be placed on agroecological practices.[15]

108. Mites are renowned for rapidly developing resistance to repeated applications of the same pesticides (Manners, 2013). Furthermore, Manners (2013) concluded that, given the likelihood that resistance will eventually develop for a chemical product, relying on chemicals to control the two-spotted mite (*Tetranychus urticae*) is a poor long-term plan. It was recommended to consider insecticide application as a minor but essential part of an overall mite management plan.

109. The sections below describe the identified non-chemical alternatives to dicofol in two groups, i.e. biological control systems and botanical preparations; and agroecological practices.

Biological control systems and botanical preparations

110. Various biological control systems and botanical preparations, i.e. reduction of pest populations by natural enemies or plant extracts, are available as a potential alternative to dicofol. When transitioning to biological control systems or botanical preparations, consideration must be given to national and regional assessment outcomes.

111. In the response to the Annex F information request PAN and IPEN provided information on biological control options (pathogens and predators) and botanical preparations with a focus on India, given the current use of dicofol and its specific climatic conditions.

[14] https://pubchem.ncbi.nlm.nih.gov/compound/177863#section=Hazards-Identification.

[15] UN Environment (2015) IV/3 Highly hazardous pesticides, Report of the International Conference on Chemicals Management on the work of its fourth session, SAICM/ICCM.4/15.

112. *Beauveria bassiana* is a naturally occurring entomopathogenic fungus causing white muscadine disease in foliar pests through contact action. Susceptible foliar pests include mites, as well as aphids, boll weevil, caterpillars, codling moth, coffee berry borer, Colorado potato beetle, diamondback moth, European corn borer, fire ants, flies, grasshoppers, Japanese beetle, leafhoppers, leaf-feeding insects, mealybug, Mexican bean beetle, psyllids (lygus bugs and chinch bugs), thrips, whiteflies, and weevils (Caldwell *et al*., 2013). *Beauveria bassiana* is available in a number of commercial formulations in different countries and can be applied by standard spray equipment. These products are generally non-toxic to beneficial insects although some, such as ladybirds, can be affected. *Beauveria* products should not be applied to water, as they are potentially toxic to fish. When and how often to apply depends on the pest being targeted, and the temperature (UNEP/POPS/POPRC.8/INF/14/Rev.1).

113. *Metarhizium anisopliae* is a widely distributed natural soil fungus that attacks a variety of insects, causing green muscadine disease. It is used commercially in a number of countries, such as India, Canada and the USA. *Metarhizium anisopliae* has been approved in the USA as a microbial pesticide active ingredient for non-food use in greenhouses and nurseries, and at limited outdoor sites not near bodies of water. Susceptible pests include mites, as well as aphids, thrips, leaf hopper, whiteflies, scarabs, weevils, gnats, ticks, locusts, termites, cockroaches, flies, and mosquito larvae (Caldwell *et al*., 2013). *Metarhizium anisopliae* is not toxic or infectious to mammals but inhalation of the spores can cause allergic reactions. It is not harmful to earthworms, lady birds, green lacewings, parasitic wasps, honey bee larvae, and honey bee adults (UNEP/POPS/POPRC.8/INF/14/Rev.1).

114. Kumar (2011) evaluated the fungal pathogen *Hirsutella thompsonii* as a mycoacaricide for *Aceria guerreronis* on coconut in India. The fungus was found to be capable of bringing down the mite population by up to 90%, resulting in considerable reduction in pre-harvest nut damage. In several trials, the fungal treatment was superior to dicofol. Kumar (2011) indicates that, therefore, over the years state and central governments in India have shown interest in *H. thompsonii* as a mycoacaricide for the coconut mite.

115. In their response to the Annex F information request, PAN and IPEN also mention the introduction of predators in order to control mites. Potential predators (insects) as an alternative to dicofol include lace-wings, ladybirds, minute pirate bug, insidious flower bug, damsel bugs, aphid midge, predatory mites, rove beetles, hover flies, mirid bugs and predatory thrips.

116. Botanical preparations or plant extracts are also used against mites, often as part of agroecology, organic farming and IPM. In the response to the Annex F information request PAN and IPEN identified a number of botanical extracts that can be used to control mites. These include: *Clerodendrum viscosum, Melia azadirach, Vitex negundo, Gliricidia maculata, Wedelia chinensis, Morinda tinctoria, Pongamia glabra,* garlic, *Swietenia mahagoni* seeds, *Sophora flavescens, Acorus calamus rhizomes, Xanthium strumarium, Clerodendrum infortunatum, Aegle marmelos, Clerodendrum inerme, Phlogacanthus tubiflorus, Achanthus aspera, Artemisia nilagirica, Phyllanthus amarus* and *Lantana camara*. Mamun and Ahmed (2011) reviewed the widely available indigenous plants that may be used for the control of pests of tea in Bangladesh. They report that botanical products are environmentally safe, less hazardous, economic and easily available. Several of the indigenous plant extracts reviewed can effectively be used to control red spider mites on tea, such as the extracts of karanja (*Pongamia pinnata*), sweet flag (*Acorus calamus*), coriander (*Coriandrum sativum*) and artemesia (*Artemisia vulgaris*). One botanical preparation – neem or azadirachtin – is approved by the Government of India for mite control on tea (PAN and IPEN 2016).[16]

117. All the biological alternatives described above are already in use and therefore technically feasible, at least in the geographical and other circumstances where they are applied. They are also widely accessible, including in developing countries. No information on the costs of replacing dicofol with biological alternatives was found. As stated in the section on technical feasibility, Eyhorn (2007) reported that the longer term economic position of using organic agroecological approaches on cotton fields compared to chemical approaches was good with cost neutral / cost savings. However, it was likely income loss through yield reduction in the transitional year.

Agricultural practices, agroecology, organics and Integrated Pest Management (IPM)

118. Agricultural practices herein mean any cultural practice to support pest management. The agricultural practices included here are mainly practices that are used in agroecology, IPM and organic farming, such as varietal selection, use of certified pest free plants, selection of appropriate planting time, crop rotation or the use of botanical pesticides or biological controls.

[16] http://cibrc.nic.in/biopesticides2012.doc.

119. Agroecology, organic farming and IPM all emphasize the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourage natural pest control mechanisms.

120. Manners (2013) mentions a number of relatively simple practices to reduce the likelihood that the two spotted spider mite (TSM) will infest or re-infest crops, such as: "1. Wherever possible, reduce weeds that may harbour TSM, particularly solanaceous weeds, clover and mallows. 2. Avoid introducing infested seedlings or other plant material into the crop. 3. Remove/quarantine old, infested plants that may be a source of mites for new plantings. 4. In glasshouses, mite-proof screens and doors can sometimes be installed to reduce the likelihood of pests entering. 5. Reduce staff movement in and through areas that are known to have mite populations. 6. Overhead watering may help reduce populations of TSM. However, be aware that wet plants are more difficult to monitor when using methods such as beating. 7. Identify infestations early through regular monitoring. 8. Examine monitoring records to determine patterns in farm infestations."

121. Chen and Kwan (2013) documented IPM technologies for leaf mites control in China. Overall, the IPM demonstration in the three demonstration sites covered a total area of 31,000 hectares (reported as 465,447 mu in Chen and Kwan, 2013). The demonstration areas covered 11 towns, 200 villages, with participation of over 1,800 families. Through demonstration, 8 types of alternatives were identified as economically viable substitute of dicofol for mites control for cotton. The project concludes that the successful introduction, demonstration and promotion of IPM technologies to substitute dicofol usage provided a viable alternative to pesticide use, resulted in significant benefits to the farmers in terms of reduced quantity and frequency of pesticide use, increased quantity and improved quality of crops, expanded market and export potential and generated increased profit. Furthermore, the elimination of dicofol use contributed to food safety, human health and the local and global environment. The IPM techniques effectively implemented and demonstrated in three counties in China on cotton, citrus and apples, included for example the investigation and forecast of the development of leaf mite in order to keep timely and effective control; increase in cover plants in orchards to provide habitat to natural enemies of leaf mite; the adjustment of cultivation to make it unsuited for the development of mites; and the improvement of varieties which could be resistant to mites. Total 3 years (2010-2012) economic benefits generated to the farmers in the three crop types demonstration amounted to RMB 1,512 million (approximately 240 million USD in 2012) (Chen and Kwan, 2013).

122. PAN and IPEN (2016) report on a number of recommendations for non-chemical agroecological and IPM control of mites in cotton, citrus, cut flowers and tea. Use of good agricultural practices greatly helps to prevent mites from reaching economically damaging levels. These include for example (but not limited to) using mite-tolerant varieties; thinning out dense shade in tea plantations to prevent the excessive build-up of mites; using cover crops in citrus orchards to provide habitat for natural enemies; avoiding nutrient and water stress; ensuring good drainage; uprooting and burning infested plants; removing alternate host plants (*Borreria hispida, Scoparia dulcis, Melochia corchorifolia* and *Fussiala suffruticosa*) in and around tea plantations and; keeping the field free of weeds.

2.3.4 Summary of alternatives

123. A range of alternatives to dicofol have been identified. Different types of alternatives are available, including over 25 chemical alternatives, biological controls (pathogens, predators), botanical preparations, and agricultural practices (such as those that are used in agroecology, organic farming and integrated pest management). The range of alternatives reflects the various pest-crop combinations for which dicofol is applied, in regions with very different climatic conditions.

124. A number of chemical alternatives are available, with proven efficiency and efficacy. Some do have a hazard profile similar to dicofol or other hazardous characteristics, including meeting the FAO/WHO criteria for highly hazardous pesticides, while other alternative pesticides are considered to be less toxic.

125. All the alternatives described are considered to be technically feasible alternatives, available and accessible in a number of countries. No essential uses for dicofol have been identified for which no alternatives are available. Indeed, prior to its phase-out in the USA, about 50% of dicofol that was used had been applied on cotton but only about 4% of the total crop of cotton was treated with dicofol, suggesting that in many cases alternatives are available and affordable (UNECE, 2010). However, the available information does not allow conclusions to be drawn on whether this is the case for all areas where dicofol is still used.

126. Non-chemical alternative products and processes, and more specifically biological control systems, botanical preparations, agroecological practices, organic farming and IPM, have proven to be

very efficient as an alternative to dicofol in different countries (including India, China, Australia) and for different crops, such as cotton, tea, citrus, apples.

2.4 Summary of information on impacts on society of implementing possible control measures

2.4.1 Health, including public, environmental and occupational health

127. The POPRC concluded that dicofol is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects. Several Parties and observers state that the current use of dicofol gives rise to adverse health and environmental effects and expect that the control of dicofol will positively impact health and the environment. Several Parties and observers also stated that it was important to note that dicofol was now banned in many countries with chemical and/or non-chemical alternatives technically feasible and available. The production and use of dicofol had fallen below 1,000 t per year by 2012, compared to 5,500 t in 2000, indicating that its use could be justifiably ceased to protect human health and environment.

2.4.2 Agriculture, aquaculture and forestry

128. Several Parties and observers to the Stockholm Convention have provided information within the Annex F responses to highlight that many different chemical and non-chemical alternatives exist which could act as viable alternatives to dicofol. Observers to the Stockholm Convention (PAN and IPEN) also highlighted that many countries have already banned dicofol and switched to alternative approaches without substantial economic impacts. The use of safer chemical or non-chemical alternatives would reduce the risk of health effects to agricultural workers and consumers, while also limiting negative environmental effects from use of dicofol. Additionally the studies documented by Chen and Kwan (2013) and Eyhorn (2007) both demonstrate that moves towards IPM based approaches can prove successful, with similar crop yields and labour demands avoiding the use of chemical alternatives completely.

129. Eyhorn (2007) indicated that crop yield reductions of 10–50% in the first year of transition could be expected with new techniques, with income recovery and potential increases occurring after transition compared to conventional farming. Information such as this is limited to India and it is unclear what additional steps could be taken to limit the transitional impacts.

2.4.3 Biota (biodiversity)

130. Observers (PAN and IPEN) expect positive impacts on biodiversity if the use of dicofol is prohibited. Information provided by PAN and IPEN particularly highlights the impact of dicofol upon insects, and the indirect effects for the eco-system which will in turn have overall impacts for biodiversity. The use of non-chemical alternatives can prove effective at mite control for a range of crops without adversely affecting the biodiversity of the natural or agricultural environment. Dicofol is toxic to predatory mite species that provide valuable natural pest management services (Wu et al, 2011; Carbera et al 2004; Childers et al, 2001; Hardman et al, 2003). Exposure to sublethal amounts of dicofol resulted in task-dependent reduced learning in the honeybee in laboratory studies (Stone *et al.*, 1997).

2.4.4 Economic aspects

131. Only very limited data on economic aspects has been provided through the Annex F responses. Equally, only limited data has been found from other sources to supplement the development of the risk management evaluation dossier for dicofol. One Party (India) stated within their Annex F response that a comparative analysis of other chemical alternatives within their nation found that dicofol was the most economically advantageous for treatment of mites, based on price and efficacy. However further specific details of this analysis have not been provided within the Annex F submission. Observers (PAN and IPEN) provided a counter-point to this noting that dicofol is already banned in many countries with successful transition to both non-chemical and/or chemical alternatives without any obvious negative economic impact witnessed.

132. Chen and Kwan (2013) and Eyhorn (2007) indicated potential initial transition costs and impacts upon agricultural output which would also have economic implications for farming communities, but with longer term effects either cost neutral or result in higher incomes than conventional farming approaches in specific circumstances. No data is provided on the full financial impact of the transitional costs to organic farming.

133. Chen and Kwan (2013) highlighted the need for settlement packages and re-training for those personnel working at dicofol manufacturing facilities to limit the impact of ceasing production.

Equally, considerable effort was placed on training and support for farming communities to help change farming practices and switch to non-chemical approaches largely based around IPM.

2.4.5 *Movement towards sustainable development*

134. Elimination of dicofol is consistent with sustainable development plans that seek to reduce emissions of toxic chemicals. The elimination of dicofol is relevant to a number of the Agenda 2030 Sustainable Development Goals, in particular Goal 2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture), Goal 3 (ensure healthy lives and promote well-being at all ages), and Goal 15 (protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).

135. A relevant global plan is the Strategic Approach to International Chemicals Management (SAICM).[17] SAICM makes the essential link between chemical safety, sustainable development, and poverty reduction. The Global Plan of Action of SAICM contains specific measures to support risk reduction that include prioritizing safe and effective alternatives for persistent, bioaccumulative and toxic substances. The Overarching Policy Strategy of SAICM aims to ensure, by 2020, that chemicals or chemical uses that pose an unreasonable and otherwise unmanageable risk to human health and the environment based on a science based risk assessment and taking into account the costs and benefits as well as the availability of safer substitutes and their efficacy, are no longer produced or used for such uses. Additionally, the FAO has agreed to facilitate the phase out of Highly Hazardous Pesticides,[18] the definition of which includes those pesticides that are deemed to be POPs.[19] The fourth international conference on chemicals management (ICCM 4), which assists with the implementation of SAICM, emphasises the need to replace highly hazardous pesticides with agro ecologically based approaches. The sixth meeting of the Conference of the Parties to the Stockholm Convention, taking into account the reports by POPRC, also referred to giving priority to ecosystem-based approaches to pest control.[20].

136. The assessment of non-chemical alternatives within section 2.3.3 within this dossier has highlighted that a number of viable options exist which could be used instead of the application of chemical pesticides. These agroecological practices, which include the use of biological controls and plants known to be poisonous to mites, represent a sustainable option to effectively manage the pest without use of chemical options. Further information on the proportion of farming practices using chemical vs non-chemical approaches has not been identified.

2.4.6 *Social costs (employment etc.)*

137. Chen and Kwan (2013) highlighted potential negative social impacts for those personnel who are employed within the facilities manufacturing dicofol. However, the global decline in the manufacture and use of dicofol, which fell below 1,000 t per annum in 2012, compared to 5,500 t in 2000, would mean that a relatively small number of people would be affected should a prohibition on dicofol be introduced. The study by Chen and Kwan (2013) noted that these effects could be offset through support to find alternative employment at national level.

138. Eyhorn (2007) highlighted that the move towards an organic farming approach for cotton farmers in India actually helped to empower the farmers. The fear of failing crops from use of untested approaches, together with tight economic margins, meant that farming communities were reluctant to switch to alternative chemicals or approaches and relied heavily on the guidance of pesticide retailers (Eyhorn, 2007; Wang *et al.*, 2015). However, at the end of a two year study based on 60 farmers using conventional chemical techniques and 60 using organic farming approaches, the crop yields were similar, as were the labour requirements but the costs were reduced.

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[17] http://www.chem.unep.ch/saicm/.

[18] New Initiative for Pesticide Risk Reduction. COAG/2007/Inf.14. FAO Committee on Agriculture, Twentieth Session, Rome, 25-28 April 2007. ftp://ftp.fao.org/docrep/fao/meeting/011/j9387e.pdf ftp://ftp.fao.org/docrep/fao/meeting/011/j9387e.pdf.

[19] Recommendations. First Session of the FAO/WHO Meeting on Pesticide Management and 3rd Session of the FAO Panel of Experts on Pesticide Management, 22-26 October 2007, Rome, Italy. http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/JMPM_2007_Report.pdf

[20] Decision SC.6/8 (UNEP/POPS/COP.6/36)

2.5 Other considerations

2.5.1 Access to information and public education

139. Several Parties provided information on actions taken to promote access to information and training. Canada provided details of information which can be found on Health Canada's Pest Management Regulatory Agency website.[21] Additionally, Canada also provided review dossiers on a number of chemical alternatives to dicofol as part of pesticide regulation and registration programs. India provided information detailing active ongoing training programs provided to farming communities on the safe use and storage of pesticides. The European Commission makes a range of information available through the Commission website. This includes both sections on the safe use and management of pesticides in general,[22] but also on the topic of persistent organic pollutants.[23] PAN Germany provides an on-line service for non-chemical pest management in tropical crops[24]. FAO provides an agroecology knowledge hub.[25]

2.5.2 Status of control and monitoring capacity

140. Several Parties to the Stockholm Convention stated through the Annex F responses that monitoring and control programmes were either already underway or were planned to start in the near future. Austria (2016) provided details held by the Environment Agency of Austria for monitoring of dicofol in wastewater, suspended solids and biota. A total of 252 samples have been analyzed, with only one sample identified as having concentrations above the limit of quantification. Additionally, under the European Union EQS Directive, a mandatory requirement is placed on all European Member States to develop inventories of releases and losses which are made publically available through river basin management plans. This will include dicofol as one of the named sets of pollutants for estimates of environmental concentrations in the aquatic environment. Note that inventories of releases and losses relate to the quantities of material released into the environment rather than an obligation for ambient monitoring. They do, however, serve as a valuable tool to identify and quantify magnitude of releases to the aquatic environment. Serbia (2016) provided details of plans under Official Gazette of Republic of Serbia No.24/14 which places Serbia in alignment with the European EQS Directive (2008/105/EC) and a need to limit releases of named substances, including dicofol. A surface water monitoring programme for dicofol is expected to start in Serbia by not later than 2018. India (in their Annex F response) provided information stating that monitoring programmes for dicofol were still in development, but that there was an intention to conduct monitoring programs in the near future.

141. Monitoring data is scarce for dicofol in surface waters, ground waters, sediments and biota. In Europe, James *et al*. (2009) reported that only very few EU Member States routinely monitor for dicofol in water or sediment and there was no routine monitoring of dicofol in biota. EU Directive 2013/39/EU requires EU Member States to establish supplementary monitoring programmes for priority substances added to the Directive, with monitoring required by the end of 2018. Since 2013, a monitoring study of fish in six German rivers indicted general compliance with the EQS for dicofol (Fliedner *et al*., 2016). However there is little published data for dicofol levels in most countries, and the situation in terms of compliance with EQS is unclear. A report by Entec (2011) indicated that the UK, Italy and Demark were expected to meet the EQS, while levels as high as 0.06 µg/L had been measured in France. Dicofol concentrations previously reported in terrestrial and aquatic organisms and birds in various locations (OSPAR, 2008) were below the MRL stipulated in the EU Directive 2013/39/EU. A study of groundwater samples, collected from eight tube wells of different vegetable farm fields in Delhi, India reported dicofol concentrations of 0.191 to 0.293 µg/L (Thakur *et al*., 2015). This is more than two orders of magnitude higher than the EU EQS.

142. For levels of dicofol found in food, Article 32 of Regulation (EC) No 396/2005 requires EU Member States to monitor concentrations of pesticide residues to ensure compliance with the stated MRLs (see Table 2.2). National authorities are responsible for taking samples and reporting measured levels to the Commission. The European Food Safety Authoity (EFSA) publishes annual reports[26] of measured pesticide levels based on the data provided. Dicofol is monitored and report by nearly all Member States in this process. Table 2.4 summarizes the data on dicofol published in these reports

[21] http://www.hc-sc.gc.ca/cps-spc/pest/index-eng.php.

[22] https://ec.europa.eu/food/plant/pesticides/sustainable_use_pesticides_en.

[23] http://ec.europa.eu/environment/chemicals/international_conventions/index_en.htm.

[24] http://www.oisat.org/.

[25] http://www.fao.org/agroecology/en/.

[26] https://www.actu-environnement.com/media/pdf/news-28813-efsa-rapport-2015-residus-pesticides-aliments.pdf

since 2007. Dicofol has been measured above the MRLs in a small number of cases. In the USA, The Department of Agriculture has carried out a national pesticide residue monitoring program since 1992[27]. This sampling programme has detected low (<1 µg/m^3) levels of dicofol in various fruits and vegetables but no reported sample has been above EPA tolerance levels. In general terms, the number of detections of dicofol has declined in samples in the period 1992-2015. In the UK, the Expert Committee on Pesticide Residues in Food[28] tested 24 samples of agricultural products (14 from outside EU, 10 from inside the EU) in 2015. Dicofol was not detected at or above their reporting limits. A study of pesticide residues in Indian tea by Kottiappan *et al*. (2013) reported that in 468 samples tested, none were above the EU MRL for dicofol.

Table 2.4
Summary of data from EFSA Annual Report on Pesticide Residues

Year	Number of samples above the reporting level	Number of samples above the MRL[29]	Details of non-compliant samples
2007	71 out of 7239 samples)	0	n/a
2008	103 (out of 9369 samples)	2	Cucumber Spinach
2009	6 (out of 6734 samples)	0	n/a
2010	6 (out of 7493 samples)	3	Apples
2011	<1% (out of 8739 samples)	0	n/a
2012	Not specified	2	Peppers (imported from Turkey)
2013	Not specified	0	n/a
2014	Not specified	0	n/a
2015	Not specified	0	n/a

3 Synthesis of information

143. Dicofol is an organochlorine miticidal pesticide, used to control mites on a variety of crops. Dicofol was introduced commercially in 1955. The substance has been used primarily in East and Southeast Asia, the Mediterranean coast, as well as in Northern and Central America. Intended uses of dicofol cover fruits, vegetables, ornamentals, field crops, cotton, tea, and Christmas tree plantations. Between 2000 and 2007, global production of dicofol was estimated to have been 5,500 t/y but production has declined sharply since then as a number of countries have phased out production and usage, including Benin, Brazil, Canada, Columbia, EU Member States, Guinea, Indonesia, Japan, Mauritania, Oman, Saudi Arabia, Sri Lanka, Switzerland and USA,. Production of dicofol now predominantly takes place in a small number of nations, with key production remaining in Southern Asia. Until recently, China was one of the major global producers of technical DDT and dicofol, producing approximately 97,000 t of technical DDT between 1988 and 2002. In 2014, the last remaining technical dicofol producer in China ceased production of technical dicofol. Dicofol is produced in India in a closed system in batches, at a level of 93 t in 2015-2016. The exemption to produce and use of DDT as a closed-system site-limited intermediate in the production of dicofol has been extended until May 2024 by decision SC-7/1 (UNEP/POPS/COP.7/36).

144. At its twelfth meeting in September 2016, the Committee adopted the risk profile for dicofol (UNEP/POPS/POPRC.12/11/Add.1) and concluded that dicofol is likely, as a result of its long-range environmental transport, to lead to significant adverse human health and environmental effects such that global action is warranted (POPRC-12/1).

145. Currently applied control measures cover a broad spectrum of possible options including the prohibition and restriction of production, use, import and export, the replacement by chemical and/or non-chemical alternatives, the establishment of exposure limits in workplaces, application of quality standards, the environmentally sound management of obsolete stock and the clean-up of contaminated sites.

146. The successful prohibition on the production, sale and use of dicofol by a wide number of nations growing different crops within different geographies and climatic conditions indicates that

[27] https://www.ams.usda.gov/datasets/pdp/pdpdata

[28] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/487932/pesticide-residues-quarter2-2015-report.pdf

[29] MRLs set by Regulation (EU) No 899/2012) are shown in Table 2.2.

viable chemical and non-chemical alternatives do exist; however, the available information is not sufficient to demonstrate that this is true in all cases. A restriction on production and use would be less effective at protecting the environment and human health than a full prohibition but would reduce the total quantity of dicofol used and potential exposure under certain scenarios. It could be possible to limit the use of dicofol to only key critical uses which would limit potential exposure while also limiting economic impacts where technically feasible options are unavailable for specific crop/pest combinations. However, no critical uses have been identified. No specific examples of critical uses were provided by the Parties and observers submitting information under Annex F.

147. While there has been a decline in the production and use of dicofol, it has been manufactured in significant quantities in the recent past, with a diverse set of potential applications and end users. Product size can also vary significantly from as small as 1 litre containers to 200 kg containers. This represents a complex supply chain and challenge for the identification, collection and safe destruction of obsolete stock of dicofol. While such goods may have been appropriately labelled to help identify the active ingredient, an awareness campaign and concerted efforts working with farming communities and other end users would likely be needed to help manage the collection and safe destruction of stock to prevent mismanaged loss to the environment.

148. Limited data is available to help establish environmental quality standards for dicofol in water, soil, sediment in order to protect environmental effects. For maximum residues levels in food to protect human health from dietary exposure work has been undertaken to assess and develop limit values for food in the WHO, EU, and Australia, with the data reported within this risk management evaluation. Similarly, there is limited monitoring data available to assess compliance with MRL or EQS values established for dicofol in food, surface water, ground water and biota. Systematic monitoring of dicofol in food is carried out in the EU and USA. The results of this monitoring have been summarized in this risk management evaluation.

149. Furthermore, it would be theoretically possible to reduce/avoid occupational exposure by imposing restrictions on the nature of manufacture (such as limiting this to closed-systems only and phasing out all remaining open-production facilities) and worker activities (e.g. by requiring and enforcing the use of correct PPE in all global geographic areas). However, a number of studies indicate that the level of use and awareness of PPE in certain developing countries is insufficient to ensure the safety of farm workers using hazardous pesticides.

150. The alternatives to dicofol, considered as technically feasible, include over 25 chemical pesticides, agroecological practices such as those used in agroecology, organic farming and IPM, biological controls (pathogens, predators) and botanical preparations. The range of alternatives reflects the various pest-crop combinations to which dicofol is or has been applied, in regions with very different climatic conditions. All the alternatives described are considered to be technically feasible, available and accessible in a range of countries (including China and Australia) and for different economically important crops, such as cotton, tea, citrus, and apples. India also provided information on available chemical alternatives, though they are not an exact replacement for dicofol in India.

151. The available information (primarily from Annex F submissions) is not currently sufficient to conclude that these alternatives could be feasibly implemented in all cases where dicofol is still used. The characteristics of chemical and non-chemical alternatives should be considered when choosing alternatives to dicofol, and their consistency with sustainable development. This emphasizes the need for further assessment under the local conditions and consideration of the specific agroecosystems and agricultural practices used, giving priority to ecosystem-based approaches to pest control.

4 Concluding statement

152. Having concluded that dicofol is likely, as a result of its long-range environmental transport, to lead to significant adverse effects on human health and/or the environment such that global action is warranted; having prepared a risk management evaluation and considered the management options; the Persistent Organic Pollutants Review Committee recommends, in accordance with paragraph 9 of Article 8 of the Convention, that dicofol be considered by the Conference of the Parties to the Stockholm Convention for listing and specifying the related control measures under the Stockholm Convention in Annex A without specific exemptions.

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