Chlorpyrifos

Risk management evaluation

Second Draft

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Executive summary

1. At its nineteenth meeting the Persistent Organic Pollutants Review Committee (POPRC) reviewed and adopted the draft risk profile for chlorpyrifos. The POPRC, having reviewed the risk profile, decided (POPRC-19/3) that chlorpyrifos is likely to cause significant adverse human health and environmental effects due to its long-range environmental transport. This finding supports the need for global action. A risk management evaluation was therefore prepared that includes an analysis of possible control measures for chlorpyrifos in accordance with Annex F to the Convention. Parties and Observers were invited to submit to the Secretariat the information specified in Annex F by 8 December 2023.

2. Responses regarding the information specified in Annex F to the Stockholm Convention have been provided by 13 Parties and six Observers. The risk management evaluation is based on these responses, additional literature sources, including cited references in the risk profile on chlorpyrifos, and the risk management evaluation of methoxychlor, which had similar uses to chlorpyrifos.

3. Chlorpyrifos is a broad-spectrum organochlorine pesticide (OCP) that has been in products for uses that can be broadly divided into the following categories: agricultural uses for food and feed crops, agricultural uses for non-food crops; veterinary uses; and uses in residential settings, industrial uses or public health applications. The majority of uses are in commercial agricultural settings, but volumes of use in each category are not known. Chlorpyrifos is used globally, although 15 countries plus the European Union (EU) have completely banned the use of chlorpyrifos, and its use is under review in several countries. Ongoing production of chlorpyrifos takes place primarily in China, India, Brazil, United States of America (USA) and EU, estimated to be approximately in the volume of 50,000 tonnes/year, but data are limited.

4. Possible control measures, some of which are currently applied by several nations, range from complete prohibition and restriction of production, use import and export; establishment of exposure limits and Personal Protective Equipment (PPE) in workplaces; the establishment of maximum residue levels (MRL) in water, soil, sediment and food and feed; and the environmentally sound management of stockpiles and clean-up of contaminated sites.

5. A prohibition of production, use, import and export by listing in Annex A without exemptions is the most effective control measure to prevent harm to human health and the environment. Several countries in a wide range of climates, economic development levels, and specific chlorpyrifos applications have successfully implemented this to date. Restricting production, use, import and export by listing in Annex A or B with exemptions would limit the potential release of chlorpyrifos to the environment where it is still being used. However, information on the exposure reduction and socioeconomic impacts of a restriction is limited. The management of obsolete stockpiles of chlorpyrifos presents a challenge due to the limited information available on the supply chain and possible end users. There is a potential risk resulting from the mismanagement of obsolete stockpiles and potential release to environment either intentionally or unintentionally, for example from the loss of containment during storage or handling. Some Parties noted that they rely on export to manage chlorpyrifos waste, that a phase-out period prior to the ban was beneficial in managing stockpiles, while incineration is not recommended. Limited information on costs related to control measures was provided, but varying cost impacts are expected depending on the country's use of chlorpyrifos and regulatory status.

6. Alternatives to chlorpyrifos have been identified by considering the uses of the substance for specific pests (e.g., aphids, mosquitos, termites, armyworms and locusts) and for specific applications (e.g., cotton, wheat and livestock), as well as investigating current common practices. Alternatives against common veterinary pests such as blowflies, lice and ticks have also been identified. Several chemical and nonchemical alternatives to chlorpyrifos have been identified for a wide range of uses. Among the chemical alternatives, diamide insecticides, spinosyns, avermectins, and pyrethroids have been identified. However, some chemical alternatives have expired use approvals in some countries (e.g., pyrethroids in the EU) or have more targeted uses. Several non-chemical alternatives to chlorpyrifos, such as agroecological practices, biological control systems, botanical preparations and physical barriers have also been successfully implemented.

7. Limited data suggests that transitioning to alternative pest control methods may lead to higher initial costs, but will reduce human health and environmental burden and costs in the long term and potentially reduce overall costs, increase productivity and/or quality of crops.

8. In conclusion, in accordance with paragraph 9 of Article 8 of the Stockholm Convention on POPs, the POPRC recommends the Conference of the Parties to the Stockholm Convention to consider listing chlorpyrifos under the Stockholm Convention in Annex A/B with/without exemptions.

1. Introduction

9. In June 2021, the EU submitted a proposal to list chlorpyrifos in Annex A to the Stockholm Convention (UNEP/POPS/POPRC.17/5). Following a review by the Persistent Organic Pollutants Review Committee (POPRC) at its seventeenth meeting (January 2022), it was concluded that chlorpyrifos fulfilled the screening criteria in Annex D and established an intersessional working group to review the proposal further and to prepare a draft risk profile in accordance with Annex E to the Convention (POPRC-17/4).

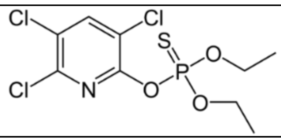
10. The POPRC considered the draft risk profile at its eighteenth meeting (September 2022) and adopted decision POPRC-18/3, by which it decided to defer its decision on the draft risk profile to its nineteenth meeting (UNEP/POPS/POPRC.18/INF/27). The revised draft risk profile was presented at the nineteenth meeting (October 2023) (UNEP/POPS/POPRC.19/4). The POPRC, having reviewed the risk profile, decided (POPRC-19/3) that chlorpyrifos is likely to cause significant adverse human health and environmental effects due to its long-range environmental transport. This finding supports the need for global action. The POPRC also established an intersessional working group to prepare a risk management evaluation that includes an analysis of possible control measures for chlorpyrifos in accordance with Annex F to the Convention.

11. Parties and observers were invited to submit to the Secretariat the information specified in Annex F by 1 December 2023. The submitted information and other relevant information are considered in this document.

1.1 Chemical identity of chlorpyrifos

12. Chlorpyrifos is an organophosphate pesticide. Table 1 provides details of the chemical structure and identity for chlorpyrifos. Identified Synonyms and trade names of chlorpyrifos are listed in the INF document [insert document reference].

Table 1. Information pertaining to the chemical identity of chlorpyrifos

Common name **IUPAC**	Chlorpyrifos O,O-Diethyl O-3,5,6-trichloro-2-pyridinyl phosphorothioate
CAS registry number **EC number**	2921-88-2 220-864-4
Abbreviations	CPY
Molecular formula	$C_9H_{11}Cl_3NO_3PS$
Molecular mass	350.59 g/mol
Structural formulas examples	

1.2 Production and uses

1.2.1 Production

13. As discussed in the risk profile, chlorpyrifos was first produced commercially in 1965 by Dow Chemical Company in the USA. Various methods for the commercial preparation of chlorpyrifos have been reported, with a commonly preferred approach involving the reaction of 3,5,6-trichloro-2-pyridinol with diethyl phosphorochloridothioate under basic conditions e.g., such as in the presence of sodium carbonate (Agency for Toxic Substances and Disease Registry (Agency for Toxic Substances and Disease Register [ATSDR] 1997).

14. Although data on total global production volumes are not available, information from the China Crop Protection Industry Association (CCPIA) (Annex E, 2022) estimated that before 2007 global production and use was about 10,000 tonnes/year, which has subsequently grown to around 50,000 tonnes/year. Data from the Annex F submissions provided by individual countries suggest that current global production volumes of chlorpyrifos remains around the figure of 50,000 tonnes/year. However, it is also noted the reported volumes from specific counties vary significantly between years, so there is some indication that in a given year, this value could be an underestimation.

15. Ongoing production of chlorpyrifos (on the basis of Annex F submissions) is indicated in China, India, Brazil, USA and EU. Further detail and discussion of the volumes and trends in production in these countries is provided in the INF document (#add reference). While most production previously occurred in North America and Europe, it is indicated that China and India are currently the biggest producers of chlorpyrifos globally since Corteva (formerly Dow Chemical) announced the end of chlorpyrifos production by the end of 2021 (Global Green Environmental Network, 2024 Annex F).

16. A number of other countries (e.g. Serbia, Argentina) have reported the import of chlorpyrifos active ingredient, used for the production of plant protection products and/or import of the products containing chlorpyrifos with ongoing sales of those products in those countries (further detail provided in the INF document (#add reference)). It is also noted that a number of countries have implemented bans or restrictions on production, import and/or export of chlorpyrifos (see Section 1.5).

17. A wide range of commercial products containing chlorpyrifos have been identified, with many individual trade names specified (see INF document Table 8 (#add reference)). Based on searches of publicly available databases[1] over 300 suppliers of products containing chlorpyrifos have been identified globally. The majority of identified suppliers are in China, with smaller numbers of suppliers identified in India, USA, EU and other countries. Chlorpyrifos has also been co-formulated as mixtures with other insecticides and fungicides (Pesticide Action Network [PAN] 2013).

1.2.2 Use

18. As discussed in the risk profile (UNEP/POPS/POPRC.19/4) chlorpyrifos is a broad-spectrum chlorinated organophosphate, which has been widely used globally as an active substance in insecticide, acaricide and termiticide products to control a variety of pests (e.g. aphids, termites, locusts, grasshoppers, boll worms, cutworms, white grub, borers, fall armyworm, scales, whitefly, weevils, thrips, and leaf miners), and in soil, on foliage, as a seed treatment, and on animals (ATSDR, 1997; PAN, 2013). The INF document presents a detaileddetailed information on different uses per country where information has been available (#add reference).

19. Chlorpyrifos has been in products for uses that can be broadly divided into the following categories: (i) agricultural uses for food and feed crops, (ii) agricultural uses for non-food crops; (iii) veterinary uses; and (iv) uses in residential settings, industrial uses or public health applications. There is insufficient data to establish the relative volume of use per category and sub-category, however agricultural use (food) is the most common authorized category of use (see INF document (#add reference)).

20. Pesticide products containing chlorpyrifos have been registered for use on many agricultural food and feed crops including uses on fruits (including citrus, apples, pears, peach, bananas, lychees, pineapple, watermelon), vegetables (including cabbage, spinach, sorrel, pepper, tomato, beans, onion, eggplant, cauliflower, potatoes), as well as crops such as corn, wheat, barley, rapeseed, grain and grain storage, sorghum, soybeans, sugar cane and sugar beets, mustard, sunflowers, peanuts, chickpeas, cocoa, tea, coffee, and fodder crops, as well as rice paddy (Annex F submissions, 2023; Foong *et al.*, 2020; US Environmental Protection Agency [PA)2009).

21. In agriculture, chlorpyrifos is commonly used as a foliar spray, or applied directly to soil and incorporated into it before planting (US EPA, 2009). It may also be applied to bark or seeds. Formulations for chlorpyrifos include emulsifiable concentrate, dust, flowable, granular wettable powder, microcapsule, pellet, and spray. It is applied by aerial spraying, chemigation (injecting pesticides into irrigation waters), ground boom sprayers, tractor-drawn granular spreaders, airblast sprayers, low- and high-pressure hand wands, backpack sprayers, hydraulic hand-held sprayers, shaker cans, belly grinders, push-type spreaders, large tank sprayers, compressed air sprayers, hose-end sprayers, and aerosol sprayers (US EPA, 2006; PAN, 2013).

22. Non-food agricultural applications for chlorpyrifos include use for cotton, as well as on poplar, grass, mulberry, rubber trees, for example to control locusts, aphids, armyworms, pillbugs, chinch bugs, common stalk borers, cutworms, flea beetles, and grasshoppers (ATSDR, 1997). It is also used on golf course turf, in commercial greenhouses, ornamental plants in nurseries, as well as in floriculture and silviculture (PAN, 2013; Pereira *et al.*, 2011).

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[1] A search was conducted of the web-based trading platforms were: Lookchem, World of chemicals, Chemnet, Chemsrc, Buyersguidechem, Molbase and Chemicalbook. The search was performed from 2023-12-04 – 2023-12-08.[2] See https://pan-international.org/wp-content/uploads/PAN_HHP_List.pdf (accessed 01.02.2024)

23. Chlorpyrifos has been used in veterinary applications, including in ear tags for cattle and as a sheep dip for the control of lice, blowfly and ked (ATSDR, 1997) and in animal health for general ectoparasite control (PMFAI Annex F, 2023), such as ectoparasites of cattle (Kenya, 2024).

24. Chlorpyrifos is also used in residential settings, for example to control pests in homes, and in industrial applications, e.g. industrial plants, food processing plants, warehouses, ships and commercial properties (Annex F submissions, ATSDR, 1997; PAN, 2013). A common use of chlorpyrifos in both residential and industrial applications is as a wood preservative, including on processed wood products, fence posts and utility poles, railway ties and railway box cars. It is reported that chlorpyrifos is widely used to control termites and borers in wood as well as in general building and construction settings (India Annex F, 2023).

25. Public health applications for chlorpyrifos include uses for the control of urban pests (including cockroaches, mosquitoes, flies, ants and termites), and in the control of vector-borne diseases. For example, it can be used as both a larvicide and adulticide for mosquito (for disease vector control), against fire ants, cockroaches, fleas, bugs and termites (China and India, Annex F, 2023).

26. According to information in the Annex F (2023) submissions, chlorpyrifos is still widely used in many countries and regions across each of the categories of use detailed above. The specific uses authorized in different countries, including the specific crop/pest combinations, vary widely.

1.2.3 Emissions

27. Chlorpyrifos can be released into the environment, primarily either during manufacturing, or from direct application during use. Additionally, spills or leaks during storage or preparation before use, as well as handling and cleaning equipment after use can contribute to its release (Damalas and Koutroubas, 2016). Upon its application as a pesticide, chlorpyrifos is directly released to the environment and can be further distributed by several potential pathways resulting in its dispersion into various environmental compartments such as air, soil, surface water (rivers, canals and lakes), sediment and groundwater (Wołejko *et al*., 2022).

28. Chlorpyrifos is considered to be semi-volatile and can be released to the atmosphere, either during production, by volatilization during foliage or soil application using ground or air broadcast equipment or during application as an ectoparasite, particularly cattle dip (ATSDR, 1997) Following application in the field, volatilization has been shown to contribute significantly to early losses of chlorpyrifos from soil surfaces (up to 25% within 24–48 h) and plant surfaces (80% within 24–48 h) (Australia Annex E, 2022). This has been shown to result in chlorpyrifos being detected in the air in major agricultural regions (California Department of Pesticide Regulation, 2014).

29. Chlorpyrifos has the potential to contaminate surface water through spray drift during application. It can also sorb to soil or sediment and may enter aquatic environments through runoff for several months following application (Das *et al*., 2020; Nandhini *et al*., 2021). Data indicates that most chlorpyrifos runoff is generally via adsorption to eroding soil rather than by dissolution in runoff water (UNEP/POPS/POPRC.19/4). Leaching or runoff from fields, pesticide disposal pits, and hazardous waste sites can inadvertently contaminate both groundwater and surface water with chlorpyrifos. Entry into water bodies can also occur from accidental spills, redeposition of atmospheric chlorpyrifos, and discharge of wastewater from chlorpyrifos manufacturing, formulation, and packaging facilities (ATSDR, 1997).

1.3 Data sources

1.3.1 Overview of data submitted by Parties and observers

30. This risk management evaluation is based on information that has been provided by Parties and observers to the Convention, including information provided within the Annex F call for evidence and provided by the following countries and observers:

31. Parties: Argentina, Brazil, Canada, China, Germany, India, the Netherlands, Norway, Oman, Republic of Moldova, New Zealand, Thailand, United Kingdom of Great Britain and Northern Ireland.

32. Observers: COLEAD, Global Green Environmental Network, International POPs Elimination Network (IPEN) and Alaska Community Action on Toxics (ACAT), Pesticide Action Network (PAN), Pesticides Manufactures & Formulators Association of India (PMFAI), Ecojustice Canada.

1.3.2 Other data sources

33. Additionally, information has been used from open information sources, as well as from scientific literature (see list of references). The following key references were used as a basis to develop the present document: (a) The risk profile on chlorpyrifos (UNEP/POPS/POPRC.19/4 and the accompanying INF document (UNEP/POPS/POPRC.19/INF/1); (b) the background documentation submitted to the Chemical Review Committee (CRC) associated with the proposed listing of chlorpyrifos under the Rotterdam Convention; (c) publicly available databases of commercially available chemical products (see Section 1.2.1); (d) the Risk Management Evaluations for other pesticides including methoxychlor (UNEP/POPS/POPRC.17/13/Add.1) and dicofol (UNEP/POPS/POPRC.13/7/Add.1).

1.4 Status of the chemical under International Conventions

34. Chlorpyrifos is not currently listed under an international agreement.

35. At the 19th meeting of the Chemical Review Committee of the Rotterdam Convention on Prior Informed Consent (PIC) in 2023, it was recommended that chlorpyrifos be listed in Annex III of the Convention. Notifications of final regulatory action meeting Annex II criteria for listing banned or severely restricted chemicals in Annex III came from the EU, Malaysia, Sri Lanka and Turkey.

36. Chlorpyrifos is included in PAN's International List of Highly Hazardous Pesticides (HHP)[2]. This links to the Global Framework on Chemicals (GFC) and to Resolution V/11 on Highly Hazardous Pesticides adopted at the International Conference on Chemicals Management, ICCM5, in September 2023. More specifically, target A7 of the GFC requests that by 2035, stakeholders have taken effective measures to phase out HHP in agriculture where the risks have not been managed and where safer and affordable alternatives are available; and to promote transition to and make available those alternatives. As to Resolution V/11, the UN community endorses the formation of a global alliance on highly hazardous pesticides; it requests i.a. to support low- and middle-income countries in their efforts to strengthen national regulatory frameworks and phase out highly hazardous pesticides.

1.5 Any national or regional control actions taken

37. Regulatory control actions for chlorpyrifos have been taken in a large number of countries. These actions prohibit or restrict the production, trade, use (in either all or some specified settings) and/or set maximum residual concentrations of chlorpyrifos. An overview of regulatory action taken in different countries was previously provided in the risk profile (UNEP/POPS/POPRC.19/INF/11). An update to this table has been developed on the basis of further information provided by Parties indicating new regulatory controls, or update to existing controls have been put in place (see INF document (#add reference)).

38. A full ban on the use of chlorpyrifos is in place in a number of countries and regions: Argentina, Canada, Chile, Colombia, EU (27 Member States), Morocco, Norway, Saudi Arabia, Sri Lanka, Switzerland, Thailand, Trinidad and Tobago, Turkey, UK, Vietnam (Annex F submissions, 2023; Ministry of Agriculture and Rural Development, 2020[3]; PIC, 2023; UNEP/FAO/RC/CRC.19/8; UNEP/POPS/POPRC.19/4). The phase out period (where specified) was generally between 1-2 years. More detailed information can be found in the INF document (#add reference).

39. Restrictions on the production, sale, use, import and/or export of chlorpyrifos are applied by a number of countries. Information has been provided by Australia, China, Egypt, India, Indonesia, Kenya, Malaysia, New Zealand, Oman, USA, Uzbekistan and Yemen in INF document (#add reference). Some countries (e.g. Australia[4], New Zealand[5], USA, Uzbekistan) are currently reviewing or reassessing chlorpyrifos uses due to health and environmental concerns (details in INF document (#add reference)).

40. The use and application restrictions vary by country and there is no consistent approach to regulatory control actions taken. For example, in Malaysia, chlorpyrifos is only allowed to be used for "public health uses and the control of 'urban pests' such as cockroaches, termites, mosquitoes, ants,

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[2] See https://pan-international.org/wp-content/uploads/PAN_HHP_List.pdf (accessed 01.02.2024)

[3] https://faolex.fao.org/docs/pdf/vie209585.pdf (accessed 12.01.2024)

[4] https://www.apvma.gov.au/news-and-publications/publications/gazette/gazette-25-12-dec-23 (accessed 04.01.2024)

[5] https://www.epa.govt.nz/industry-areas/hazardous-substances/chemical-reassessment-programme/active-projects/ (accessed 04.01.2024)

flies and bugs” (UNEP-FAO-RC-CRC.19). In Egypt it only is permitted to be used on cotton (Egypt Annex E, 2022), while in Oman it is only allowed for use against termites (Oman Annex F, 2023). The use of chlorpyrifos is also said to be severely restricted in Yemen but further details are not available (UNEP/FAP/RC/CRC.19/INF/6).

2. Summary of information relevant to the risk management evaluation

2.1 Identification of possible control measures

41. The objective of the Stockholm Convention (Article 1) is to protect human health and the environment from POPs. This may be achieved by listing chlorpyrifos in: a) Annex A to eliminate releases from intentional production and use (specific exemptions allowed) or (b) Annex B to reduce releases from intentional production and use (specific exemptions and acceptable purposes allowed); and/or (c) Annex C to reduce or eliminate releases from unintentional production.

42. Identification of possible control measures should address the potential direct exposure of humans to chlorpyrifos in occupational settings (including manufacture, product formulation, handling, and agricultural application and use), exposure at the waste stage, direct non-occupational exposure from uses such as application indoor or household use, and also indirect exposure from residual levels in food, as well as environmental releases and exposure.

43. Based on the nature of chlorpyrifos production and use, and noting that no evidence of unintentional production of chlorpyrifos has been identified, the following control measures are potentially available to address the above-mentioned aspects: (1) prohibition of production, use, import and export (Annex A listing, no exemptions); (2) restriction of production, use, import and export (Annex A or B listing with specific exemptions and/or acceptable purposes allowed).

44. In addition to the control measures considered above, the following additional aspects are considered (e.g. for additional national/regional-level actions), to ensure the control measures prevent or minimize exposure of humans and the environment: (3) measures to address occupational exposure, including establishment of exposure limits, use of personal protective equipment (PPE) or guidance or education and at the national level; (4) establishment of maximum residue limits in water, soil, sediment and/or food at the national level; and (5) environmentally sound management of obsolete stockpiles and clean-up of contaminated sites (in accordance with Article 6 of the Convention). These considerations are consistent with those considered in the past by the POPRC for other pesticides, including methoxychlor and dicofol.

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

2.2.1 Technical feasibility of possible control measures

Prohibition of production, use, import and export by listing in Annex A without exemptions

45. Prohibition of production, use, import and export of chlorpyrifos (i.e. by listing chlorpyrifos in Annex A to the Stockholm Convention with no exemptions) would likely represent the most effective and efficient means to protect human health and the environment.

46. A full prohibition of chlorpyrifos has already been successfully implemented in a number of countries (see Section 1.5) and chemical and non-chemical alternatives have been identified across most uses (see Section 2.3). It is also noted that these countries represent a diverse range in terms of climate, level of economic development and the specific applications (crop/pest combination) and category of use for chlorpyrifos (see Section 1.2.2), indicating these alternatives are generally viable and already used in practice.

47. For example, Malaysia (2023) (UNEP/FAO/RC/CRC.19/8/9) indicated that the anticipated withdrawal of chlorpyrifos in agriculture would not cause adverse impacts due to availability of cost-effective alternatives. Specific examples of chemical alternatives demonstrated to be feasible for vegetables and rice paddy were detailed. Similarly, Sri Lanka (2023) (UNEP/FAO/RC/CRC.19/8) indicated that a full ban on chlorpyrifos was considered feasible because chemical alternatives are available that are considered sufficient for all uses. It was also noted that the Integrated Pest Management (IPM) concept and its practices have been practiced as the government policy.

48. Canada (Annex F, 2023) noted that a previous regulatory decision on chlorpyrifos in Canada (RVD 2020-14) had identified two uses for which there were no alternatives available (for canola – for alfalfa looper control; and garlic – for dark sided and red backed cutworm) (Canada, 2020) allowing them a two-year period of use extension. However, a later decision (REV 2021-04) noted that the two remaining registrants for chlorpyrifos had not provided the information required for an updated health risk assessment, so all remaining uses were also subsequently cancelled.

49. It should also be noted that the specific situation and perception regarding the availability and feasibility of alternatives for a specific pest and/or crop differs between countries. For example, inputs from China (Annex F, 2023) and India (PMFAI 2023; India, 2023 Annex F) indicate the permitted use of chlorpyrifos for rice crops, while Sri Lanka and Malaysia have implemented a ban on chlorpyrifos for this use on the basis of the availability of feasible alternatives. Furthermore, the input of China (Annex F, 2023) highlighted that, while chlorpyrifos continues to be used for citrus crops, alternatives are available but are not used as they are not considered economically viable. Other countries (e.g., India) have now prohibited use of chlorpyrifos for citrus crops.

50. The consideration of full prohibition of chlorpyrifos (listing under Annex A) with or without exemptions will need to carefully consider the availability of alternatives to the wider range of uses for chlorpyrifos (see Section 1.2.2). A number of Parties and Observers have highlighted specific uses where it is argued that finding alternatives is challenging or not currently possible, however the current assessment has identified alternatives (see Section 2.2.2.). Similarly, since in many cases national-level bans have been put in place based on a detailed assessment of human health and environmental risks (see INF document (#add reference)), it will be important to take health and environmental impacts of any continued use into consideration when determining if a full prohibition should be implemented or if exemptions should be allowed (see below).

51. Wang *et al*. (2015) and the European Parliament (2021a) provide a perspective on the technical feasibility of prohibition and switch to alternatives, particularly in developing countries. It is noted these sources discuss pesticides more broadly and not chlorpyrifos explicitly, however the insights are relevant to this RME. Specific discussion on the switch to alternatives for chlorpyrifos is provided in Section 2.3 and 2.4 of this RME.

52. The European Parliament (2021a) highlighted that implementation of alternatives (e.g. IPM) in developing countries is difficult to achieve in practice due to a number of factors. These include: the difficulty in maintaining government support due to resistance from farmers and the [IPM] system complexity, external factors such as climate events and pandemics, the lack the of short- to medium-term business incentives for producers of pesticides, and the [economic and technical] challenges of the alternatives themselves.

53. Wang *et al*. (2015) noted that many farmers in China continued to use specific pesticides even when restrictions were implemented, and safer alternatives were available. Based on a survey of 472 Chinese farmers on practices and perspectives on the use of chemical pesticides, Wang *et al*. (2015) highlighted that due to economic constraints and fear of failing crops, many farmers were reluctant to change from their preferred choice of pesticides to alternatives they were unfamiliar with. It was also noted that pesticide retailers play a key role in influencing farmers' choice of restricted pesticides.

54. In conclusion, the efficacy of listing chlorpyrifos in Annex A for global elimination without exemptions (Prohibition) has been demonstrated by several countries already implementing a full ban. This would therefore likely represent the most effective means to protect human health and the environment from the risks associated with chlorpyrifos. Data provided through the Annex F submissions suggest that a number of chemical and non-chemical alternatives are already widely available (see Section 2.3.2), although combined data on price and efficacy was not sufficient to carry out a detailed review.

Restriction of production, use, import and export by listing in Annex A or B with exemptions

55. Chlorpyrifos could be added to Annex A or B with exemptions (or acceptable purposes). This would allow production and use for certain applications and limit the potential release to the environment of chlorpyrifos in countries where the pesticide is still being used and it is demonstrated that feasible alternatives for those uses are not currently available. While many countries have opted for a full prohibition of chlorpyrifos, in many countries regulatory measures are in place that still allow use of chlorpyrifos for specified uses (see section 1.5, 1.2.2, and INF document (#add reference) and a number of Parties and Observers have highlighted uses where it is argues alternatives are not currently available (see Section 2.2.2) .

56. Information on reduced exposure and socioeconomic impacts of restrictions are very limited due to a number of countries already having phased out the use of chlorpyrifos. A restriction with specific exemptions would reduce environmental loads of chlorpyrifos (albeit to a lesser extent than a full prohibition) and if a restriction with exemptions is implemented, additional measures would be required to address continuing human and environmental exposure resulting from those remaining chlorpyrifos uses.

57. Two pathways exist for release and exposure to humans (both workers and the general public), firstly during the manufacturing, formulation, handling (including at the waste stage) and/or via application of chlorpyrifos as a direct pathway (inhalation/ingestion/dermal contact) – where the general public is indirectly exposed via volatilization and dust; and secondly via contamination of food and water as an indirect pathway. It is also noted that exposure of the wider population to pesticides can also occur via inhalation of dust in homes, for example in locations near areas of application (Hung *et al.*, 2018; Teysseire *et al.*, 2021). Therefore, if a recommendation is made to list chlorpyrifos with specific exemptions for its continued use for certain specific applications, it should be accompanied by recommendations for additional measures to prevent or minimize exposure, e.g. for workers through the required use of PPE and enhanced controls in those applications, and improved guidance and education; and for the wider public through measures to impose limits on the level of residues in food and water (as well as measures to monitor and enforce these measures) and to limit exposure of the public from volatilized chlorpyrifos following application. These aspects are discussed in detail below.

58. For veterinary applications, restrictions on specific applications could be included where the risk of release to humans and the environment is high. For example, the restriction could limit the use of chlorpyrifos to specific settings to ensure release to the environment is prevented or minimized (i.e., prohibiting its use over open soil). This may mean that new equipment or infrastructure would be needed where chlorpyrifos is used, which could in turn carry additional costs.

59. In conclusion, a restriction of the production and use of chlorpyrifos (listing under Annex A with specific exemptions for specified uses) may be appropriate if it is determined there are at present no alternatives. However, while this would contribute to a reduction of environmental releases to the environment and the level of exposure to humans, this would be less successful than a full prohibition in reducing human health and environmental risks. To establish the appropriate restriction, an understanding of potential remaining routes of environmental release and human exposure (and establishing measures to control such exposure) associated with the manufacture, use and disposal of chlorpyrifos is essential, as well as identifying any uses where no feasible alternatives currently exist.

Controlling occupational exposure, for example through establishment of exposure limits, exposure reduction measures and requirements for PPE in workplaces

60. In accordance with Article 3(6) of the Convention if a specific exemption or an acceptable purpose is recommended for chlorpyrifos, Parties must take appropriate measures to ensure that any production or use under such exemption or purpose is carried out in a manner that prevents or minimizes human exposure and release into the environment.

61. Exposure routes differ for occupational workers and the general population, with inhalation and dermal exposure being increasingly likely in occupational settings and exposure via ingestion of contaminated food or drinking water more likely in the wider general population. Workers in industries that produce chlorpyrifos, or actively apply it in a range of settings (including farm workers who enter treated fields) are at higher risk of exposure than the wider general population. For the latter, those who use the insecticide in homes and gardens and people who ingest food treated with chlorpyrifos are at higher risks of exposure (ATSDR, 1997).

62. Standard occupational exposure limits (OEL) for the use of chlorpyrifos have previously been determined. The (US) Occupational Safety and Health Administration (OSHA) has set a Permissible Exposure Limit (PEL) of 0.2 mg/m^3 [6] for the average amount of chlorpyrifos that may be present in air during an 8-hour workday. A skin notation is included in the final rule to prevent the systemic effects that have been demonstrated to occur in humans dermally exposed to chlorpyrifos. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a Threshold Limit Value (TLV) of 0.1 mg/m^3 (inhalable fraction and vapor). An Acceptable Operator Exposure Level (AOEL) (US) has been set at 0.0015 mg/kg/day (Fenske *et al*. 2012).

63. To protect workers during manufacture, occupational exposure could be reduced by ensuring that production facilities use closed systems only. It is indicated that in India, the chlorpyrifos

[6] https://www.cdc.gov/niosh/pel88/2921-88.html (accessed 05.01.2024)

manufacturing process is carried out in closed system, with receiving, unloading, storage and charging of raw materials conducted through pipelines (India, 2023; PMFAI, 2023 Annex F). It is further indicated that the process is controlled and monitored closely, and that exposure of workers is controlled for example through the use of automated processes and machinery during packing and storage. Details of the manufacturing process for chlorpyrifos in other countries have not been identified.

64. Farmers are considered to be the most important occupational group exposed through direct transdermal contact and by inhalation during the preparation of spraying solutions, loading of sprayer tanks, and use of pesticides (Wołejko *et al*., 2022). Chlorpyrifos has high potential for adverse effects in such occupational applications, especially in developing countries, where very high exposure levels have been detected for workers applying chlorpyrifos, for example in Vietnam and Egypt (Phung *et al*., 2012; 2013). It is indicated that dermal exposure is of particular importance (Aponso, 2002; Fenske *et al.*, 2012). Exposure to workers has also been exacerbated by, for example, using greater than the recommended dose, poorly maintained spraying equipment, and not wearing adequate PPE (Aponso, 2002).

65. While the use of PPE such as impervious clothing, gloves, and face shields are recommended when working with chlorpyrifos-based products (PMFAI Annex F, 2023), it has been warned that even when all feasible PPE or engineering controls are used this may not be adequate to prevent or minimize occupational exposure as the use of PPE or maintenance and calibration of pesticide application equipment are not easily implemented or are not effective (US EPA, 2009; FAO[7]).

A number of studies (provided in PAN, 2023 Annex F) have highlighted the challenges and barriers associated with the level of use and overall effectiveness of PPE for reducing pesticide exposure to workers in countries where the use of chlorpyrifos is still widespread, including: a lack of available equipment, costs, wetness of PPE (caused by irrigation, sweat, and rain), illiteracy (inability to read labels that are usually the only source of safety instructions) lack of in-person education and training and technical support, leading to lack of overall awareness; physical discomfort, particularly in humid climates, with PPE not appropriately designed to take into account body type and gender considerations[8] (Walton *et al.*, 2017; European Parliament, 2021; WHO, 2014; Banerjee *et al*., 2014; Gesesew *et al*., 2016; Garrigou *et al*., 2020; Neupane *et al*., 2014). In practice, therefore using PPE as a control measure for chlorpyrifos exposure may be limited by the above-mentioned problems with current practices and contrary to the International Code of Conduct (ICC)[9] in countries with hot climates.

66. In conclusion - if continued production and use are allowed for certain specific uses by listing chlorpyrifos in Annex A or B (with exemptions), occupational exposure to workers during manufacture should be reduced by (i) ensuring that production facilities use closed systems only; (ii), ensuring appropriate PPE is consistently worn to enhance protection of workers, especially farmers during preparation and use. Challenges impacting the efficacy of using PPE and pesticide application equipment as control measures to reduce human exposure, especially in developing countries have been identified and must be addressed. Furthermore, the monitoring of such measures would impose challenges, especially in a global context. It should also be emphasized that while these control measures are expected to be effective for direct human exposure among workers, they do not significantly reduce broader environmental release and/or exposure of the general population and the environment.

Maximum residue limits in water, soil, sediment or food

67. Chlorpyrifos has been detected globally, in all continents and in all environmental compartments, including soil, sediment, air, fresh water, marine water, rain, snow, sea ice and biota, in regions close to application areas and in remote locations (UNEP/POPS/POPRC.19/INF/11). Furthermore, the consumption of contaminated food and water is an important source of secondary exposure, while breast milk an important source of exposure for infants (UNEP/POPS/POPRC.19/4). Therefore, to prevent or minimize exposure to humans and the environment from continued use of

[7] http://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/code/hhp/en/. (accessed 05.01.2024)

[8] https://www.ccohs.ca/oshanswers/prevention/ppe/personal-protective-equipment-body-type-and-gender-considerations.pdf (accessed 01.02.2024).

[9] The International Code of Conduct on Pesticide Management (FAO and World Health Organization (WHO), 2014) Article 3.6 states that "Pesticides whose handling and application require the use of PPE that is uncomfortable, expensive or not readily available should be avoided, especially in the case of small-scale users and farm workers in hot climates".

chlorpyrifos, if specific exemptions are recommended, Parties should also consider setting concentration threshold limits for chlorpyrifos in the environment and in drinking water, food and feed within national regulatory frameworks.

68. Existing guidelines and recommendations exist for chlorpyrifos at international level. For example, the WHO (2004) guidelines for drinking water quality include a guideline value for chlorpyrifos of 30 µg/L (rounded figure). Furthermore, Codex[10] sets specific values for the highest level of pesticide residue that is legally tolerated in or on food or feed when pesticides are applied correctly in accordance with Good Agricultural Practice.

69. It is noted that many countries and regions already set limits or environmental quality standard values (EQSs) for chlorpyrifos. For example, a large number of countries have set MRLs for chlorpyrifos in a wide range of specific food types under national legislation[11] – including Argentina, Australia, Brazil, Canada, Chile, China, Colombia, Costa Rica, EU, UK, Hong Kong, India, Indonesia, Israel, Japan, Malaysia, New Zealand, Norway, Philippines, Russia, Singapore, South Africa, South Korea, Switzerland, Taiwan, Thailand, USA, and Vietnam (see INF document (# add reference), for more detailed discussion).

70. Monitoring results of chlorpyrifos concentrations in food were reported previously in the risk profile (UNEP/POPS/POPRC.19/INF/11) and in many cases exceedances of MRL values have been noted. For example, as discussed in PAN (2013), residues of chlorpyrifos have been found in a wide variety of foods in many different countries, highlighting cases of relatively high concentrations detected in India, China, and Pakistan.

71. Results from the Norwegian pesticide residues monitoring program (Norway Annex E, 2022) have shown MRL exceedances for chlorpyrifos in various food commodities exceeding the limit by a factor of 10 in some cases. For 2020, residues of chlorpyrifos were found above the MRL (0.01 mg/kg) in dried beans, from Madagascar and Turkey, respectively. For 2019, residues of chlorpyrifos were found above the MRL (0.02 mg/kg) in coriander leaves from Laos, while for 2018, they were found above the MRL (0.01 mg/kg) in pears from China and in table grapes from Chile.

72. In Malaysia, it is reported that chlorpyrifos residues consistently exceeded national MRLs in recommended crops, including crops intended for export. In addition, according to data generated by the National Poison Centre Malaysia over a 10-year period (2006-2015), 40% of reported cases of insecticide poisoning involved pesticides from the organophosphate group, with chlorpyrifos being the most commonly reported pesticide (UNEP/FAO/RC/CRC.19/8).

73. While some countries have monitoring programs in place for controlling pesticide residues in food (see Section 2.5.2), very limited information has been provided on routine monitoring of chlorpyrifos levels in food products in the countries that have set MRLs. Such monitoring is likely lacking in many parts of the world. Setting environmental limits would allow a risk assessment scheme to consider whether these could be met after use. Clearly, setting of limit values for chlorpyrifos should be accompanied by measures to monitor concentration levels in the environment, as well as drinking water, food, and feed, to ensure exposure is being limited in practice.

74. Setting of MRL and/or EQSs and implementing specific Risk Management Measures and monitoring programs to ensure these are met, would help prevent and minimize releases to the environment but would be limited in comparison to a prohibition or restriction on production and use, so should be seen as an accompanying measure to a prohibition or restriction only.

Environmentally sound management of obsolete stockpiles and clean-up of contaminated sites

75. In accordance with Article 6 of the Convention, if chlorpyrifos is listed under Annex A or B, Parties will be required to ensure that stockpiles or wastes containing chlorpyrifos are managed in a manner protective of human health and the environment.

76. The management of obsolete stockpiles of chlorpyrifos presents a challenge due to the limited information available on the supply chain and possible end users. Products containing chlorpyrifos have been formulated for use in both larger scale farm settings and also for home gardening. The Pesticide Info database[12] lists over 5,000 products containing chlorpyrifos with possible continued use of these products. Control measures considered for chlorpyrifos could include information or education campaigns to help farmers and other consumers to safely dispose of obsolete products to ensure the safe management. It also highlights a potential risk for the mismanagement of obsolete

[10] https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/pestres/en/

[11] Based on a search of available databases provided by the governments of Australia and New Zealand.

[12] Provided by PAN https://www.pesticideinfo.org/chemical/PRI2051 (accessed 05.01.2024)

stockpiles and potential release to environment either intentionally or unintentionally, for example from the loss of containment during storage or handling.

77. The previously recommended treatment and disposal methods for chlorpyrifos are incineration, adsorption, and landfilling (International Register of Potentially Toxic Chemicals (IRPTC), 1989). Several non-combustion techniques developed for DDT (dichlorodiphenyltrichloroethane) are likely relevant for environmentally sound disposal of chlorpyrifos. These include Gas-Phase Chemical Reduction, Base catalyzed decomposition (BCD), Supercritical Water Oxidation (SCWO), Hydrodec and Ball Milling (UNEP/CHW.14/7/Add.1/Rev.1). One other option for the disposal of chlorpyrifos products is through thermal destruction/incineration in hazardous waste treatment facilities. Chlorpyrifos is a candidate for incineration at temperatures ≥650°C and exhaust gases should be controlled (although no specifics regarding control measures are listed). Weber *et al.* (2020) have found that under thermal decomposition (at the high temperatures mentioned above), chlorpyrifos decomposes into 3,5,6-trichloro-2-pyridinol (which is (eco)toxic), ethylene, and hydroxypyridinones (HOPOS) (which are (eco)toxic). The detection of HOPOS in uncontrolled conditions has proven elusive, making it difficult to detect in emissions during incineration. For these reasons incineration is not recommended.

78. Information on quantities of chlorpyrifos that have been destroyed is scarcely reported. Argentina (Annex F, 2023) has indicated that they must export all expired pesticides for treatment but have not provided further details of where they export to or the treatment the expired pesticides undergo. Alternate means of destruction of chlorpyrifos that have been deployed at full scale are not publicly available.

79. The short-term, phased approach to the removal of chlorpyrifos from the market, and for the cessation of its use in Canada, minimized the potential for waste and disposal implications of obsolete stockpiles (Canada Annex F, 2023).

80. The EU and UK have not identified stockpiles of chlorpyrifos or chlorpyrifos contaminated wastes at this time (Annex F, 2023). New Zealand indicated in its Annex F response that information on the collection and disposal of chlorpyrifos waste is not available, and moreover, there is not an appropriate disposal facility within the country should chlorpyrifos be listed as a Persistent Organic Pollutant (POP) (Annex F, 2023). There is a notable lack of information regarding stockpiles, which represents a challenge for the identification, collection, and safe destruction of any obsolete stockpiles of chlorpyrifos that may exist. Concerted efforts working with farming communities and other end users would likely be beneficial to help manage the collection and safe destruction of any obsolete stockpiles to prevent mismanaged loss to the environment.

2.2.2 Identification of uses for which there is at present no alternative

81. In many countries the use of chlorpyrifos remains authorized, with ongoing registrations for certain specific uses granted (see Sections 1.2.2 and 1.5). A number of countries (including India, China and Malaysia) have highlighted the importance of chlorpyrifos in **public health applications**, i.e., to control urban pests such as cockroaches, and **termites**, and also potentially in the control of vector-borne diseases. China (Annex F, 2023) has highlighted that chlorpyrifos plays an important role in pesticides for public health use because of its rapid knockout and high killing rate. India (Annex F, 2023) highlighted the lack of feasible and cost-effective alternatives for the broad-spectrum use of chlorpyrifos in crop protection (particularly **sucking insects** on **cotton**), soil treatment, seed treatment, **locust control and malaria vector control**. It was noted in particular, given the migratory nature of locusts, that restriction of chlorpyrifos may have an impact on locust control programs and in endemic situations like pest outbreak of invasive pests. India also noted the use of chlorpyrifos is key against **wood borers** and **termites**. Kenya also highlighted the lack of alternatives for use against **ectoparasites in cattle**, while China highlighted the use of chlorpyrifos against **rice pest borer, rice leaf roller and rice planthopper**. Additionally, in the Annex F request for information, PMFAI and India mention chlorpyrifos as an important part of IPM since the use of chlorpyrifos within IPM prevents the build of resistance to other pesticides (e.g., pyrethroids). However, in other countries covering these range of climates, alternatives have been successfully implemented (e.g. veterinary, public health and residential uses in Egypt are banned). While the reason for allowing continued use in specific applications (crop/pest type) is not always explicitly stated, a common explanation for this continued use typically relates either to the perceived lack of alternatives, or the perceived need for use in public health applications.

82. For the above key uses, chemical and non-chemical alternatives have been identified in sections 2.3.2 and 2.3.3, respectively, and INF document (# add reference). In terms of **public health applications,** such as cockroaches, fipronil can be used against organisms in the order Blattodea,

while *Stemona collinsiae* root extracts can help deter them. The INF document presents a list of alternatives against several order and species. While against **termites and wood borers,** both chemical and non-chemical alternatives have been identified, such as imidacloprid and borates, and physical barriers (e.g. tightly packed granite particles). Imidacloprid and Flonicamid have been used on **cotton** to combat **sucking pests** as well as diafenthiuron to combat whiteflies, while IPM has been used successfully in Ethiopia to grow cotton and phase out the use of chlorpyrifos. For **locust control**, the fungus *Metarhizium acridum* has been shown to specifically target the order Orthoptera and has been successfully used to combat locusts' outbreaks in China, Australia and Somalia.

83. In terms of **malaria vector control**, the WHO (2006) report on pesticides and their applications for the control of vectors and pests of public health importance includes chlorpyrifos on the list of recommended compounds and formulations to control mosquito larvae. Chlorpyrifos is also included on the list of insecticides suitable for cockroach control, although not explicitly 'recommended'. WHO (2013) also includes chlorpyrifos in the recommended insecticides for larval control of malaria vectors in humanitarian emergencies. However, in both cases it is noted that other insecticides are also included on those lists. It should be further noted that, in terms of disease vector control (e.g., for malaria), as stated in the WHO Guidelines for Malaria (WHO, 2022), larviciding only reduces vector density and so does not have the same potential for health impact as other approaches such as insecticide treated nets (ITNs) and indoor residual sprays (IRS). Therefore, larviciding should not be seen as a substitute to ITNs and IRS or a means to fill coverage gap in areas with significant malaria risk; rather, larviciding represents a potential supplementary strategy for malaria control. Chlorpyrifos is not included in the WHO (2023) list of insecticides to be used in ITNs or IRS[13]. Alternatives to chlorpyrifos for malaria control have been identified in section 2.3.2, such as broflanilide, bendiocarb, bifenthrin and alpha-cypermethrin.

84. With regards to **ectoparasites in cattle**, both chemical and non-chemical alternatives have been identified: DEET (N,N-diethyl-m-toluamide) is used to repel insects (including mosquitos) rather than kill them, while the fungus *Metarhizium anisopliae* is mentioned against ticks, and blowflies and lice are part of the order Diptera, against which the use of clothianidin, fipronil, teflubenzuron, as well as *Beauveria bassiana* have been mentioned. Rice-duck farming systems have been used successfully for suppression of **rice planthoppers, rice leafhoppers, yellow stem borer and rice leafrollers**, while diamine insecticides, e.g. cyantraniliprole, can be used against Lepidoptera in general.

85. It should also be noted that chlorpyrifos has been banned or restricted against uses in countries with similar climates to those that have claimed uses as key, (e.g. Sri Lanka has a total ban, and Egypt has banned all uses except in cotton, Malaysia has banned all uses except against urban pests). Overall, a large number of alternatives to a wide range of pests have been identified (see INF document (# add reference) and sections 2.3.2 and 2.3.3).

86. In addition, in 2021, several requests were received by the NGO the Rainforest Alliance for the granting of limited exceptions to specific crop, pest, and country combination scenarios available under their Exceptional Use Policy[14]. Authorization was granted for the use of chlorpyrifos in bananas and pineapples[15], but in both cases they indicated that the authorizations will not be renewed (Rainforest Alliance, 2021a and 2021b).

87. Alternatives for uses considered to be key by specific countries have been identified (see above, section 2.3 and INF documents), and no [explicit] examples of uses without alternatives have been identified. The successful implementation of bans, restrictions and use of alternatives in a range of climates, crops and non-agricultural uses, indicates that it is therefore unlikely that there are remaining uses with no alternatives.

2.2.3 Costs and benefits of implementing control measures

88. Possible costs related to the prohibition of chlorpyrifos and the associated uses of chemical and non-chemical alternatives include: (1) enforcement costs for governments and authorities, (2) costs accruing to companies that still manufacture chlorpyrifos and potential impacts on their staff, (3) costs accruing to farmers and other users using chlorpyrifos (from switching to alternatives and due to possible initial changes in volumes and quality of yields), (4) costs for management of obsolete

[13] The insecticides included in the WHO list are: Pyrethroids (e.g., alphacypermethrin, deltamethrin, lambda-cyhalothrin, etofenprox, bifenthrin); Organophosphates (e.g., malathion, fenitrothion, pirimiphos-methyl); Carbamates (e.g., bendiocarb, propoxur); Neonicotinoids (e.g., clothianidin).

[14] granting limited exceptions to specific crop, pest, and country combination scenarios where no feasible alternatives to HHPs are available

[15] In Costa Rica, Ecuador, Côte d'Ivoire

pesticides, waste disposal costs and remediation of contaminated sites; (5) costs due to training for proper use of chlorpyrifos products and clear information on these products and (6) benefits- would derive from the reduced environmental pollution and human health effects, such as conservation of biodiversity and reduced ill health. No data has been identified or provided to calculate the scale of the possible economic losses and cost-savings at a global level.

89. A targeted restriction on specific uses of chlorpyrifos would likely cause similar economic impacts as a prohibition, although at a more limited scale. It could theoretically be possible to limit the use of chlorpyrifos to only key uses, which would limit potential economic impacts. However, no uses without alternatives have been identified.

90. Limited Annex F information was provided on costs, including environmental and health costs, related to efficacy and efficiency of possible control measures in meeting risk reduction goals for chlorpyrifos. As alternatives for other pesticides have been in use for decades, costs for replacing chlorpyrifos are expected to impact countries still manufacturing, producing, and using chlorpyrifos more than countries that have phased out use. While it is expected there will be some cost impacts, PAN and the submitters for Argentina state that as long as chlorpyrifos is in use, there is a high cost for human health and the follow-on economic impacts (Trasande, 2017). No information on costs relating to transition from chlorpyrifos to alternatives has been found, and these costs will depend on which alternatives are available in each country. Information provided by the PMFAI[16] indicates that in India, chlorpyrifos costs USD 0.2-2.4/hectare per spray, while the other identified alternatives range from 3-10 times the cost for the specific regional crops (PMFAI Annex F, 2023) (see section 2.3.2 and INF document #add reference). A 2017 report by the California Department of Food and Agriculture's Office of Pesticide Consultation & Analysis (OPCA) revealed a similar situation: identified alternatives to chlorpyrifos for key crops could be 35-400% more expensive, depending on the crop (OPCA, 2017). Many countries have already completed the transition, thus the costs are not seen as prohibitive. However, short term economic losses due to, for example, loss of jobs within manufacturing and formulation industries and training costs for farm workers to adopt new approaches are possible (European Parliament, 2021b). For the loss of jobs in manufacturing and formulation, this would probably be compensated by new jobs with alternatives. It is possible that a temporary reduction in crop productivity will be experienced in areas where chlorpyrifos is used as a generic plant protection product, and that this may be followed by increased productivity when non-chemical alternatives and IPM practices are followed (see section 2.3.3). This should be considered as part of the POPRC assessment and technical assistance program of the Convention. At the same time, prohibitions prevent further costs related to impacts on human health and the environment as well as further remediation and environmental management costs resulting from manufacture and use of chlorpyrifos.

91. Prohibition and restrictions on the production, use, import and export of chlorpyrifos have already been completed by many countries globally, each with different crops, geographies, and climatic conditions, demonstrating that it is technically and economically feasible to prohibit or restrict the substance. The cost impacts of any additional control measure will naturally vary significantly between those countries which are already regulating chlorpyrifos via a total ban and those that are partly doing so, and where the use of chlorpyrifos may still be on-going.

2.3 Information on alternatives (products and processes)

2.3.1 Overview of alternatives

92. A range of alternatives to chlorpyrifos have been identified based on the supporting information provided by Argentina, Canada, COLEAD, Germany, Global Green Network, India, IPEN and ACAT, New Zealand, Oman, PAN, PMFAI, the Netherlands, and Thailand (Annex F, 2023), through a review of the literature, as well as based on the risk management evaluation of methoxychlor (UNEP/POPS/POPRC.17/13/Add.1). Chlorpyrifos has been used across a broad range of crops, agricultural uses for non-food crops, veterinary uses, and 'other' uses including in residential, public health and industrial applications in an equally broad set of geographical regions (see Section 1). Different types of alternatives are available, including chemical alternatives and non-chemical alternatives such as biological controls, agroecological practices, organic farming, and IPM.

93. COLEAD (Annex F, 2023) provided a list of potential chemical and non-chemical alternatives to chlorpyrifos registered in the African, Caribbean, and Pacific (ACP) countries. Chemical alternatives are also mentioned in the responses received by Argentina, New Zealand, India, PMFAI,

[16] On the basis https://ppqs.gov.in/statistical-database (accessed 09.02.2024)

and Oman while IPEN and ACAT, and PAN mention potential non-chemical alternatives. Canada has provided a link to Health Canada's Pesticide Label Search[17] webpage where currently registered alternatives to specific uses of chlorpyrifos can be found.

94. A list of identified chemical and non-chemical alternatives can be found in the INF document (#add reference).

2.3.2 Chemical alternatives

95. The main chemical alternatives to chlorpyrifos identified can be grouped by chemical family into: diamide insecticides, neonicotinoids, spinosyns, pyrethroids and avermectins. Each of these groups contains a number of substances which are available as alternatives to chlorpyrifos. Additional information on the potential chemical alternatives to chlorpyrifos has been identified through a review of literature and covers a range of crops and veterinary applications, demonstrating that alternatives do exist for many uses and are already in active use.

96. Any transition to alternative substances must be mindful of the health and environmental hazard profiles of the alternatives under consideration. To ensure that a potential alternative is safer, leading to the protection of human health and the environment, the risk of the chemical being considered should be fully assessed, including in accordance with Article 3.6 of the ICC on Pesticide Management and the criteria for highly hazardous pesticides (HHP).[18] It should be considered whether the alternatives would meet the Annex D criteria of the Stockholm Convention. Additionally, the Pesticide Action Network (PAN) also developed an HHP-guide, which can be used to assess a potential alternative (PAN, 2021).

97. Oman (Annex F, 2023) mentions imidacloprid and chlorpyrifos-methyl as potential alternatives to chlorpyrifos. While chlorpyrifos-methyl exhibits reduced persistence in the environment compared to chlorpyrifos, it still shares similarities with chlorpyrifos in terms of human health and environmental concern. More specifically, it can affect the nervous system by inhibiting acetylcholinesterase, an enzyme crucial for proper nerve signal transmission. This can lead to a range of health problems, including nausea, dizziness, respiratory issues, and in severe cases, neurological damage. Additionally, lower effectiveness of chlorpyrifos-methyl compared to chlorpyrifos, implies higher amounts would be needed to achieve the same effect. Therefore, by considering chlorpyrifos-methyl as a potential alternative to chlorpyrifos, special attention needs to be given to a possible "regrettable substitution".

98. A number of chemical alternative substances have been mentioned by New Zealand (NZ) as part of the Annex F response which are given for various pest/crop combinations. While the majority of listed substances can be used if they are approved and registered, there are some substances that are currently on NZ EPA's publicly available workplan for reassessment, including lambda-cyhalothrin, alpha cypermethrin, deltamethrin, permethrin, clothianidin, and imidacloprid. Additionally, two substances provided on the list of alternatives, diazinon and methamidophos, are to be phased-out in New Zealand by July 2028 and July 2024, respectively. Lambda-cyhalothrin, alpha cypermethrin, and deltamethrin were categorized in a screening of chemical alternatives to endosulfan as candidates that could be POPs substances (UNEP/POPS/POPRC.8/INF/12).

99. As part of the Annex F submission, India and PMFAI provided the spray costs of chlorpyrifos (see chapter 2.2.3) as well as the spray costs per hectare in India for some chemical alternatives. For this the use rate was multiplied with the costs. The costs were taken from the statistical database of India (Government of India, 2024) (see INF document #add reference**Error! Reference source not found.**).

100. In the USA, CDPR (2014) analyzed the costs and benefits of alternatives to chlorpyrifos for several crops such as alfalfa, almonds, citrus and cotton. In several cases the costs for alternative active ingredients are lower than those for chlorpyrifos. The costs differ depending on the crop and pest regarded. Additionally, US EPA (2020) also analyzed the costs and benefits of the use of chlorpyrifos and its alternatives. In here too, the alternatives are cheaper than chlorpyrifos for specific crop-pest combinations. For example, the use of imidacloprid costs only USD 12/hectare ($5/acre) against Filbert aphids, leafrollers and filbert worms in hazelnuts compared to USD 27/hectare ($11/acre) for chlorpyrifos. This is in contrast to the findings by OPCA (2017), where alternatives can be 35-400% more expensive depending on the crop.

[17] http://pr-rp.hc-sc.gc.ca/ls-re/index-eng.php (accessed 05.01.2024)

[18] https://www.fao.org/3/I3604E/i3604e.pdf (accessed 05.01.2024)

101. The aforementioned sources also include examples of an increase in costs when switching to an alternative. Thus, the costs of an alternatives may be higher or lower depending on the pest-crop-combination being assessed (US EPA, 2020; Goodhue *et al.,* 2020; CDPR, 2014).

Diamide insecticides

102. Diamide insecticides are a fast-growing group of pesticides due to their selective mode of action. These substances target the ryanodine receptor of lepidoptera pests, which regulate the intracellular calcium concentrations. Diamide insecticides induce a continuous release of calcium into the cells which causes rapid muscle disfunction, paralysis and eventually leads to the death of the pests. Due to the specific mode of action these substances exhibit a low mammalian toxicity (Du and Fu, 2023; Li *et al*., 2023).

103. This class can be further differentiated into anthranilic diamides to which chlorantraniliprole (rynaxypyr) and cyantraniliprole (cyazypyr) belong and into phthalic diamides to which flubendiamide belongs (Li *et al*., 2023). All three substances were mentioned by Argentina and Thailand as part of the Annex F responses.

104. Chlorantraniliprole also known under the trade names "rynaxypyr" and "coragen" is the first commercially available anthranilic diamide insecticide targeting specifically lepidopteran insects (e.g., bollworms). It has been available on the market since 2008. Chlorantraniliprole is resistant to hydrolysis under neutral and acidic conditions, however one brominated degradation product has been found to be highly toxic to bacteria (Li *et al*., 2023). Due to its lipophilic nature chlorantraniliprole binds to fatty foods and can be accumulated through the food chain. Thus, several countries have already regulated the substance. In China, chlorantraniliprole was restricted in 84 different foodstuffs with MRL in the range 0.01 to 40 mg/kg (GB 2763–2021). In the EU the substance is approved as an active ingredient until 31.12.2024 (Regulation 1107/2009) after which it will be reviewed. Maximum residue levels for chlorantraniliprole between 0.01 and 40 mg/kg have also been established for 381 foodstuffs in the EU (Regulation 2021/1884).Similarly in Canada, the USA (PC-Code 090100) and India, chlorantraniliprole is also registered as an active ingredient. A review by EFSA (2013) concluded that chlorantraniliprole is very toxic to aquatic invertebrates and sediment dwelling organisms and that the substance is likely persistent in soil.

105. Cyantraniliprole, also known as "cyazypyr", has a similar structure to chlorantraniliprole and also the same mode of action. It is also used against lepidopteran insects (e.g., bollworm and armworm), dipteran leafminers, fruit flies, beetles, weevils, whiteflies, thrips, aphids, and psyllids. It can be used in agricultural and non-agricultural usesThe substance is allowed for use in Canada, USA (PC-Code 090098), India and Europe. Maximum residue levels have also been established in the EU for cyantraniliprole, ranging from 0.01 mg/kg to 30 mg/kg (Regulation 2023/1068).

106. In Brazil diamide insecticides (chlorantraniliprole, cyantraniliprole and cyclaniliprole) are used in seed treatment of maize and sorghum instead of chlorpyrifos to combat armyworms (Rainforest Alliance, 2021a).

107. Broflanilide (also a diamine compound), also known under the name VECTRON® T500, demonstrated a high efficacy and long residual activity against pyrethroid-susceptible and resistant malaria vectors in Tanzania, Benin and Burkina Faso (UNEP-POPS-DDT-EG.9-3). The substance may be a suitable alternative to chlorpyrifos in combatting the spread of malaria. The substance also meets the OECD definition of PFAS and thus may be persistent and harmful to humans and the environment. Other potential alternatives to chlorpyrifos for malaria vector control are carbamates (bendiocarb), neonicotinoids (clothianidin), other organophosphates (pirimiphos-methyl) and pyrethoids (bifenthrin, alpha-cypermethrin). More information on malaria vector control is further discussed below under each chemical category where appropriate and can be found in (UNEP-POPS-DDT-EG.9-3).

108. According to WHO's Recommended classification of pesticides by hazard, cyclaniliprole and flubendiamide are classified as slightly hazardous while chlorantraniliprole and cyantraniliprole are classified as unlikely to present acute hazard (WHO, 2019). More information on diamide insecticides can be found in the INF document (## add reference).

Spinosyn

109. Another group of alternatives to chlorpyrifos is the group of spinosyns. They are produced via the fermentation of two species of *Saccharopolyspora*, which ultimately produce the desired compounds. The core structure is peptide based and substituted with a sugar molecule. Two pesticide products fall under this group: spinosad and spinetoram (Argentina Annex F, 2023). According to

WHO's Recommended Classification of Pesticides by Hazard, spinosad is classified as slightly hazardous and spinetoram as unlikely to present acute hazard (WHO, 2019).

110. Spinosyns exhibit broad-spectrum activity against a wide variety of pests, including Lepidoptera and Diptera along with some members of several other insect orders, such as planthoppers, leafhoppers, spider mites and cockroaches (Kirst, 2010). Further target insects are sawfly larvae, certain beetles, psyllids, some Orthoptera, fleas, and red fire ants (US EPA, 2009). They can be used on, for example, potatoes, grapes, pome fruits, stone fruits, berries, and vegetables (Canada, 2018). In the Netherlands spinosad is approved (among others) as active ingredient in ant baits (Netherlands Annex F, 2023).

111. Spinosad has also been used in combatting ticks in cattle farming among other pesticides such as pyrethoids, fipronil and fluazuron (Selles *et al.*, 2021). It can also be used against lice by applying it twice 45-60 days apart. Similarly, avermectins (see below for more information) are also used to treat lice infestations in cattle and other livestock (Johnson, 2021).

112. Similar to the diamine insecticides, the spinosyns specifically target insects and have lower toxicity and reduced risk toward mammals, birds and aquatic animals compared to other broad-spectrum pesticides like chlorpyrifos. However, it is important to note that some spinosyns such as spinosad exhibit high persistence in the environment. In the absence of sunlight spinosad breaks down with half-lives ranging from 30 to 259 days in water and 161 to 250 days in sediment (anaerobic) (National Pesticide Information Center (NPIC), 2014).

113. Spinetoram and spinosad are both used in Peru to combat armyworms in asparagus and capsicum (Rainforest Alliance, 2021a). Other applied pesticides against armyworms in Peru include organophosphates and pyrethroids (discussed further below). More information on spinosyns can be found in the INF document (## add reference).

Avermectins

114. Avermectins are insecticides isolated from the fermentation of the soil bacterium *Streptomyces avermitilis*. The effectiveness of avermectins, including abamectin, ivermectin, doramectin, eprinomectin and moxidectin, in treating a range of pests (mostly for livestock, horticultural crops, or general nuisance) has been documented for a long time (Strong and Brown, 1987). More information on avermectins can be found in the risk management evaluation of Methoxychlor (UNEP/POPS/POPRC.17/13/Add.1).

115. According to WHO classification of pesticides by hazardous properties, abamectin is classified as highly hazardous (WHO, 2019) while for other avermectins mentioned above classification is not provided.

Pyrethroids

116. Pyrethroids are a large family of insecticides which work as contact poisons to affect the nervous system of insects. They have a broad range of applications (spanning different climatic conditions), including plant protection, control of pests in cattle farming, and mosquito control. This group includes permethrin, cypermethrin, bifenthrin, esfenvalerate, fluvalinate, tefluthrin, and deltamethrin, among others (FAO, 2014). Due to their broad range of application, they can be a viable alternative to chlorpyrifos.

117. Cypermethrin and permethrin are reportedly 'the main insecticides currently used to control mosquitos' (Stoops *et al*., 2019). Fenvalerate can also be used in treating mosquitos (Helson and Surgeoner, 1983). One issue arising from the popular use of pyrethroids is resistance in mosquitos (Bajunirwe, 2020; Amelia-Yap *et al*., 2018; Bustamante Gomez *et al*., 2016). There is more evidence for increasing pyrethroid resistance relative to other insecticide classes (WHO, 2018; Kuri-Morales *et al*., 2018). Many pyrethroids also exhibit hazardous properties. The properties and other information on pyrethroids can be found in the risk management evaluation of methoxychlor (UNEP/POPS/POPRC.17/13/Add.1).

118. Several pyrethroids, such as cypermethrin, flumethrin, cyhalothrin, and cyfluthrin are also used in combatting ticks in cattle amongst others (Obaid *et al*, 2022). Pyrethroids can also be used in animals dips, where the animal is submerged in a watery solution of a pesticide to combat pests such as lice, mites, ticks and flies. However modern solutions based on spraying are also available. Pyrethroids used in this way are for example flucythrinate, cypermethrin and cyfluthrin (Akre and Mac Neil, 2006). Other pesticides can also be used including spinosad, avermectins and neonicotinoids (Woolfacts, 2024). It is important to note that `sheep dips´ involving the use of the abovementioned chemicals have a high potential for emissions and exposure.

119. Pyrethroids such as bifenthrin, permethrin, and deltamethrin are typically applied to polyethylene barriers. These barriers are designed to stop termites from spreading. When impregnated with these chemicals, the barriers become more effective and durable (Oi, 2022).

120. According to WHO classification of pesticides by hazardous properties, cypermethrin, permethrin, bifenthrin, esfenvalerate, fluvalinate, and deltamethrin are classified as moderately hazardous, and tefluthrin is highly hazardous (WHO, 2019).

Neonicotinoids

121. Examples of neonicotinoids include imidacloprid, clothianidin, thiamethoxam, acetamiprid, nitenpyram, dinotefuran, and thiacloprid. They have been used against fleas, mites, whiteflies, termites, the Colorado potato beetle, and other insects.

122. Although neonicotinoids are used widely on a global scale, concern exists due to the risks they pose to pollinators, as highlighted by the FAO and WHO (2019). The approval of the imidacloprid, clothianidin and thiamethoxam under Regulation (EC) No 1107/2009 expired in 2019 and 2020 in the EU. The biocidal uses of imidacloprid, clothianidin and thiamethoxam as insecticides, acaricides and products to control other arthropods are authorized in the EU (Regulation (EC) No 528/2012). In 2023 neonicotinoids had emergency authorizations in 6 EU Member States. This includes clothianidin, imidacloprid, thiamethoxam and thiacloprid.[19]

123. Neonicotinoids, such as imidacloprid, are also effective at combatting termites, however, have shown adverse effects against non-target species such as bees (Naik *et al*., 2023; Oi, 2022). Alternatively, treated cellulose baits can be installed on the property. The traps work by attracting the termites, which then subsequently eat the treated cellulose and die shortly after. A typical active ingredient used in such traps is Sentricon® (Oi, 2022). To supplement other termite control methods wood treatments on the basis of e.g., borates can also be applied, however possible health and environmental negative effects of borates should be assessed before use.

124. In India imidacloprid is also applied on cotton as an alternative to chlorpyrifos to combat sucking pests. Diafenthiuron can also be applied against white flies on cotton instead of chlorpyrifos (IPEN, 2022).

125. Ngufor *et al*. (2017) suggested combining clothianidin (a neonicotinoid) and deltamethrin (a pyrethroid) to more effectively control mosquito populations showing pyrethroid resistance.

126. WHO classification indicates imidacloprid, clothianidin, thiamethoxam, acetamiprid, nitenpyram, and thiacloprid are moderately hazardous, and dinotefuran slightly hazardous (WHO, 2019).

127. Canada has recently conducted extensive evaluations of several neonicotinoids and established comprehensive risk management measures for their continued use. Further details are available at Health Canada's Neonicotinoid Insecticides webpage.[20]

128. More information on neonicotinoids can be found in the risk management evaluation of methoxychlor (UNEP/POPS/POPRC.17/13/Add.1).

Other alternatives

129. Organophosphates are among the most used pesticides globally (Maggi *et al*., 2019) and have been used to treat crops, mosquitos, and cockroaches (similar to chlorpyrifos). They are highly effective and have less frequently been linked to resistance. A number of organophosphates meet the criteria for HHPs (FAO, 2016) because of their acute mammalian toxicity, (i.e., WHO Ia and Ib classification (WHO, 2019)). Temephos and malathion have been classified as “slightly hazardous (Class III)” by WHO and could be suitable alternatives to chlorpyrifos.

130. Pyrrole insecticides including chlorfenapyr have been used to control leafminers, mites, cockroaches, flies, and other insects. Chlorfenapyr disrupts cell metabolic pathways and consequently respiration, leading to insect death (Oxborough *et al*., 2015). Furthermore, it has been used for mosquito control in insecticide-treated bed nets[21] and has potential to improve control of mosquitos

[19] Based on a search in https://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/ppp/screen/home (accessed 05.01.2024)

[20] https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/growers-commercial-users/neonicotinoid-insecticides.html (accessed 31.01.2024)

[21] https://www.cdc.gov/malaria/malaria_worldwide/reduction/itn.html (accessed 05.01.2024)

showing resistance to other insecticides (Ngufor *et al*., 2016; N'Guessan *et al*., 2007). There are concerns regarding the persistence and bird reproductive effects of chlorfenapyr (US EPA, 2001) and its high toxicity to aquatic organisms (Regulation (EC) No 1272/2008). According to WHO classification, chlorfenapyr is rated as class II which means it is moderately hazardous (WHO, 2019).

131. Non-insecticide insect control methods are also available. DEET (*N,N*-diethyl-m-toluamide) is used to repel insects (mosquitos, ticks, fleas, chiggers, leeches) rather than kill them (like chlorpyrifos does). DEET is on the US EPA high production volume list. DEET has the advantage of low risks to both humans and the environment (European Chemicals Agency (ECHA), 2010; Chen-Hussey *et al*., 2014), with its high degradation rates and low potential for bioaccumulation (Weeks *et al*., 2012). There is some concern regarding neurotoxic effects on children, although the risks are thought to be low (ECHA, 2010).

132. According to the information provided by COLEAD (Annex F, 2023), fipronil can be used against the order of Blattodea to which cockroaches belong. Additionally, Lee *et al.* (2022) mentions that pyrethroids and fipronil have been widely employed for more than two decades to control the German cockroach, *Blattella germanica* (L.) (Blattodea: Ectobiidae). Fipronil is classified as Class II moderately hazardous pesticide and has a rat acute oral LD_{50} of 97 mg/kg (WHO, 2019). Other concerns regarding negative impact on the population of bees have also been reported (Farder-Gomes *et al.*, 2021).

2.3.3 Non-chemical alternatives

133. PAN stated that pest management strategies with a high degree of efficacy and efficiency and without reliance on chemical alternatives fall into two main groups: biocontrol (for example, botanicals), for managing pests when they are present, and ecosystem management strategies, which prevent pests and/or build up the crop's resilience to the pests (for example, cover cropping). The non-chemical alternatives to chlorpyrifos discussed below include IPM, sustainable agroecological and organic agricultural practices, biological control systems and botanical preparations, as well as physical barriers and hygiene practices. Some botanical preparations may be considered to be pesticides under national regulatory systems and be subject to environmental, health and regulatory approvals, and may therefore not be considered 'non-chemical' in some countries.

134. As part of the Annex F responses, information on potential non-chemical alternatives to chlorpyrifos was provided by Argentina, COLEAD, India, IPEN and ACAT, New Zealand, PAN, PMFAI, Thailand, and UK. These are summarized in the supporting INF document (#add reference) and some of them are described below in more detail.

135. The Conference of the Parties by decision SC-6/8 (UNEP/POPS/COP.6/33) encouraged Parties when choosing chemical and non-chemical alternatives to endosulfan to assess local conditions and give priority to ecosystem-based approaches to pest control. The International Conference on Chemicals Management (ICCM4) of SAICM (Strategic Approach to International Chemicals Management) adopted a resolution that recognized HHPs as an "issue of concern" and supported and encouraged concerted action among relevant stakeholders to address HHPs, with emphasis on promoting agro-ecologically based alternatives and strengthening national regulatory capacity to conduct risk assessment and risk management (SAICM/ICCM.4/15, Resolution IV/3). With regards to the UN Sustainability Development Goals, an indicator for target 2.4 concerning sustainable agricultural is pesticide management, which largely consists of minimizing pesticide use through non-chemical alternatives, including crop rotation, biological control, and inter-cropping. PAN suggested a read-across to the risk management evaluation of endosulfan (UNEP/POPS/POPRC.8/INF/14/Rev.1) to identify non-chemical alternatives to chlorpyrifos.

Integrated pest management (*IPM) and organic and agroecological practices*

136. IPM involves combining a range of practices which work synergistically to control pests. Common practices involved include crop rotation, cultivation techniques, use of balanced fertilization, liming, irrigation/drainage practices, hygiene measures, and use of ecological infrastructure at production sites. Pest control is implemented when monitoring gives warning of harmful organisms and when scientifically sound thresholds (specific to the region and crops) have been exceeded. Non-chemical methods are used over pesticides if they provide adequate control. Furthermore, if pesticides are used, they must have minimal effects on humans and the environment. Pesticides should be applied at reduced doses to minimize risks.[22]

[22] https://ec.europa.eu/food/plant/pesticides/sustainable_use_pesticides/ipm_en (accessed 05.01.2024)

137. For example, IPM has successfully been applied in Ethiopia to phase out the use of chlorpyrifos for growing cotton. Through the use of food sprays beneficial insects could be attracted which subsequently increased the cotton yields and profitability. Organic cotton production was found to be economically profitable with a higher yield and lower production costs compared to conventionally grown cotton in the area (Amera, Mensah, and Belay, 2017).

138. According to Kumar *et al.* (2009), a farmer raising cotton on 1.0 hectare of land through community managed sustainable agriculture (CMSA) could potentially save 250 USD/year on the costs of pesticide, which is 56% of the farmer's annual income. At the same time yields were lower by roughly 20%.

139. There is some contention about the economic feasibility of IPM. This mainly stems from the multitude of factors that need to be taken into account when implementing IPM such as choice of livestock breed and crop variety, schedule for crop or livestock rotation, physical design of the landscape, augmentative biological control and insecticides and chemical used to attract, confuse or repel pests (Onstad and Crain, 2019).

140. In the An Giang province of Vietnam, IPM has been successfully applied to the farming of rice. 77.6% of the rice farmers in the province applied IPM in 2020. Applied technologies include the "three reduction, three grains" method, where less crop is planted and less fertilizer and pesticides are used, resulting in higher yield and quality of the crop. Furthermore, the "one must, five reductions" method was also applied, which requires that farms must use one high quality seed and subsequently reduce the quantity of seeds planted, decrease the quantity of nitrogen, and applied fertilizer as well as decrease the amount of water used and the amount of crop lost during harvest (IPEN Annex F, 2023). According to Tho, Dung, and Umetsu, (2021), the "one must, five reductions" model helped farmers to reduce their production cost by 10%, increased a paddy's selling price by 4.5% per kg, and obtained 10% more profit, compared to traditional farming households.

141. Pinese and Piper (1994) provides guidelines for the implementation of IPM with numerous biological control options given for insects and mite pests likely to be encountered in bananas, while Achard *et al*., (2018) mentions intercropping bananas with permanent living cover crop as an efficient alternative which can enhance pest control as well as soil health while maintaining banana growth and yield.

142. In the Annex F request for information, PAN submitted information describing agroecology as a non-chemical alternative to chlorpyrifos. Parmentier (2014) defines agroecology as "the application of ecological science to the study, design, and management of sustainable agriculture". The core principles of agroecology involve adapting to local environments, creating optimal soil conditions for plant growth, promoting biodiversity at various levels, encouraging beneficial biological interactions for soil fertility and pest management, and maximizing the utilization of farmers' knowledge and skills. A meta-analysis of peer-reviewed studies on agroecology indicated clear evidence that "agroecology builds on key characteristics which have a strong positive correlation with climate resilience" (Leippert *et al.*, 2020). The emphasis is on managing the agroecosystem to prevent pest build-up using cultural, biological, and mechanical methods rather than synthetic chemicals (Watts and Williams, 2015). A number of agroecologically based strategies, such as biocontrol, crop rotations, and cover crops, can be utilized in large scale production as well as by smallholder farmers (Naranjo *et al.*, 2015; Clark, 2015).

143. Watts and Williamson (2015) report that by opting for non-pesticide management in the second crop season of rice in India, farmers who avoided using four to five pesticide sprays, saved an estimated cost of Rs 4,000-5,000 (US $63-77) per hectare. Instead, they invested only Rs 2,725 (US $43) per hectare on biocontrol agents and pheromone traps. At the same time yields increased by 30% from 4,250 kg/ha to 5,500 kg/ha by applying agroecological practices and nutrient management.

144. Chlorpyrifos is used for a wide variety of target pests, indicating a broad and non-descript range of functionalities of chlorpyrifos. Therefore, the range of agricultural practices (including IPM) which may be adopted to perform the function of chlorpyrifos cannot be detailed in this report in an exhaustive manner. From a high-level perspective, IPM, organics and agroecology are gaining traction globally as more sustainable approaches and economic benefits have been documented in various regions (Pretty and Bharucha, 2015; Cuyno *et al.,* 2001; Del Fava *et al.*, 2017; Watts and Williamson, 2015; (IFOAM), 2021[23]). More information on IPM examples and use cases can be found in the INF document (#add reference).

[23] https://www.organic-world.net/yearbook/yearbook-2021/pdf.html (accessed 05.01.2024)

Biological control systems and botanical preparations

145. The use of biological control systems involves management of pest populations by natural enemies or plant extracts. When transitioning to biological control systems or botanical preparations, consideration must be given to national and regional assessment outcomes and regulatory limitations for specific uses.

146. It can be noted that biological control systems can have both positive and negative effects on the pest management. According to Barratt *et al.* (2011), these effects can be divided into direct and indirect. Direct effects involve the influence a biological control agent may have on non-target organisms in the new environment. This typically includes impacts on native non-target species, beneficial or valued exotic species, and sometimes unintentional control of other pests. For example, when *Microctonus aethiopoides* Loan was introduced in New Zealand to control the lucerne pest *Sitona discoideus* Gyllenhal, it ended up unintentionally affecting *Listronotus bonariensis*, an introduced pest of ryegrass. Indirect effects encompass impacts on species within the same trophic level as the biological control agent, such as competition, displacement, or hybridization with other parasitoids. Additionally, indirect effects can extend to organisms in different trophic levels, affecting overall food webs (Barrat *et al* 2011). It should be noted that chlorpyrifos and chemical alternatives also have direct effects on non-target species.

147. Entomopathogenic fungus *Beauveria bassiana* is actively used in Colombia to suppress the coffee berry borer (CBB) *Hypothenemus hampeii*. Use of this method showed a decline in use of endosulfan and chlorpyrifos from 250 liters to 75 liters and ultimately to 0 liters in the third year of the program conducted in 2004. This brought down the costs stemming from berry borer control by roughly two thirds from $6,602 in 2002 to $2,177 in 2004 (Aristizábal, Lara, and Arthus, 2012). While the overall yields decreased by ~10% from 4,391 kg/ha in 2002 to 3,938 kg/ha in 2004, the proportion of the harvest sold as high quality 'specialty' coffee increased from 50% to 86% over the same period.

148. Approximately 10% of Costa Rica's plantation area employs the pheromone trapping system outlined in the study from Alpizar *et al*., (2012). Pheromone-baited pitfall trap is used for trapping of *Cosmopolites sordidus* (banana root borer) while pheromone-sugarcane-baited open gallon trap is used for *Metamasius hemipterus* (silky cane weevil). The traps have been successfully applied in growing bananas. The same system is also actively used for growing bananas in Martinique, Guadeloupe, and the Canary Islands.

149. Pheromone traps can also be used against armyworms. Such traps are already commercially available and are typically impregnated with synthetic pheromone components of *S. frugiperda*. However, the traps also attract non-target species such as *Mythimna loreyi* (maize caterpillar). Current research indicates that by adding an additional sex pheromone of the armyworm *S. frugiperda* the selectivity of the trap can be improved (Tabata *et al*., 2023).

150. In a study from Divekar *et al*., (2024), various botanical preparations have been applied to suppress major cabbage pests such as mustard aphid, diamondback moth and cabbage butterfly. Neem oil and garlic oil demonstrated significant reduction in pest populations, with neem oil being the most effective, causing a 70%, 71%, and 69% reduction in mustard aphid, diamondback moth, and cabbage butterfly populations, respectively.

151. According to Phayakkaphon *et al.* (2021), *Stemona collinsiae* displays resistance to various pests and insect vectors, particularly against the nymph and adult stages of *Periplaneta americana* (*P. americana*), commonly known as the American cockroach. The research focused on assessing the insecticidal properties of S.*collinsiae* root extracts administered orally against P.*americana*. The roots of S.*collinsiae* are rich in diverse insecticidal phytochemicals, making them promising for developing alternative insecticides. The study revealed the effectiveness of S.*collinsiae* hexane and dichloromethane crude extracts as repellents, suggesting their potential use in formulations such as toxic baits, aerosols, or oral administration against P.*americana.* The insecticidal and repellent activities were observed to vary based on the concentration of the crude extract and the specific phytochemicals present.

152. Chlorpyrifos was used extensively in Kenya, Somalia and Ethiopia to combat locust, especially during the 2020/2021 outbreak (Mullié *et al*., 2023). To combat the outbreak multiple tonnes of pesticide were applied over two years, in many cases the concentrations were significantly above the recommended limits. Applied pesticides were chlorpyrifos, triflumuron, teflubenzuron, deltamethrin, malathion and fenitrothion. Furthermore, the fungus *Metarhizium acridum* was also applied in certain regions. Due to the overuse of chemical pesticides several negative effects were reported such as the dying of birds by overeating on poisoned locust, the dying of bees also leading to the loss of income of beekeepers. Mullié *et al*. (2023) thus recommend the use of *M. acridum* to

combat locust. *M. acridum* is a fungus which specifically targets the group of Orthoptera. Due to its specific mode of action other species such as bees, birds and fish are not affected by the fungus. It also degrades rapidly on fields and plants and costs around 15.75 USD/L, which is similar to other chemical alternatives (see section 2.3.2 and INF document #add reference). The fungus targets both newly hatched and adult locust. Additionally, the combination of *M. acridum* and the predation by local birds, locust outbreaks can be effectively managed. *M. acridum* has been successfully applied in Australia, China and Somalia (Mullié *et al*. 2023). FAO ranks *M. acridum* as the only priority 1 insecticide, indicating that it is the preferred option to combat locust (FAO, 2021). To support the use of biological control against locust, early warning systems to identify locust breeding sites, pre-empting widespread pesticide campaigns, should be implemented (Mullié *et al*., 2023).

153. According to Chandler *et al*., (2011), biological alternatives to conventional pesticides tend to be lower risk to the environment, but more expensive to manufacture and use due to current regulatory frameworks. In addition, if a technology enhances farmers' productivity without causing significant harm to the environment, it is likely to yield sustainability benefits.

154. More information on biological control systems can be found in the risk management evaluation of methoxychlor (UNEP/POPS/POPRC.17/13/Add.1) and in the INF document (##add reference).

Physical barriers and improving hygiene practices

155. In the Annex F request for information, Argentina mentions physical methods that can be used as an alternative to chlorpyrifos, such as inert gasses in airtight facilities.

156. According to de Lopez *et al*., (2020), use of transparent bags with 3-mm orifices to protect bananas during their growth has proven to be efficient in suppressing *Chaetanaphothrips signipennis* (banana thrips) found in Peru and Ecuador and *Chaetanaphothrips orchidii* (anthurium thrips) commonly found in the Dominican Republic.

157. Physical barriers can also be used to prevent termite infestation by blocking access to the wood. Various technologies exist. They can be based on tightly packaging granite particles in order to create tight areas which the termites cannot pass (Tradename: Grantigard™). Other systems are based on stainless steel meshes with mesh sizes around 0.45x0.45mm. Lastly, polyethylene barriers can also be applied to prevent the spread of termites.

158. More information on physical barriers can be found in the risk management evaluation of Methoxychlor (UNEP/POPS/POPRC.17/13/Add.1).

2.3.4 Summary of alternatives

159. Alternatives to chlorpyrifos have been identified by considering the uses of the substance for specific pests (e.g., mosquitos, termites, armyworms and locusts) and for specific applications (e.g., cotton, wheat and livestock), as well as investigating which current practices are commonly used for these purposes. Alternatives against common pests in veterinary industries such as blowflies, lice and ticks have also been identified.

160. A variety of chemical alternatives to chlorpyrifos were identified, many of which are already used and are commercially available, suggesting technical and economic feasibility of substituting chlorpyrifos globally. However, many alternatives presented here have human health and environmental concerns regarding their use. Adoption of alternatives should only be undertaken after hazard and risk assessments have been conducted for the substances. Only moderately or slightly hazardous pesticides (e.g., acetamiprid) (WHO, 2019) are recommended by the FAO for sustainable farming practices which contribute to the UN Sustainable agriculture goal (Target 2.4).

161. There are many non-chemical alternatives available. IPM has been adopted by numerous farmers worldwide proving it is a viable alternative, in some cases demonstrably increasing yield and/or profitability. Various bacteria, pheromone traps, fungi and other biological controls are also available on the market. Studies have also shown the successful implementation of physical barriers against certain pests (e.g., termites). Non-chemical alternatives can reduce pest prevalence so that less or even no chemicals are required for an effective IPM strategy, and therefore human and environmental exposure to chemicals and the corresponding risks are lowered. Several alternatives, both chemical and non-chemical, have been identified for key uses across various applications, including cotton (e.g., diafenthiuron for whiteflies, 5% neem seed kernel extract for various pests), locusts (e.g., *Metarhizium anisopliae* and *Metarhizium acridum*), termites (e.g., neonicotinoids to mitigate termite infestation and physical barriers such as tightly packaging granite particles or polyethylene barriers), borers (e.g., several natural enemies such as *Beauveria bassiana* for coffee

berry borer, *Trichogramma japonicum* for yellow stem borer, etc.), veterinary uses (e.g., DEET (N,N-diethyl-m-toluamide) utilized as an insect repellent to protect cattle from mosquitos, ticks, fleas, and chiggers, *Metarhizium anisopliae* against ticks, and several types of pyrethroids, spinosad and avermectins to combat tick infestation in cattle), and rice (e.g., rice-duck farming systems for suppression of rice planthoppers and rice leafhoppers).

162. A direct cost comparison of several alternatives to chlorpyrifos is presented at the start of section 2.3. Sources indicate that some alternatives may even be cheaper than chlorpyrifos. However, comparing the technical feasibility, efficacy, and availability is not always possible due to the multitude of uses of chlorpyrifos, along with other factors. Many newer pesticides are specific to certain pests, whereas chlorpyrifos is a broad-spectrum pesticide making it difficult to identify suitable alternatives for all uses. However, the already globally widespread use of alternatives suggests that some options will be successful, available, and feasible in all parts of the world. The choice of alternative may vary by country due to regulations, types of pests, market dynamics or other variables such as climatic conditions.

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

2.4.1 Health, including public, environmental, and occupational health

163. As noted in the Risk Profile, several Parties and Observers state in their Annex F responses that the use of chlorpyrifos gives rise to adverse public, environmental and occupational health. One Party (Argentina) states that chlorpyrifos can cause neurodevelopmental issues, particularly in vulnerable groups such as children, this was also the reason for the non-renewal of the registration in the EU (Argentina Annex F, 2023; European Food Safety Authority (EFSA), 2019).

164. The impact of chlorpyrifos on the health of farmers has been extensively studied. PAN (Annex F, 2023) states chlorpyrifos formulations behave unpredictably and it has been witnessed to create severe damage on the health of farmers (notably unintentional acute pesticide poisoning, primarily amongst farmers in Vietnam, Laos, Bangladesh and India) (Watts, 2023). A number of other studies have found that farmers suffer from damages to their health caused by chlorpyrifos, and that a lack of personal protective equipment increases these health damages (Phung *et al*., 2012; Venugopal *et al*., 2021; Marasinghe, Yu, and Connell, 2014; Liem *et al*., 2021).

165. In 2008, the EU, in alignment with the Globally Harmonized System of Classification and Labelling, classified chlorpyrifos as Aquatic Acute Tox 1, with the hazard phrase 'H400-very toxic to aquatic life,' and as Aquatic Chronic Tox 1, with the hazard phrase 'H410-very toxic to aquatic life with long-lasting effects.' In 2019, EFSA stated that chlorpyrifos meets for the classification of chlorpyrifos as toxic for the reproduction, Repro 1B, H360D 'May damage the unborn child' in accordance with the criteria set out in Regulation (EC) No 1272/2008 (see Risk Profile).

166. In a 2020 publication by de Buck *et al.* it was shown that the Dutch Government is expected to realize a considerable environmental benefit due to the prohibition of a number of pesticides, including chlorpyrifos (however the amount specifically attributable to chlorpyrifos is not reported).

2.4.2 Agriculture, aquaculture, and forestry

167. Limited data on agricultural aspects has been provided through the Annex F responses. One Party (Argentina) suggests that elimination of chlorpyrifos may serve as an impetus for fostering sustainable agricultural practices. These may include the adoption of IPM and organic farming, which are likely to contribute to the enhancement of long-term soil health and ecosystem resilience. However, India and PMFAI suggested that the prohibition of chlorpyrifos may yield adverse consequences for managing crucial pests in targeted crops, such as rice, sugarcane, cotton, and wheat in India. This has not been found to be true in all circumstances, as many Parties have noted in Annex F responses the successful elimination of chlorpyrifos within their own agricultural experiences.

168. Chlorpyrifos has been used for the control of desert locust, with the most recent notable use being the 2019-2021 outbreak in the Horn of Africa, Southwest Asia, and the area around the Red Sea (FAO, 2023). The Locust Pesticide Referee Group (LPRG) listed chlorpyrifos on the priority list of pesticides to be used against desert locust (Mullie *et al*., 2023). During this time, systematic overdosing of pesticides, including chlorpyrifos, was found in environmental monitoring (Mullie *et al*., 2023). The LPRG published a report to the FAO in 2021 detailing alternative pesticides to chlorpyrifos that are also effective against locusts (and grasshoppers). However, in Africa chlorpyrifos was still the dominant pesticide used to combat the locust outbreak (LPRG, 2021). The continued

overdosing of chlorpyrifos to control locusts (and grasshoppers) can degrade the surrounding environment, making it less habitable or farmable. Along with this, chronic overdosing can increase the risk of pesticide resistant species developing..

169. Chlorpyrifos has also historically been used for termite control, particularly in the pre-treating of homes and soils during construction. Between the 1980s and 2001, more than a million homes in the United States have been treated with formulations containing 0.25-1.0% chlorpyrifos (Pest Control Technology, 2002). Similarly in Egypt, chlorpyrifos has been used to treat mudbricks against termites to preserve the structural integrity of the construction (Salem *et al*., 2020). The use of pesticides within homes continually leads to a negative societal impact as individuals are continually exposed to pesticides without their knowledge.

170. While chlorpyrifos has been used as an insecticide to reduce mosquito populations and therefore the transmission of malaria, there have been studies dating back to 2005 of mosquitos developing pesticide resistance to chlorpyrifos (Vatandoost *et al*., 2005). Chlorpyrifos has been shown to be less effective than alternatives against various malaria vectors (Malima *et al*., 2009).

171. The toxicity of chlorpyrifos to pollinator species (see next paragraphs) may also have a negative overall impact on agriculture by reducing the number of pollinators in the area of application over time, while the potential for chlorpyrifos to enter water ways (see section 1.2.3), may ultimately have a detrimental impact on aquaculture as the substance is classified as very toxic to aquatic life.

172. Chlorpyrifos has also been used for the treatment of external parasites in cats, and as a long-acting topical parasiticide and insecticide for cattle (Jaggy and Oliver, 1990). The use in cats is not recommended due to potential chronic organophosphate toxicosis, however the use in cattle and chickens has not shown similar health impacts (Jaggy and Oliver, 1990).

2.4.3 Biota (biodiversity) and habitats

173. Limited data on biota aspects has been provided through the Annex F responses. The responding Parties and Observers state that the prohibition of chlorpyrifos will significantly enhance the safeguarding of biodiversity and the conservation of ecosystems. Chlorpyrifos is a broad-spectrum pesticide, acting as an inhibitor of acetylcholinesterase. Therefore, toxic effects and threats to non-target organisms, especially pollinators, exist. The US EPA (2023) reports that chlorpyrifos is likely to adversely affect 1778 species out of 1835 and to adversely affect 780 out of 794 critical habitats. Chlorpyrifos is known to have adverse effects on honeybees (Villalba *et al.*, 2020). Research shows that without bees as pollinators, 5-8% of the world crop production will be lost (Khalifa *et al.*, 2021). Pollinator declines can result in loss of pollination services which in turn can result in ecological and economic costs, such as the maintenance of wild plant diversity, wider ecosystem stability, crop production, food security and human welfare (Potts *et al.*, 2010). The use of chlorpyrifos also leads to contamination of adjacent water and soil, thereby expanding the exposure route of chlorpyrifos to various species and causing broader impacts on biodiversity (Perez-Lucas, 2019).

2.4.4 Economic aspects

174. Limited data on the economic aspects has been provided through the Annex F responses. One Party (Argentina) suggests in their Annex F response that farmers may experience increased costs with the transition to alternative pest control methods, such as investments in new technologies and training and a potential reduction in crop yields during the transition. Similarly, one Observer (PMFAI) states that the use of chlorpyrifos comes with a lower cost of treatment than alternative products, however the overall costs (such as reduced healthcare costs and less unusable land) outweigh the costs of alternatives. The Party and Observer did not provide further data or specific details of the analysis in their respective Annex F submissions.

175. India and China report heavy reliance on chlorpyrifos, both in manufacturing/production and for usage, with both countries part of the most populous regions of the world (Annex F, 2023). In the Annex F response from China, it is noted that several alternatives, such as spirotetramat, dinotefuran, pyriproxyfen, exist but come at a higher economic cost than chlorpyrifos for the same volume of substance. The use of targeted alternative chemicals can lead to a decrease in the total cost for a substance due to proper dosing for the crop. Similarly, alternative farming methods do not use chemicals, so the cost for an alternative substance is zero. From a societal perspective, the use of targeted alternatives or alternative farming methods could support a decrease in healthcare costs associated with pesticide overdosing and improve the ecosystem services.

176. The Annex F submission from New Zealand states that costs associated with transitioning to alternatives, where available, are anticipated and are expected to be associated with the increased costs

of alternatives themselves as well as a potential loss of production where alternatives are limited or do not exist.

177. Delonge *et al.* (2016) analyzed US Department of Agriculture (USDA) research funding, including research investments in ecologically based farming practices. In 2022, USDA announced it would invest 300 million USD to support farmers transitioning to organic, in a new Organic Transition Initiative[24].

178. While only some farmers may transition to organic farming, the practice can be economically competitive in comparison to conventional agriculture when total organic costs and benefits are taken into consideration. In a meta-analysis of a global dataset including 55 crops grown on five continents, organic agriculture was “more profitable (22-35%) and had higher benefit/cost ratios (20-24%) than conventional agriculture” (Crowder and Reganold, 2015).

179. Farms that rely on organic farming practices may provide a measure of economic stability by employing more workers for a greater amount of time. Finley *et al.* (2017) surveyed organic farming in two US states found in their analysis that more of the hired labor on organic farms worked 150 days or more compared to the average farm. Marasteanu and Jaenicke (2018) modeled economic indicators in US counties with a high number of organic farming operations and found a positive correlation with organic operations and lower county poverty rate as well as higher median household income. USDA’s Economic Research Service found that significant economic returns are possible from organic production of major commodity crops in the US (corn, wheat, and soybean).

2.4.5 Movement towards sustainable development

180. Elimination of chlorpyrifos is consistent with the UN sustainable development plans to seek reduced emissions of toxic chemicals. The elimination of chlorpyrifos is relevant to a number of the Agenda 2023 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).

181. SAICM[25] 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 moves to safer and more sustainable chemicals. This includes goals that for chemicals or chemical uses that pose an unreasonable and otherwise unmanageable risk to human health and environment that better solutions should be implemented.

2.4.6 Social costs (employment etc.)

182. Limited information regarding the social costs of the implementation of control methods for chlorpyrifos has been provided in the Annex F responses.

183. In countries with a high burden of suicides attributable to pesticides, further control measures and national bans of HHPs have been shown to be a potentially cost-effective and affordable intervention of reducing suicide by ingestion of pesticides (Lee et al., 2020). In a follow up article, Rother (2021) explains that pesticide ingestion is linked with self-harm and poisoning, especially in low-income and middle-income countries.

184. While chlorpyrifos has been recognized by a number of countries as a hazardous pesticide, there is currently significant manufacturing or production that would be impacted by control measures. Public pressures, for example in the US, have influenced state by state bans, and eventually several country-wide statements regarding chlorpyrifos by the US EPA (US EPA, 2023). As a number of countries have moved to alternatives, it is possible that the negative impacts of a ban or restriction may not be as prohibitive.

[24] https://www.farmers.gov/your-business/organic/organic-transition-initiative (accessed 19 Feb 2024)

[25] https://www.saicm.org/ (accessed 12 Jan 2024)

2.5 Other considerations

2.5.1 Access to information and public education

185. Information on access to public education and specific information for chlorpyrifos (the substance and the uses) is limited. PMFAI India promotes multi-language labels and leaflets to introduce the precautionary measures and use recommendations of chlorpyrifos (PMFAI Annex F, 2023). PPE and study material are given to users to ensure their safety. In addition, the Indian government offers training and education sessions for farmers and associated officers. Other information on pesticides more generally is provided by several Parties. However, it is important to note that often the workers are either illiterate or do not read the language the labels are printed in, so the use of text is not accessible to all who need the information. Canada provides information on chlorpyrifos and other pesticides regulation on the Health Canada's Pest Management Regulatory Agency website. The US EPA provides some guidance on using chlorpyrifos safely[26].

186. The Department of Agriculture in Thailand[27] provides suggestions on how to manage pests, including general education on pest management and alternative pesticides, with a specific information section on chlorpyrifos (Annex F).

2.5.2 Status of control and monitoring capacity

187. In Argentina, the government has recently launched a Network of Environmental Laboratories[28], where the public sector can find laboratories that can perform pesticide residual analysis, along with contact information, and the latest monitoring campaigns results are available publicly[29].

188. In Canada, the Pest Control Products Act (PCPA) and several other legislative Acts provide for compliance and enforcement authorities. These include provisions to control the misuse of pesticides and the use of unregistered or unauthorized pest control products. Health Canada's Regulatory Operations and Enforcement Branch, Pesticide Compliance Program, has primary authority for Federal enforcement. In addition, chlorpyrifos is included in the 2-year water monitoring pilot program for pesticides that the Government of Canada started in the spring of 2022 for a network of Canadian freshwater sampling locations. Chlorpyrifos is also added to the Northern Contaminants Program (NCP) as a contaminant of concern following its nomination for listing under the Stockholm Convention. Furthermore, The Canadian Health Measures Survey (CHMS) will monitor the concentration of chlorpyrifos in human body through national health surveys.

189. According to the Annex F submission, Norway includes chlorpyrifos in the national monitoring program for pesticide residues in food. Further information is discussed in detail in Section 2. The Swedish Food Agency, the responsible authority for the monitoring of pesticide residues in foods, including chlorpyrifos, has in the surveillance in 2021 reported 4 findings of food samples were the limit value for chlorpyrifos was exceeded.

190. In the Republic of Moldova, the Environment Agency will be responsible for monitoring chlorpyrifos, and the National Environment Inspectorate will take charge of the control measures. However, no further details of the monitoring programs or control measures are provided in the Annex F submission.

191. In India, the Ministry of Agriculture and Farmers Welfare (MAFW) and Central Pollution Control Board (CPCB) have taken actions to monitor key pests and pesticide residues through samples of soil and water at the National Level. Such actions aim to (1) identify key pests on crops and regions having preponderance of pesticide residues in order to focus extension efforts for IPM and Good Agriculture Practices (GAP); (2) test pesticide residues and other contaminants in environmental samples like soil and water; (3) strengthen infrastructure at quarantine stations to prevent entry of food and food commodities which have pesticide residues above maximum residue limit (MRL) to the country; and (4) test / certificate pesticide residue in export / import samples.

[26] https://www.epa.gov/ingredients-used-pesticide-products/chlorpyrifos#safe%20use (accessed 05.01.2024)

[27] https://www.doa.go.th/en/ (accessed 05.01.2024)

[28] https://laboratorios.ambiente.gob.ar/ (accessed 05.01.2024)

[29] https://ciam.ambiente.gob.ar/repositorio.php?tid=8# (accessed 05.01.2024)

3. Synthesis of information

3.1 Summary of risk management evaluation measures

192. Restricting or prohibiting the production and use of chlorpyrifos would positively impact human health and the environment by decreasing emissions and subsequently human and environmental exposures.

Production, use and releases

193. Ongoing production of chlorpyrifos takes place primarily in China, India, Brazil, USA and EU, with current global production volumes of chlorpyrifos estimated around 50,000 tonnes/year. Chlorpyrifos is used globally, although 15 countries plus the EU have completely banned the use of chlorpyrifos, and its use is under review in several countries.

194. Chlorpyrifos has been used as an active substance in products for uses that can be broadly divided into the following categories: agricultural uses for food and feed crops, agricultural uses for non-food crops (e.g., cotton); veterinary uses; and uses in residential, industrial and public health applications (e.g. to control termites, fleas, bugs and as a mosquito larvicide and adulticide). According to the Annex F (2023) submission information, chlorpyrifos is still widely used in many countries and regions across each of the categories detailed above.

195. Chlorpyrifos can be released to the environment, either during manufacturing, or from direct application. Upon its application as a pesticide, chlorpyrifos is directly released to the environment and can be further distributed into various environmental compartments such as air, soil, surface water, groundwater and sediment, and it can be also taken up by biota. Chlorpyrifos is considered to be semi-volatile and can be released to the atmosphere, either during manufacture or by volatilization during application, with early losses of chlorpyrifos from soils surfaces and plant surfaces. Chlorpyrifos can contaminate surface waters either through spray drift that occurs at the time of application or through runoff from use areas.

Possible control measures in meeting risk reduction goals

196. The following control measures are potentially available based on the nature of chlorpyrifos production and use: (1) prohibition of production, use, import and export; (2) restriction of production, use, import and export. In addition to the control measures considered above, the following additional aspects are considered (e.g. for additional national/regional-level actions), to ensure the control measures prevent or minimize exposure of humans and the environment: (3) establishment of exposure limits and PPE requirements in workplaces (including agriculture) at the national level;(4) establishment of MRL in water, soil, sediment and/or food at the national level; and (5) environmentally sound management of obsolete stockpiles and clean-up of contaminated sites.

A prohibition of production, use, import and export by listing in Annex A without exemptions would likely represent the most successful control measure in reducing emissions and exposure and reducing risks to human health and the environment. A number of countries that represent a wide range of climates, economic development levels, and specific chlorpyrifos applications have successfully implemented this to date. A restriction of production, use, import and export by listing in Annex A or B with exemptions would limit the potential release of chlorpyrifos to the environment to countries where the pesticide is still being used and it is indicated that alternatives for those uses are not currently feasible. Information on the exposure reduction and socioeconomic impacts of a restriction is limited.

197. The management of obsolete stockpiles of chlorpyrifos presents a challenge due to the limited information available on the supply chain and possible end users. Alongside landfilling in a hazardous landfill, chlorpyrifos can be completely incinerated at temperatures ≥650°C. However, incineration is not recommended due to the formation of hazardous by-products. Some parties noted that they do not have the means to appropriately manage chlorpyrifos waste and rely on export.

198. The potential costs associated with the prohibition of chlorpyrifos and its alternatives include enforcement costs for governments, impacts on chlorpyrifos manufacturing companies, costs for farmers switching to alternatives, consumer-related costs, expenses for managing obsolete pesticides, waste disposal, and remediation of contaminated sites. Limited information on costs related to control measures was provided, but varying cost impacts are expected depending on the country's use of chlorpyrifos and regulatory status.

Summary of efficacy, efficiency and availability of appropriate alternatives

199. Several chemical and nonchemical alternatives to chlorpyrifos have been identified as technically and economically feasible for a wide range of uses. Among the chemical alternatives, diamide insecticides, spinosyns, avermectins, and pyrethroids have been used or proposed. However, some of these chemical alternatives have expired use approvals in some countries (such as pyrethroids in the EU) or are for more targeted uses rather than broad spectrum. The targeted use of pesticides reduces the potential for effects on non-target organisms, both direct and indirect.

200. Several non-chemical alternatives to chlorpyrifos, IPM, agroecological practices, biological control systems, botanical preparations, and physical barriers have also been suggested. IPM integrates practices like crop rotation, balanced fertilization, and ecological infrastructure for pest control. Agroecology emphasizes adapting to local environments and promoting biodiversity, with examples from Kenya employing natural herbs, wood ash, intercropping, and crop rotation for pest management. Biological control systems involve natural enemies or plant extracts, but their implementation requires careful consideration of direct and indirect effects on non-target organisms. Botanical preparations, such as neem oil and garlic oil, have shown efficacy in reducing cabbage pests without adverse effects on beneficial insects. Physical barriers, like transparent bags for bananas and technologies to prevent termite infestation, offer additional alternatives. Finally, improved hygiene practices and waste management are recommended for pest control, aligning with the WHO's preference for sanitation over insecticides.

Summary of information on impacts on society

201. The use of chlorpyrifos may be associated with adverse public, environmental (biodiversity and habitat loss), and occupational health effects, and has the potential to particularly impacting vulnerable groups like children. In vivo animal studies provide evidence of neurodevelopmental toxicity, and epidemiological evidence suggests an association of exposure to chlorpyrifos during pregnancy with adverse neurodevelopmental outcomes in children, including changes in brain morphology, delays in cognitive and motor functions, attention problems, and tremors. While there is contradictory information regarding the impact on farmers' health, with some countries reporting no issues, others highlight unpredictability and severe damage, including unintentional acute pesticide poisoning in regions like Vietnam, Laos, Bangladesh, and India. Additionally, chlorpyrifos is classified as very toxic to aquatic life, with long-lasting effects, raising concerns about its environmental impact.

202. Limited agricultural data in Annex F responses suggests that eliminating chlorpyrifos may encourage sustainable practices like IPM and organic farming, benefiting long-term soil health and ecosystem resilience. However, an Observer (PMFAI) contends that the prohibition may have adverse consequences on pest management in crucial crops; however, many other Parties have undertaken a successful transition to alternatives. Chlorpyrifos has been extensively used against desert locusts, and while alternative pesticides were recommended, chlorpyrifos remained dominant in Africa. Additionally, historical uses for termite control, mosquito population reduction, and concerns about its impact on pollinators and aquatic ecosystems are highlighted.

203. Limited economic data in Annex F responses suggests that transitioning to alternative pest control methods may lead to increased economic costs for farmers, including investments in new technologies and training, higher costs of alternatives and potentially reduced crop yields during the transition. However, the costs are balanced or outweighed by the social costs, such as organic farming which offers a number of benefits, the use of targeted pesticides which could reduce the overall amount of substance needed (and therefore the costs to farmers), a reduction in healthcare costs due to minimized pesticide exposure, and overall improved ecosystems associated with societal, economic and environmental benefits.

204. The elimination of chlorpyrifos aligns with the UN sustainable development plans to reduce emissions of toxic chemicals and is pertinent to several Agenda 2030 Sustainable Development Goals, particularly Goals 2, 3, and 15, focusing on sustainable agriculture, health, and terrestrial ecosystem protection. Furthermore, the SAICM emphasizes the crucial connection between chemical safety, sustainable development, and poverty reduction, promoting measures to reduce risks, prioritize safe alternatives for harmful substances, and phase out chemicals that pose unreasonable risks by 2020.

205. Access to information and public education on chlorpyrifos is limited, but one Observer (PMFAI) in India provides detailed information, advocating for multi-language labels and leaflets to communicate precautionary measures. Several governments, such as Argentina, Canada, and the US, offer information on chlorpyrifos and pesticides in general, covering topics like regulation, safe usage guidance, and exposure risks. Argentina has launched a network of environmental laboratories, and

Canada has legislative Acts and programs for compliance, enforcement, and monitoring chlorpyrifos in water.

3.2 Possible risk management measures

206. The most efficient control measure for reducing the releases of chlorpyrifos to the environment would be to list the substance in Annex A without exemptions. Listing chlorpyrifos in Annex A would also entail that the provisions of Article 3 on export and import and of Article 6 on identification and sound disposal of stockpiles and waste would apply.

207. Based on the information submitted by Parties and observers in the Annex F submissions during the risk management evaluation and the collective experience reported, the phase-out of chlorpyrifos may be challenging in certain specific applications, and in some specific regions. However, alternative options seem to exist for the different uses and applications of chlorpyrifos based on Annex F information provided by Parties and Observers and additional research.

208. [PLACEHOLDER] The following specific exemptions are recommended: [to be discussed] / No specific exemptions are recommended

4. Concluding statement

209. Having decided chlorpyrifos is likely, as a result of long-range environmental transport, to lead to significant adverse effects on human health and/or the environment such that global action is warranted, and 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 chlorpyrifos be considered by Conference of the Parties to the Stockholm Convention for listing under the Stockholm Convention in Annex A or, B [with specific exemptions for specific applications where alternatives are not currently available]/[without specific exemptions]

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