Annex*

Additional information relating to the draft risk management evaluation for chlorpyrifos

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1. Introduction

1.1 Chemical identity of chlorpyrifos

1. [Link to the other INF Excel sheet]

1.2 Production and uses

1.2.1 Production

1. While production previously mainly occurred in North America and Europe, China and India are currently two of the biggest producers of chlorpyrifos globally have now become two of the leading global producers of chlorpyrifos. It was indicated that, following the prohibition of five highly toxic organophosphate pesticides in China, chlorpyrifos became one of the most dominant insecticides used in the country (Chen et al. 2012).

2. A wide range of commercial products containing chlorpyrifos have been identified, with many individual trade names indicated specified (see INF document Table 8, (#add reference).). Based on searches of publicly available databases1 over 300 suppliers of chlorpyrifos-containing products containing chlorpyrifos have been identified globally. The majority of suppliers are in China, with smaller numbers of suppliers identified in India, USA, UK, EU and other countries. Chlorpyrifos is has also been found co-formulated as in mixtures with other insecticides, including abamectin, acetamiprid, buprofezin, cyfluthrin, cypermethrin, diazinon, dichlorvos, emamectin, ethiprole, fenobucarb, hexaflumuron, isoprocarb, permethrin, phoxim, pymetrozine pyretrozine, spinosad, thiram, triazophos, trichlorfon, and fungicides such as mancozeb and carbendazim (Pesticide Action Network, 2013).

3. **China** - In 2022, China produced about 32,400 tonnes of chlorpyrifos (China Annex F, 2023).

4. **Serbia** – It has reported that in the period 2018-2020, chlorpyrifos was imported as a raw material for the production of plant protection products, however no information was provided on volumes of import or use (UNEP/FAO/RC/CRC.19/INF/6).

5. **India –** Total capacity for chlorpyrifos production in India in 2020-21 was reported by the Pesticides Manufacturers & Formulators Association of India (PMFAI) to be 30,000 tonnes (PMFAI Annex F, 2023) with an actual production volume of 24,000 tonnes, of which 10,000 tonnes were used domestically, 12,000 tonnes were exported, and 2,000 tonnes were in stockpiles (PMFAI Annex F, 2023). However, a lower overall production volume was reported by India (Annex F, 2023), with an annual production of 8,000-8,500 tonnes being reported between 2020 and 2023. The reason for this discrepancy is unclear. One of the principal major producers in India (Gharda Chemicals Ltd), indicated that in over the last three years (2020-2023), production volumes of production had declined decreased by a third, and export while volumes of export had declined by half.

6. **Brazil** – In 2022, it is reportd that chlorpyrifos was one of the ten most commercialized active ingredient for pesticides in Brazil (Brazil, 2024 Annex F). It is estimated that in 2022 approximately 6,700 tonnes of chlorpyrifos were produced, with a further 2,200 tonnes imported. Data on production and import volumes were provided for the years 2009-2022, indicating significant year-to-year trends. It is noted that volumes of production and import have been reported to be as high as 13,000 tonnes and 6,400 tonnes respectively (in 2014).

7. **USA** – As discussed in the risk profile, while volumes of chlorpyrifos production in the USA have not been provided, it is likely to have declined significantly in the past 25 years due to it being voluntarily cancelled or phased out, as well as national-level and State-level restrictions (UNEP/POPS/POPRC.19/4).

8. **EU** – the placing on the market and use of chlorpyrifos in plant protection products is has been prohibited since 2020 following the non-renewal of its approval. Furthermore, in several EU states, such as Sweden, chlorpyrifos has never been used as a plant product. However, production and export of chlorpyrifos are not banned in the EU. Export notifications of chlorpyrifos have been forwarded by the EU to 22 and 28 importing countries in 2022 and 2023 respectively, indicating. This indicates that the export of chlorpyrifos(or plant protection products containing chlorpyrifos) from the EU continues to take place is still ongoing In effect, 52 tonnes of chlorpyrifos were exported from the EU to nine importing countries in 2022. The countries exporting it in 2022 were Belgium, Denmark, and Poland and the receiving countries were Algeria, Belarus, Costa Rica, Honduras, Lebanon, Pakistan, Qatar, the Russian Federation and Tunisia. No data are available for 2023 or other years.

9. **Argentina** – It is indicated that the import of chlorpyrifos to Argentina has declined sharply in the past decade, with a reported decease from 4,700 tonnes in 2013 to 1,300 tonnes in 2019 (PNUD, 2021)[2]. Argentina reported the import of 600 tonnes of chlorpyrifos (formulated product[3]) and 3,000 tonnes of active chlorpyrifos substance in 2021, originating predominantly from China, with lower volumes imported from India and Brazil (UNEP/FAO/RC/CRC.19/INF/6). A regulatory phase out of the production, use, import and export of chlorpyrifos was required in Argentina by the end of 2022, with 70 tonnes of active substance imports reported for 2022 (originating from China), while 200 and333 tonnes of formulated product were exported in 2021 and 2022, respectively, to other South American countries (Bolivia, Uruguay, Paraguay).

10. **Canada –** Canada commented that all imports and, manufacturing and trade were cancelled as of December 2021. As discussed in the risk profile, while volumes of chlorpyrifos production in the USA have not been provided, it is likely to have declined significantly in the past 25 years due to it being voluntarily cancelled or phased out, as well as national-level and State-level restrictions (UNEP/POPS/POPRC.19/4).

11. **Australia** – it was reported that sales of 2,200 tonnes of chlorpyrifos in 2021-2022, which is understood to cover formulated products and active substance (UNEP/FAO/RC/CRC.19/INF/6).

1.2.2 Use

12. A common use of chlorpyrifos in both residential and industrial applications is as a wood preservative in a number of wood treatments, including processed wood products, fence posts and utility poles, railway ties and railway box cars. It is reported that chlorpyrifos has a widespread useis widely used to control termites and borers in wood and as well as in general building and construction settings (India Annex F, 2023).

Further information on uses in different counties (as detailed in Annex F submissions):

13. **China** – Following the prohibition of five highly toxic organophosphate pesticides in China, chlorpyrifos became one of the most widely-used insecticides (Chen *et al*. 2012). It is indicated that chlorpyrifos is currently registered for a number of specific products for food and feed crops, including rice, wheat, corn, apple, citrus, litchi, pear, longan, peach, peanut, sugarcane, soybean, etc., as well as products for non-food crops, including cotton, poplar, grass, mulberry, rubber tree, etc. It is also registered in China for specific public health uses, where one product for mosquito and fly control can only be used by professionals in public places and the others are baits for indoor cockroach control (China, Annex F, 2023).

14. **India** –as of 2016-17, chlorpyrifos is the most frequently used pesticide, accounting for 9.4% of the total insecticide consumption (IPEN Annex F, 2023), due to its availability across the country (locally produced), its efficacy, cost & compatibility, and ease of implementation as first line of defense for locust control and in emergency pest outbreak of invasive pests. In India, there are six solo formulations and five combination formulations with pyrethroids neonicotinoids and pyrazoles registered for use for agricultural (food and feed) uses on field, specific vegetable and fruit crops as well as rice paddy (16 crops in total). Additionally, these formulations are registered for non-food crops, namely cotton (PMFAI Annex F, 2023). Use is also permitted for non-agriculture applications in animal health for ectoparasite control, to protect buildings for termite control and for wood treatment. An overview of the specific products, crops and target pests approved for use in India is provided in the Excel INF document (#add reference).

15. **African countries** – It is reported that chlorpyrifos is registered for over 480 uses across 27 African countries[4] (COLEAD Annex F, 2023). Specific approved uses include controlling African bollworm (*Helicoverpa armigera*), aphids, termites, grasshoppers, fall armyworm, locusts, scales, whitefly, weevils, thrips, rice stem borer, and leaf miner. This includes uses of chlorpyrifos various in agricultural applications for food and feed crops, such as cocoa, tea, coffee, chickpeas, rice, wheat, maize, citrus, pineapple, cabbage, peppers, tomato, fruit trees, and vegetables in general. Additionally, it is used in non-food crops, such as cotton. It is also indicated that chlorpyrifos is used in Nigeria to control boll worms, cutworms, white grub, termites, and borers on crops like cotton, fruit (e.g., watermelons) and vegetable crops like spinach, sorrel (Zobo), and rice paddy among others, as well as on cotton (International Pollutants Elimination Network (IPEN), 2022). In Kenya it used in control of ectoparasites on cattle in combination with cypermethrin (comments on the, Kenya 2024).

[2] It was not explicitly indicated in the reference if this refers to active substance or formulated product.

[3] Although not explicitly stated, it is understood this refers to the volume of the product.

[4] Angola, Benin, Botswana, Burundi, Ivory Coast, Comité Sahélian des pesticides (CSP) including: Burkina Faso, Cabo Verde, Chad, Guinée-Bissau, Mali, Mauritania, Niger, Senegal and The Gambia, Dominican Republic, Ethiopia, Gabon, Ghana, Guinée, Kenya, Madagascar, Malawi, Mozambique, Sierra Leone, Tanzania, Togo, Zimbabwe.

16. **Brazil** –There are currently 24 registered formulated products (PF) containing chlorpyrifos and 35 technical pesticide (PT) products registered with this active ingredient.

In Brazil, chlorpyrifos has the following approved agricultural uses:

a) foliar application on cotton, peanuts, oats, potatoes, coffee, rye, barley, citrus, peas, beans, chickpeas, lentils, apples, millet , corn, pasture, soybean, sorghum, tomato (only for low-growing tomato, for industrial purposes), wheat and triticale;

b) localized application in the banana crop;

c) soil application in potato and maize crops.

The following uses are also authorized: a) non-agricultural to control ants, only in the form of granulated bait; b) household cleaning products in the form of baits packed in bait holders equipped with safety device, to prevent exposure of children, at the maximum permissible concentration of 1% w/w; c) as a wood preservative, exclusively for the treatment of wood intended for sleepers, posts, crossarms, posts for rural fences, supports and beams, for the purpose of registration with IBAMA (ANVISA, 2022). Additionally, in Brazil it is used for veterinary purposes, indicated for topical use (pour-on), to combat the following ectoparasites that affect cattle: Ticks of the genus Boophilus microplus (adults). Larvae of Dermatobia hominis. Flies of the genera Haematobia irritans (adults) and Dermatobia hominis (adults).

17. **New Zealand** – In New Zealand, substances containing chlorpyrifos are restricted to professional use only, and are registered for agriculture across a variety of crops, with some minor uses for pest control in industrial and non-agricultural settings. In Malaysia, while a widespread restriction has been implemented for most agricultural uses, use remains permitted for public health applications, i.e., to control urban pests such as cockroaches, and termites (UNEP/FAO/RC/CRC.19/8). Egypt (Annex E, 2022) report that use of chlorpyrifos in all food crops is now banned, with only use on cotton remaining permitted.

18. **Other countries** – e.g. Australia, Belarus, Kazakhstan, Nepal, Oman, and Uruguay, currently observe wide use of chlorpyrifos in agriculture and pest control. For example, Oman (Annex F, 2023) indicate that its use is permitted for termites control with approval and supervision as deemed appropriate by the competent authority. In Nepal, chlorpyrifos reportedly comprises almost 50% of the total amount of imported insecticides imported and is used for various crops such as barley, wheat, paddy, grams, yellow lentil (Mung), peanuts, sugarcane, cotton, mustard, brinjal, cabbage, cauliflower, onions, potatoes, oranges. (Alaska Community Action on Toxics (ACAT)/IPEN Annex F, 2023). In Kazakhstan, 16 products containing chlorpyrifos are registered for use for the following crops: rapeseed, potato, apple and peach trees, cabbage, gourd family, corn, sunflower, cotton, sugar beet, safflower, alfalfa and hops (ACAT/IPEN Annex F, 2023).

1.2.3 Emissions

19. [No additional data]

1.3 Data sources

20. [No additional data]

1.4 Status of the chemical under International Conventions

21. [No additional data]

1.5 Any national or regional control actions taken

22. Summary of country restrictions:

23. In **Australia** – In 2019 the Australian Pesticides and Veterinary Medicines Authority (APVMA) cancelled the registration of CPY products for domestic and home garden use and in certain public spaces such as parks and footpaths. In 2020, the APVMA cancelled the remaining product registrations and label approvals of products that included a combination of home garden and agricultural uses. In December 2023, APVMA indicated that it proposes to ban the remaining uses of CPY[5]. This is subject to an open consultation and a final decision is expected in July 2024. [noted this is still pending].

[5] https://www.apvma.gov.au/news-and-publications/publications/gazette/gazette-25-12-dec-23 (accessed 04.01. 2024)

24. In **China**, CPY has been prohibited from being used on vegetables since the end of 2016, however it is used on a number of other crops (see section 1.2.2, CCPIA Annex E, 2022; China Annex F, 2023).

25. In **Egypt**, CPY has been restricted to use on cotton (termites and locusts) at the end of 2022 (Egypt Annex E, 2022).

26. In **India**, as of 2016-17, CPY is the most frequently used pesticide in India, accounting for 9.4% of the total insecticide consumption (IPEN Annex F, 2023). An overview of the specific products, crops and target pests approved for use in India is provided in Table 3 of document UNEP/POPS/POPRC.19/INF/11.[6] CPY products are used in India for non-agricultural purposes, namely pre and post construction treatment for buildings, forestry and protecting wood from termites & borers (PMFAI Annex F, 2023). The use of CPY was due to be reviewed in 2018 following completion of recommended studies. The review is not available, but CPY was included in the draft ban notification issued by the Indian Government in May 2020 and the ban has not been implemented[7]. However, the use of CPY on berries, citrus and tobacco was revoked in September 2023, and in in cases where the Maximum Residue Level (MRL) is exceeded, specific States can temporarily ban the use of CPY (PMFAI Annex F, 2023). For example, in August 2022, the Governments of Punjab and Haryana banned the use of CPY for 60 days in Basmati Rice to control residue levels. In India, chlorpyrifos use is permitted on specific crops and target organisms (see section 1.2.2 and INF document (#add reference). In 2021 the Indian Government issued a draft ban notification, although it has not yet been implemented[8]. However, some uses have been revoked and in cases where the Maximum Residue Level (MRL) is exceeded, specific States can temporarily ban its use (PMFAI Annex F, 2023).

27. **Malaysia** banned agricultural uses of CPY from May 2023. Use of CPY is allowed for public health uses and the control of 'urban pests' such as cockroaches, termites, mosquitoes, ants, flies and bugs (UNEP-FAO-RC-CRC.19). It is unclear whether domestic uses for pest control are still allowed.

28. In **New Zealand**, agricultural product authorisations have been given for specific crop/pest combinations in agricultural uses, there are no authorised veterinary applications and industrial uses are allowed against spiders, ants and slaters (woodlice). The substance is currently being reassessed by NZ EPA based on potential significant human health and environmental risks[9].

29. In **Oman**, the use of CPY is permitted against termites only, with approval and supervision as deemed appropriate by the competent authority (Oman Annex F, 2023).

30. In the **USA**, indoor uses are prohibited and the US EPA revoked all CPY food tolerances (residual concentrations) in 2022, meaning that non-agricultural uses were not allowed. In November 2023 a ruling overturned the US EPA's decision. The US EPA's website indicates that it expects to propose a new rule to revoke the tolerances associated with all but the 11 uses referenced by the court. Those 11 uses are: alfalfa, apple, asparagus, cherry (tart), citrus, cotton, peach, soybean, strawberry, sugar beet, wheat (spring), and wheat (winter) and represent about 55% of the total chlorpyrifos agricultural use between 2014-2018[10,11] . However, bans on CPY on food or feed crops in specific states (such as California, Hawaii, New York and Oregon) remain valid.

31. In **Uzbekistan**, the Ministry of Health of the Republic of Uzbekistan plans to take measures for the phased restriction and decommissioning of CPY (Uzbekistan Annex E, 2022).

32. In **Yemen**, it has been reported that the use CPY is severely restricted, but there is limited information on its uses (UNEP/FAP/RC/CRC.19/INF/6).

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[7] https://ipen.org/sites/default/files/documents/copyedited_final_chlorpyrifos-_country_situation_report_revised66.pdf (accessed 11.01.2024)

[7] https://ipen.org/sites/default/files/documents/copyedited_final_chlorpyrifos-_country_situation_report_revised66.pdf (accessed 11.01.2024)

[8] https://ipen.org/sites/default/files/documents/copyedited_final_chlorpyrifos-_country_situation_report_revised66.pdf (accessed 11.01.2024)

[9] https://www.epa.govt.nz/industry-areas/hazardous-substances/chemical-reassessment-programme/active-projects/ (accessed 4 January 2024)

[10] https://www.epa.gov/ingredients-used-pesticide-products/chlorpyrifos (accessed 4 Jan 2024)

[11] https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/G/SPS/NUSA3443.pdf&Open=True (accessed 19 Feb 2024)

2. Summary of information relevant to the risk management evaluation

2.

2.1 Identification of possible control measures

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

33. Information provided by Sri Lanka (2023) to the CRC (UNEP/FAO/RC/CRC.19/8), which indicated that a full ban 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.

34. The Alternative section in RME has detailed the availability and feasibility of chemical and non-chemical alternatives to chlorpyrifos. The prohibition of the production, sale and use of chlorpyrifos by a number of nations, from a variety of geographical and climatic regions that cover a diverse range of crops, livestock and pests, indicates these alternatives are generally viable and already used in practice.

35. The specific situation and perception regarding the availability and feasibility of alternatives for a specific pest and/or crop may differ between countries. For example, inputs from China (Annex F, 2023) and India (PMFAI Annex F, 2023) indicate the permitted use of chlorpyrifos for rice crops, while Sri Lanka ana Malaysia have implemented a ban for this use on the basis of available alternatives. Furthermore, the input of China (Annex F, 2023) highlighted that, while chlorpyrifos continues to 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.

36. The risk management evaluations of other pesticides, such as dicofol (see UNEP/POPS/POPRC.13/7/Add.1) and methoxychlor (see UNEP/POPS/POPRC.17/13/Add.1), provide some further insight into the main issues facing agricultural communities when transitioning from pesticides more generally. While chlorpyrifos is not chemically related to these other pesticides, it can be considered in this risk management evaluation that these insights will also be relevant for the control of chlorpyrifos.

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

37. While many countries have opted for a full prohibition of chlorpyrifos (see above), in many countries regulatory measures are in place that still allow use of chlorpyrifos for specified uses (see section 2.2 and INF document (#add reference)).

38. Chlorpyrifos has high potential for adverse effects in occupational applications, especially in developing countries (Phung et al., 2012). For example, exposure levels in Vietnam for farmers using chlorpyrifos on rice, measured post application, ranged from 0.35 to 94 µg/kg/day, exceeding "most of the acute guidelines", and were significantly higher than in a similar study in Sri Lanka, (highest level there was 8.4 µg/kg/day), with even higher levels of exposure have been recorded amongst pesticide applicators in Egyptian cotton fields using backpack mist blowers (Phung et al., 2012). Additionally, Phung et al. (2013) which indicated that during a single event spraying of chlorpyrifos in Vietnam is likely to have adverse effects on Vietnamese rice farmers, with 29-33% affected.

39. Standard occupational exposure limits (OEL) for the use of chlorpyrifos have previously been identified. The (US) Occupational Safety and Health Administration (OSHA) has set a Permissible Exposure Limit (PEL) of 0.2 mg/m^3 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).

40. Workers in industries that produce chlorpyrifos, or actively apply it in a range of settings (including farm workers who enter treated fields after insecticide application) are at higher risk of exposure, while among the general population, people who use the insecticide in homes and gardens and people who ingest food exposed to chlorpyrifos are at higher risks of exposure (ATSDR, 1997). 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).

41. Fenske et al (2012) determined, in a study conducted in the USA, that 94-96% of internal doses in these workers comes from dermal exposure, and that all workers exceeded the US AOEL of 1.5 µg/kg/day. Wołejko et al. (2022) suggested there is still a perception that skin exposure to chlorpyrifos is not as dangerous or as relevant as other routes of exposure. Therefore, especially in developing countries, both farmers and others involved in the production, transport, sale, and use of pesticides have not paid sufficient attention to skin exposure.

42. A study by Aponso (2002) on exposure and risk assessment for farmers occupationally exposed to chlorpyrifos in Sri Lanka showed that farmers using chlorpyrifos on cucurbits were exposed to unnecessarily high levels via dermal exposure. It was revealed that exposure was reduced by wearing long-sleeved shirts but that wearing long pants during spraying did not necessarily reduce the exposure. It was also revealed that more than 30% of the farmers in the study used more than the officially recommended dose of chlorpyrifos to achieve a better pest control. Many of the knapsack spray tanks were old and about 30% were leaking. Many of the workers did not use a head cover despite the fact that the cucurbit crops grow and are sprayed on over-head canopies. Most farmers did not use gloves when mixing concentrated pesticides.

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

43. For both liquid emulsion-based products and wettable powders this includes the need to ensure that skin, face, and head be covered, and that chemical-resistant protection should be worn at all times. The report of the Indian Expert Committee from the Ministry of Agriculture & Farmers Welfare (MAFW) on the review of 66 pesticides, suggests that gloves and masks should be supplied with each pesticide pack (PMFAI Annex F, 2023). However, US EPA (2009) stated that, even when all feasible PPE or engineering controls are used, there are still occupational exposures of concern. Furthermore, it is suggested that, in developing countries, highly hazardous pesticides (HPP) may pose significant risks to human health or the environment because risk reduction measures such as the use of PPE or maintenance and calibration of pesticide application equipment are not easily implemented or are not effective (Food and Agriculture Organization of the United Nations (FAO)).

44. Many barriers to using PPE as a control measure for general pesticides have been documented. For instance, it is often reported that farmers do not use PPE due to lack of supplies, expense, time, or due to discomfort. The most common barrier reposted by Walton et al. (2017) was wetness (caused by irrigation, sweat, and rain) which was associated with health concerns and also reduced effectiveness of protective clothing. Wet PPE may even increase dermal absorption of pesticides. European Parliament (2021) also highlighted that health concerns associated with the handling and use of pesticides are greater in developing countries because farmer often do not have adequate PPE and are often unable to read labels that are usually only source of safety instructions. In person education for farmers on these topics is rarely available.

45. 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 comfortable, expensive or not readily available should be avoided, especially in the case of small-sale users and farm workers in hot climate". Furthermore, a number of studies indicate that the level of use and awareness of PPE in certain developing countries is insufficient to ensure the safety of farm workers dealing with hazardous pesticides (Banerjee et al., 2014; Gesesew et al., 2016; Neupane et al., 2014). As such, using PPE as a control measure for chlorpyrifos exposure may be limited by the observed problems with current practices and contrary to The International Code of Conduct (ICC) in countries with hot climates.

46. Potential for exposure and impacts on human health to workers during the manufacture of chlorpyrifos depends upon the manufacturing process. It is indicated that manufacture of chlorpyrifos takes place in several countries (see Section 1.2), however there is limited data available on the manufacturing process used, i.e., if this an open or closed process. To protect workers during manufacture, occupational exposure could be reduced by ensuring that producing facilities use closed systems only. The PMFAI (Annex F, 2023) indicated chlorpyrifos manufacturing process in India is carried out in closed system, with receiving, unloading, storage and charging of raw materials conducted through pipelines. The process is controlled and monitored closely and it is expected that release / emission / losses during production are minimal (PMFAI Annex F, 2023). Details of the manufacturing process for chlorpyrifos in other countries have not been identified.

47. During manufacturing and use, PPE should be worn at all times to better protect workers, particularly farmers during preparation and use. The effectiveness of using PPE and pesticide application equipment as control measures to reduce human exposure are likely to be limited considering the observed problems with current practices, especially in agriculture, and the

requirements of the ICC on Pesticide. Furthermore, the monitoring of such measures would impose challenges, especially in a global context. It should also be emphasized that such control measures are expected to be effective for direct human exposure for workers, however these measures do not significantly reduce the wider environmental release and/or exposure of the general population to chlorpyrifos.

Key studies investigating occupational exposure and health effects

48. **Phung et al. (2012)** - exposure levels in Vietnam for farmers using chlorpyrifos on rice, measured post application, ranged from 0.35 to 94 µg/kg/day, exceeding "most of the acute guidelines", and were significantly higher than in a similar study in Sri Lanka, (highest level reported was 8.4 µg/kg/day), while even higher levels of exposure have been found amongst pesticide applicators in Egyptian cotton fields using backpack mist blowers.

49. **Phung et al. (2013)** - indicated that single-event spraying using chlorpyrifos in Vietnam is likely to have adverse effects on Vietnamese rice farmers over a lifetime of pesticide spraying events.

50. **Fenske et al (2012)** – assessed chlorpyrifos exposures 12 Egyptian cotton field workers, determining that 94-96% of internal doses came from dermal exposure, and that all workers exceeded the US AOEL of 1.5 µg/kg/day.

51. **Wołejko et al. (2022)** - suggested there is still a perception that skin exposure to chlorpyrifos is not as dangerous or as relevant as other routes of exposure. Therefore, especially in developing countries, both farmers and others involved in the production, transport, sale, and use of pesticides have not paid sufficient attention to skin exposure.

52. **Aponso (2002)** – investigated the exposure and risk assessment for farmers occupationally exposed to chlorpyrifos in Sri Lanka showed that farmers using chlorpyrifos on cucurbits were exposed to unnecessarily high levels via dermal exposure. It was revealed that exposure was reduced by wearing long-sleeved shirts but that wearing long pants during spraying did not necessarily reduce the exposure. It was also revealed that more than 30% of the farmers in the study used more than the officially recommended dose of chlorpyrifos to achieve a better pest control. Many of the knapsack spray tanks were old and about 30% were leaking. Many of the workers did not use a head cover even though the cucurbit crops grow and are sprayed on over-head canopies. Most farmers did not use gloves when mixing concentrated pesticides.

Key studies relating to the use of PPE use with pesticides:

53. **PMFAI Annex F, 2023 –** For both liquid emulsion-based products and wettable powders this includes the need to ensure that skin, face, and head be covered, and that chemical-resistant protection should be worn at all times. The report of the Indian Expert Committee from the Ministry of Agriculture & Farmers Welfare (MAFW) on the review of 66 pesticides, suggests that gloves and masks should be supplied with each pesticide pack.

54. **The Food and Agriculture Organization of the United Nations (FAO)12** has suggested that, in developing countries, highly hazardous pesticides (HPP) may pose significant risks to human health or the environment because risk reduction measures such as the use of PPE or maintenance and calibration of pesticide application equipment are not easily implemented or are not effective.

55. **Walton et al. (2017) -** reported that the most common barrier reported by was wetness (caused by irrigation, sweat, and rain) which was associated with health concerns and also reduced effectiveness of protective clothing. Wet PPE may even increase dermal absorption of pesticides

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

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

57. The previously recommended treatment and disposal methods for chlorpyrifos are incineration, adsorption, and landfilling (International Register of Potentially Toxic Chemicals (IRPTC), 1989).

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

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.

58. Information on quantities of chlorpyrifos that have been destroyed is scarcely reported. A search of the US EPA Toxics Release Inventory (TRI) explorer database indicates that 47,000 pounds or 21,000 kg of chlorpyrifos waste was managed by treatment in 2019. The TRI data should, however, be used with some caution since only certain types of facilities are required to report; therefore, the information may not be exhaustive. 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.

59. 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. The short-term, phased approach to the removal of chlorpyrifos from the market, and for the cessation of its use in Canada, minimizesd the potential for waste and disposal implications of obsolete stocks (Canada Annex F, 2023). Given the historic agricultural use pattern of chlorpyrifos in Canada, and its degradation profile under such use conditions, a significant presence of contaminated sites within Canada is not anticipated (Canada Annex F, 2023).

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

Summary of status of MRLs for different parties is provided in the INF Excel document

Information provided on environmental standards and maximum residual limits (MRLs) from Parties:

60. EU – As discussed in the risk profile, under EU legislation, the Annual Average Environmental Quality Standard for chlorpyrifos in surface water is 0.03 µg/L. In October 2022, the European Commission published a proposal to amend existing water legislation , which includes lowering the safe threshold to 4.6 × 10-5 µg/L in both inland water and other waters, while the maximum allowable concentration threshold would lower to 2.6 × 10-3 µg/L for inland water and 5.2 × 10-4 µg/L for other waters.

61. In 2018, eight EU Member States had incidences of exceedance [of the current] EQS, covering a total of 70 water bodies. Regarding groundwater, only one country, Spain, (for two water bodies) exceeded EQS levels in the 2nd River Basin Management Plans (RBMPs). In Austria, in 2018, chlorpyrifos was found at concentrations of 0.018 µg/L in surface water (European Environment Agency (EEA), 2018). The proposed lowering of EQS values, by factors between 40 (EQS for acute exposure in freshwater, MACEQS) and 650 (EQS for chronic exposure in marine waters, AA-EQS) (Backhaus, 2023), suggest further work will be needed to assess water bodies in compliance.

62. In the EU, MRLs for chlorpyrifos have been set by the EU (Regulation (EC) No 396/2005) and are included in Table 4 (UNEP/POPS/POPRC.17/INF/7). Under both the UK and EU regimes a limit has been set for chlorpyrifos of 0.01 mg/kg covering a wide range of fresh fruit, vegetables, nuts, fungi, and sugar. For teas (and other infusions), hops and spices, a limit of 0.01 mg/kg applies. Additionally, for meat products (all types) the 0.01 mg/kg threshold applies (UK Annex F, 2021).

63. In the EU, the MRL for food was lowered to 0.01 mg/kg in 2020, after the non-renewal of the substance registration (Commission Regulation (EU) 2020/1085). However, it is noted that the MRL values set for chlorpyrifos is not a toxicological risk-based threshold value, but it is based on the default lowest limit of analytical determination in EU law.

64. China – In March 2022, China released National Food Safety Standard for Drinking Water Quality which entered into force on April 1, 2023. This uses the WHO guideline value of 30 µg/L for chlorpyrifos.

65. USA – It is noted that chlorpyrifos is detected in surface waters in the USA, usually at concentrations below 0.1 µg/L; also detected in groundwater in less than 1% of the wells tested, usually at concentrations below 0.01 µg/L.

66. The US Food and Drug Administration (FDA) has set tolerances for chlorpyrifos in agricultural products ranging from 0.05 to 15 mg/kg in food (equivalent to mg/kg) (ATSDR, 1997), however as noted in Section 1.5, there is an on-going judicial review on the matter. According to the ToxFAQsTM for chlorpyrifos (ATSDR, 1997), the US EPA recommends that children not drink water with chlorpyrifos levels greater than 30 µg/L.

67. The consumption of contaminated food and water is an important source of secondary exposure to chlorpyrifos, while breast milk is considered an important source of exposure to chlorpyrifos for infants (UNEP/POPS/POPRC.19/4). Therefore, establishment of concentration threshold limits for chlorpyrifos either at national or international levels, are predominantly focused on drinking water, food and feed.

68. The WHO (2004) guidelines for drinking water quality include a guideline value for chlorpyrifos of 30 µg/L (rounded figure). It is noted that chlorpyrifos is detected in surface waters in the USA, usually at concentrations below 0.1 µg/L; also detected in groundwater in less than 1% of the wells tested, usually at concentrations below 0.01 µg/L. According to the ToxFAQsTM for chlorpyrifos (ATSDR, 1997), the US EPA recommends that children not drink water with chlorpyrifos levels greater than 30 µg/L.

69. In March 2022, China released National Food Safety Standard for Drinking Water Quality which entered into force on April 1, 2023. This uses the WHO guideline value of 30 µg/L for chlorpyrifos.

70. At international level, Codex sets MRLs for all food and animal feed, specifying the highest level of a pesticide residue that is legally tolerated in or on food or feed when pesticides are applied correctly in accordance with Good Agricultural Practice. A large number of countries have set MRLs for chlorpyrifos in many specific food types under national legislation13 – including Argentina, Australia, Brazil, Canada, Chile, China, Colombia, Costa Rica, EU, UK, Hong Kong, India, Indonesia, Israel, Japan, Malaysia, New Zealand, Philippines, Russia, Singapore, South Africa, South Korea, Switzerland, Taiwan, Thailand, USA, and Vietnam.

71. In the EU, MRLs for chlorpyrifos have been set by the EU (Regulation (EC) No 396/2005) and are included in Table 4 (UNEP/POPS/POPRC.17/INF/7).14 Under both the UK and EU regimes a limit has been set for chlorpyrifos of 0.01 mg/kg covering a wide range of fresh fruit, vegetables, nuts, fungi, and sugar. For teas (and other infusions), hops and spices, a limit of 0.1 mg/kg applies. Additionally, for meat products (all types) the 0.01 mg/kg threshold applies (UK Annex F, 2021).

72. In the EU, the MRL for food was lowered to 0.01 mg/kg in 2020, after the non-renewal of the substance registration (Commission Regulation (EU) 2020/1085). However, it is noted that the MRL values set for chlorpyrifos is not a toxicological risk-based threshold value, but it is based on the default lowest limit of analytical determination in EU law.

73. The US Food and Drug Administration (FDA) has set tolerances for chlorpyrifos in agricultural products ranging from 0.05 to 15 parts per million in food (equivalent to mg/kg) (ATSDR, 1997), however as noted in Section 1.5, there is an on-going judicial review on the matter.

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

74. Common areas of authorized use across different countries are for certain specific pests on crops (both food and non-food, e.g. against termites and African bollworm in agriculture and cotton in Ethiopia), wood protection (e.g. to control termites, also note that India have indicated it is key for use against wood borers), locust control (e.g. to protect cotton and other crops), in public health applications (e.g. in Malaysia) and for ectoparasite control in cattle (in Kenya).

75. Additional, specific examples highlighted in the information gathered for this risk management evaluation include: in cotton (against termites and locusts in Egypt, termites and African bollworm in agriculture and cotton in Ethiopia), in Malaysia for public health and structural uses (e.g.

against cockroaches and termites), and in Oman it is only used against termites (Annex E and Annex F submissions, and INF document (#add reference)

76. California Department of Pesticide Regulations (CDPR, 2014) presented the findings of a study by the CDPR and the University of California Statewide Integrated Pest Management Program (UC IPM) to identify key uses of chlorpyrifos in alfalfa, almonds, citrus, and cotton in California. Three categories of use were defined: i) key pests for which there are no or few alternatives, ii) important pests for which there are alternatives and iii) occasional pests for which there are alternatives. Identified key uses included controlling alfalfa weevils, blue alfalfa aphid, and cowpea aphids in alfalfa; leaf-footed bug and stink bugs in almonds; ants in citrus; and late-season aphids and whiteflies in cotton. However, it was noted that use of chlorpyrifos had declined over the past decade (2010-2020) as California growers shifted to safer alternatives. As of 2020, use of chlorpyrifos in California ceased following an agreement between the CDPR and pesticide manufacturers. CDPR and the California Department of Food and Agriculture (CDFA) have since established a cross-sector working group, and earmarked funding to identify, evaluate and recommend safer, more sustainable pest management alternatives to chlorpyrifos[15].

77. In India it is said to be key in the management of pests in target crops such as rice, sugarcane and wheat, as well as cotton and agroforestry, for the control of locusts. However, in other countries covering the range of climates found in India, alternatives have been successfully implemented.

78. 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[16]. Authorization was granted for the use of chlorpyrifos in bananas (for the control of aphids, mealybugs and Scarring beetle)[17] and pineapples (for the control of Symphylan)[18]. In both cases authorizations were granted with an expiration date of June 30 2023, after which it is indicated that the authorizations will not be renewed (Rainforest Alliance, 2021a and 2021b).

2.2.3 Costs and benefits of implementing control measures

79. [No additional data]

2.3 Information on alternatives (products and processes)

2.3.1 Overview of alternatives

80. [No additional data]

2.3.2 Chemical alternatives

81. As part of the Annex F submission, the pesticide manufacturer association of India (PMFAI) provided spray costs per hectare in India for some chemical alternatives to chlorpyrifos by multiplying the use rate with the costs (see Table 1).

Table 1. Summary of spray costs of alternatives per hectare in India as quoted in the Annex F submission from India and PMFAI.

Alternative	Cost	Alternative	Cost
Acephate	$7	Emamectin benzoate	$20
Buprofezin	$9	Flonicamid	$15
Chlorantraniloprole	$51	Fipronil	$15
Cyantraniliprole	$72	Flubendiamide	$16
Clothianidin	$38	Imidacloprid	$8
Chlorfenapyr	$22	Indoxacarb	$7
Cartap Hydrochloride	$9	Spinosad	$40

[15] https://www.cdpr.ca.gov/docs/pressrls/2019/100919.htm (accessed Jan 2024)

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

[17] In Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Philippines

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

Dinotefuran	$11	Spiromesifen	$20
Diafenthiuron	$15	Tolfenpyrad	$35
Deltamethrin	$9	Triflumezopyrim	$34

Diamide insecticides

82. Flubendiamide belongs to the group of phthalic diamides. It also interacts with the ryanodine receptors in insects, inducing a release of calcium. The substance contains several perfluorinated moieties and thus falls under the Organisation for Economic Co-operation and Development (OECD) definition of PFAS (OECD, 2021). Flubendiamide is the first commercially available phthalic diamide pesticide developed in 1998. The substance was registered in the Philippines in 2006 and in Thailand in 2007 to, among other things, combat the spread of *Plutella xylostella* (Diamondback moth) (Troczka *et al*., 2016). The substance is also registered as an active ingredient in India, USA, and Europe.

Spinosyns

83. Spinosad is a naturally occurring mixture of two spinosyns, spinetoram is a semi-synthetic spinosyn product (Sparks et al., 2020). It is produced through a chemical modification of spinosad, involving the removal of one of its sugar moieties. Spinetoram showed greater potency, earlier onset of activity and longer duration of control against certain insects when compared with spinosad while retaining broad-spectrum insect control and low effects on non-target species (Kirst, 2010).

84. Spinosad mode of action is attacking the nicotinic acetylcholine receptor and then the gamma-aminobutyric acid receptors. It kills insects by hyper-excitation of the insect nervous system (Raghavendra and Velamuri, 2018). Spinetoram also attacks the gamma-aminobutyric acid receptors. Both spinosad and spinetoram are considered to be toxicologically equivalent (US EPA, 2009).

85. Spinosad is an approved active ingredient in India, the EU (Regulation 1107/2009) and the USA (PC-Code 110003). In Canada the substance is currently under re-evaluation (Canada, 2018). Similarly, spinetoram is also approved as active ingredient in Europe (Regulation 1107/2009), India and Canada.

2.3.3 Non-chemical alternatives

IPM and organic and agroecological practices

86. In Siaya County in Kenya, the Dala Rieko CBO, a farmer organization engaging about 1000 smallholder farmers employ a number of practices without chlorpyrifos to manage pests and diseases. These include the use of natural herbs to spray crops, use of wood ash, intercropping, and crop rotation (Centre for Environmental Justice and Development (CEJAD), 2021).

87. In a study from Doni et al., (2015) system of rice intensification (SRI) is presented as a successful innovation and cost-effective method in the organic farming in Malaysia. The study found that paddy cultivated using the SRI methods exhibited significant improvements in various growth and yield parameters, including plant height, productive tiller, biomass, filled grain, 1000 grain weight, and overall yield. The potential yield obtained, at 7.58 tons/ha, surpassed the Malaysian average national yield of 3.64 tons/ha.

88. In Chile in the 2008/2009 season 1,302 ha of 175,760 ha of agricultural area under organic management were apple trees. Pino and Díaz (n.d.) state that for the successful cultivation of organic apples good soil is necessary, ideally a soil composed of 50% solids and 50% pore space. To repel insects, preparations such as compost tea, humus tea, supermagro (a biofertilizer mad with bovine manure, macro- and micronutrients) as well garlic and chili pepper extracts can be used. For certain pests such as the apple moth (Cydia pomonella) pheromone traps can be used. Against scabs (Venturia inaequalis) preventative control by closely monitoring the timing of conditions for spore germination and fungal penetration is the most efficient measure.

89. Further IPM and biological control measures applied in Chile are described by Godoy et al. (2018) for lettuce, tomato and onion. This includes measures against pests such as flies (Aleyrodidae, Delia antiqua, Anthomyiidae and Liriomyza huidobrensis), fungi (e.g., Leveillula Taurica, Botrytis cinerea, Alternaria solani, Botrytis, Fusarium, Sclerotinia sclerotiorum, Erysiphe cichoracearum, Peronospora destructor and Bremia lactucae), moths (e.g., Agrotis and Gelechiidae), aphids (e.g., Nasonovia ribisnigri) and thrips (e.g., Frankliniella occidentalis and Thrips tabaci).

90. IPM can be applied in both conventional and organic farming. In a review of farming systems, Durham and Mizik (2021) emphasized that the economic impact of IPM is often poorly

understood, thereby impeding its adoption. Reitz et al., (1999) conducted a commercial trial in celery using a low-input IPM program over four years. The results showed a reduction of over 25% in pesticide usage, leading to significant cost savings attributed to lower insecticide use. Additionally, the pest management costs for the IPM program were more than 250 USD per hectare less compared to the grower's standard program, without significant differences in yield or net profit.

Biological control systems and botanical preparations

91. Naranjo et al., (2015) provides an overview on various approaches and methods available for economic evaluation of biological control of arthropod pests using arthropod natural enemies. Additionally, the review paper includes estimated values for conservation biological control (CBC) and the costs saved by not using insecticides in different crop systems. These savings ranged widely, from 0 USD/ha to 2,202 USD/ha.

92. Pheromone trapping systems are favored in Guam to suppress the banana root borer. A study from Reddy, Cruz, and Guerrero, (2009) showed that trap type, trap dimensions, color and position of the trap largely influence the overall performance. Ground traps and traps larger in size outperformed the ramp and pitfall traps. In a color choice test, the banana weevil preferred the brown traps over other colors, with mahogany being more appealing than other shades of brown. Additionally, traps positioned in the shade of the canopy captured significantly more adults than those exposed to sunlight.

93. A study conducted in Mexico by González et al., (2018) showed that native isolates of entomopathogenic fungi Cordyceps bassiana and Metarhizium anisopliae are both effective in reducing Cosmopolites sordidus populations in Mexican organic banana plantations.

94. Red rust banana thrips pose a threat for sustainable banana growth in Ecuador and Peru. However, as shown by Clercx *et al.*, (2015), *Isaria fumorosea* had entomopathogenic effects in concentrations of 8×10^{6} conidia mL^{-1} in the laboratory, and 3×10^{10}, 10^{11} and 10^{12} conidia L^{-1} in the field. These results pointed out possible sustainable solutions for IPM in organic and conventional banana growth.

95. As part of the study from Divekar *et al.*, (2024) neem oil and garlic oil demonstrated a similar cost–benefit ratio (2.19 and 2.03, respectively), comparable to the tolfenpyrad insecticide. The tested botanicals, including neem oil and garlic oil, did not have adverse effects on predatory coccinellids and syrphids, making them suitable candidates for inclusion in the cabbage IPM programs (Divekar *et al*., 2024)

96. Studies from Watts and Williams, (2015) and Long et al., (2013) mention rice-duck system as a successful method for growing rice without the use of synthetic chemicals. According to Long et al 2013, presence of ducks in the fields contributes to a reduction in plant diseases, pests, and weeds through their secretions, excreta, as well as their activities such as treading, pecking, and predation. The integration of rice and ducks in the agricultural system is effective in preventing rice planthoppers and rice leafhoppers, with control effects reaching up to 98.47% and 100%, respectively. Additionally, this system demonstrates positive effects on the control of Chilo suppressalis (Asiatic rice borer), Tryporyza incertulas (yellow stem borer), and rice leafrollers. Noteworthy control results are also observed for sheath blight.

97. Long et al., 2013 mentions that in Guangdong Province, in 2001, rice-duck farmers were making a net income of USD 323.52 per hectare more than rice-only growers. If the rice is grown organically, i.e., without any chemical pesticides or fertilizers, then the rice-duck cultivators could produce USD 6,478.2 net income per hectare more than conventional fields. The substantial disparity arises due to the significant price gap, with organic rice being approximately eight times more expensive than conventional rice. Additionally, the value of ecological services for non-tillage rice-duck cultivation is estimated to be USD 2,928.64 per hectare (Long et al., 2013). It can however be assumed that due to the increase in price the organic rice is mainly exported, increasing its carbon footprint.

98. In the Annex F request for information, Argentina mentions the use of diatoms to attack insects directly by dehydration as an alternative to chlorpyrifos.

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

2.4.1 Health, including public, environmental, and occupational health

99. Chlorpyrifos is a known potent in vivo inhibitor of acetylcholinesterase and in the Risk Profile human cohort study results suggest 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, problems with attention, and tremors. In addition, the prohibition of chlorpyrifos proves to have a positive impact on reducing pesticide suicides (Lee et al., 2020).

2.4.2 Agriculture, aquaculture, and forestry

100. [No additional data]

2.5 Other considerations

101. [No additional data]

3. References

Agency for Toxic Substances and Disease Registry (ATSDR) (1997) Toxicological profile for chlorpyrifos. https://ww.atsdr.cdc.gov/ToxProfiles/tp84.pdf. Accessed 31 January 2024.

Aponso, G.L.M., (2002). Exposure and risk assessment for farmers occupationally exposed to chlorpyrifos. *Annals of the Sri Lanka Department of Agriculture* 4, 233-244, https://www.proquest.com/openview/c618d22880f4d94bfbe499cced5188a3/1?cbl=18750&diss=y&pq-origsite=gscholar&parentSessionId=wCoVqqkoc6OJ0AdzihbWkEvEM9csIgC8mu0FIWgBoSw%3D. Accessed 04 January 2024.

Backhaus, T. (2023). Commentary on the EU Commission's proposal for amending the Water Framework Directive, the Groundwater Directive, and the Directive on Environmental Quality Standards. *Environmental Sciences Europe* 35, 22, https://doi.org/10.1186/s12302-023-00726-3.

Banerjee, I., Tripathi, S. K., Roy, A.S., Sengupta, P. (2014). Pesticide use pattern among farmers in a rural district of West Bengal. India, *J Nat Sci Biol Med* 5(2), 313-316, DOI: 10.4103/0976-9668.136173

California Department of Pesticide Regulation (CDPR), (2014). Identifying and Managing Critical Uses of Chlorpyrifos Against Key Pests of Alfalfa, Almonds, Citrus, and Cotton. Report by the University of California Agriculture and Natural Resources California for Department of Pesticide Regulations. https://ipm.ucanr.edu/legacy_assets/ipmproject/cdpr_chlorpyrifos_critical_use_report.pdf Accessed 19 February 2024

Centre for Environmental Justice and Development (CEJAD), (2021). Extent and use of non-chemical pest management alternatives among smallholder vegetable farmers in Kenya: the case of Siaya and Migori counties. Available at https://ipen.org/sites/default/files/documents/cejad_kenya_tfsdgs3_hhps.pdf Accessed 19 February 2024

Chen, C., Qiana, Y., Liu, X., Tao, C., Lian, Y. Li, Y. (2012). Risk assessment of chlorpyrifos on rice and cabbage in China. *Regulatory Toxicology and Pharmacology* 62(1), 125-130, https://doi.org/10.1016/j.yrtph.2011.12.011

Clercx, L. Zambrano, A. Bejarano, J.D. Flores Espinoza, B.C. (2015). Towards biological control of red rust banana thrips in organic and conventional banana. *Acta Hortic*. 1105, 73-80 DOI: 10.17660/ActaHortic.2015.1105.11.

Divekar, P.A., Majumder, S., Halder, J., Kedar, S.C., Singh, V. (2024). Sustainable pest management in cabbage using botanicals: Characterization, Effectiveness and Economic Appraisal. *J Plant Dis Prot* 131, 113-130. https://doi.org/10.1007/s41348-023-00812-x.Doni, F., Sulaiman, N., Isahak, A., Zain, C., Wan Mohamad, W., Shari, A., Yusoff, W. (2015). Impact of System of Rice Intensification (SRI) on Paddy Field Ecosystem: Case Study in Ledang, Johore, Malaysia. *Journal of Pure and Applied Microbiology* 9. 927-933

Durham, T. C. and Mizik, T. (2021). Comparative economics of conventional, organic, and alternative agricultural production systems, *Economies*. 9(2), 64. https://doi.org/10.3390/economies9020064.

European Environment Agency (EEA). (2018). European waters - Assessment of status and pressures 2018. EEA Report No 7/2018. https://www.eea.europa.eu/publications/state-of-water. Accessed 19 February 2024

European Parliament (2021). The use of pesticides in developing countries and their impact on health and the right to food. https://www.europarl.europa.eu/cmsdata/219887/Pesticides%20health%20and%20food.pdf; Accessed 04 January 2024.

Fenske, R.A., Farahat, F.M., Galvin, K., Fenske, E.K. Olson, J.R. (2012). Contribution of inhalation and dermal exposure to chlorpyrifos does in Egyptian cotton field workers, *Int J Occup Environ Health* 18(3), 198-209, doi: 10.1179/1077352512Z.00000000030.

Food and Agricultural Organisation (FAO) and World Health Organisation (WHO), (2019). Detoxifying agriculture and health from highly hazardous pesticides, a call for action. http://www.fao.org/3/ca6847en/ca6847en.pdf. Accessed 19 February 2024

Food and Agricultural Organisation (FAO) (2020). SDG Indicator 2.4.1 Proportion of agricultural area under productive and sustainable agriculture, methodological note, revision 10. Available at http://www.fao.org/3/ca7154en/ca7154en.pdf. Accessed 19 February 2024

Gesesew, H.A., Woldemichael, K., Massa, D., Mwanri, L. (2016). Farmers knowledge, attitudes, practices and health problems associated with pesticide use in rural irrigation villages, South Ethiopia, *PLoS ONE*, 10(2):e-121093 https://doi.org/10.1371/journal.pone.0150341.

Godoy, P., Zolezzi, M., Sepúlveda, P., Estay, P.P., Chacón, G.C. (2018). Principales plagas y enfermedades en lechuga, tomate y cebolla. Boletín INIA N° 388, Instituto de Investigaciones Agropecuarias. Centro Regional de Investigación La Platina, La Pintana, Chile. 58 p. http://bibliotecadigital.fia.cl/bitstream/handle/20.500.11944/146443/Manualdecampoprincipalesplagasyenfermedadestomatelechugacebolla_BolINIA388.pdf?sequence=1&isAllowed=y Accessed 19 February 2024

González, D.N., Chávez, M.A.A., Gutiérrez, R.L., Cupul, W.C., Ochoa, J.M.m Velasco, E.G. (2018). Suitability of Cordyceps bassiana and Metarhizium anisopliae for biological control of Cosmopolites sordidus (Germar) (Coleoptera: Curculionidae) in an organic Mexican banana plantation: laboratory and field trials. *Journal of Plant Diseases and Protection* 125, 73-81, https://link.springer.com/article/10.1007/s41348-017-0126-4.

Kirst, H.A., (2010). The spinosyn family of insecticides: realizing the potential of natural products research. *The Journal of Antibiotics* 63, 101-111. https://doi.org/10.1038/ja.2010.5.

Lee, Y.Y., Chisholm, D., Eddleston, M., Gunnell, D., Fleischmann, A., Konradsen, F. (2020) The cost-effectiveness of banning highly hazardous pesticides to prevent suicides due to pesticide self-ingestion across 14 countries: an economic modelling study. *Lancet Glob Health* 9:3. https://doi.org/10.1016/S2214-109X(20)30493-9

Long, P., Huang, H., Liao, X., Fu, Z., Zheng, H., Chen, A., Chen, C. (2013). Mechanism and capacities of reducing ecological cost through rice–duck cultivation. *J Sci Food Agric* 93(12), 2881-2891. doi: 10.1002/jsfa.6223

Naranjo, S. E., Ellsworth, P. C., and Frisvold, G. B., (2015). Economic value of biological control in integrated pest management of managed plant systems. *Annual Review of Entomology* 60, 621-645, https://doi.org/10.1146/annurev-ento-010814-021005.

Neupane, D., Jors, E., and Brandt, L. (2014). Pesticide use, erythrocyte acetylcholinesterase level and self-reported acute intoxication symptoms among vegetable farmers in Nepal: a cross-sectional study. *Environmental Health* 13, 98, https://doi.org/10.1186/1476-069X-13-98.

Organisation for Economic Co-operation and Development (OECD), (2021). Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances. ENV/CBC/MONO(2021)25. Series on Risk Management. No 61. https://one.oecd.org/document/ENV/CBC/MONO(2021)25/En/pdf. Accessed 19 February 2024

Pesticide Action Network (PAN), (2013). Chlorpyrifos. Monograph. Prepared by Meriel Watts, PhD http://dev.panap.net/sites/default/files/monograph-chlorpyrifos.pdf. Accessed 12 December 2023.

Phung, D.T., Connell, D., Miller, G., Chu, C. (2012). Probabilistic assessment of chlorpyrifos exposure to rice farmers in Viet Nam, *Journal of Exposure Science and Environmental Epidemiology* 22, 417-423. DOI: 10.1038/jes.2012.32.

Phung, D.T., Connell, D., Yu, Q.M., Chu, C. (2013). Health risk characterization of chlorpyrifos using epidemiological dose-response data and probabilistic techniques: a case study with rice farmers in Vietnam. *Risk Analysis* 33(9), 1596-1607. https://doi.org/10.1111/risa.12023.

Pino, C.T. and Díaz, B.T., (n.d.). Manejo agronómico de manzanos orgánicos. Producción Hortofrutícola Orgánica. https://biblioteca.inia.cl/bitstream/handle/20.500.14001/7459/NR38264.pdf?sequence=9&isAllow%20ed=y. Accessed 19 February 2024

Reddy, G.V.P., Cruz, Z.T., and Guerrero, A., (2009). Development of an Efficient Pheromone-Based Trapping Method for the Banana Root Borer Cosmopolites sordidus, *J Chem Ecol* 35, 111-117.

Reitz, S.R., Kund, G.S., Carson, W.G., Phillips, P.A., Trumble, J.T. (1999). Economics of reducing insecticide use on celery through low-input pest management strategies. *Agriculture, Ecosystems and Environment* 73(3), 185-197. https://doi.org/10.1016/S0167-8809(99)00016-X.

Sparks, T.C., Crouse, G.D., Benko, Z., Demter, D., Giampietro, N.C., Lambert, W., Brown, A.V. (2020). The spinosyns, spinosad, spinetoram, and synthetic spinosyn mimics - discovery, exploration, and evolution of a natural product chemistry and the impact of computational tools. *Pest Management Science* 77(8), 3637-3649. https://doi.org/10.1002/ps.6073

The International Register of Potentially Toxic Chemicals (IRPTC), (1989). IRPTC data profile on: chlorpyrifos. International Register of Potentially Toxic Chemicals, United Nations Environment Programme, Geneva, Switzerland. January 1989. https://wedocs.unep.org/20.500.11822/29801. Accessed 19 February 2024

Troczka, B.J., Williamson, M.S., Field, L.M., Davies, T.G.E. (2016). Rapid selection for resistance to diamide insecticides in Plutella xylostella via specific amino acid polymorphisms in the ryanodine receptor. *Neurotoxicology*, 60, 224-233. https://doi.org/10.1016/j.neuro.2016.05.012.

United States Environmental Protection Agency (US EPA), (2009). Pesticide Fact Sheet: Spinetoram, https://www3.epa.gov/pesticides/chem_search/reg_actions/registration/fs_G-4674_01-Oct-09.pdf. Accessed 19 February 2024

Walton, A., LePrevost, C., Linnan, L., Sanchez-Bitkhead, A., Mooney, K. (2017). Benefits, facilitators, barriers and strategies to improve pesticide protective behavior: Insights from farmworkers in North Carolina Tabacco Field. *Int J Environ Res Public Health* 14(7), 677. https://doi.org/10.3390/ijerph14070677.

Watts, M. and Williamson, S. (2015) Replacing chemicals with biology: phasing out high hazardous pesticides with agroecology. Pesticide Action Network Asia and the Pacific. ISBN 978-983-9381-70-2. Available at http://files.panap.net/resources/Phasing-Out-HHPs-with-Agroecology.pdf. Accessed 19 February 2024

Weber, N.H., Stockenhuber, S.P., Benhelal, E., Grimison, C.C., Lucas, J.A., Mackie, J.C., et al. (2020). Products and mechanism of thermal decomposition of chlorpyrifos under inert and oxidative conditions. *Envir. Sci. Processes & Impacts* 22(10), 2084-2094. DOI: 10.1039/d0em00295j.

Wołejko, W., Lozowicka, B., Jablonska-Trypuc, A., Pietruszynska, M., Wydro, U. (2022). Chlorpyrifos Occurrence and Toxicological Risk Assessment. *Environmental Research and Public Health*, 19(19), 12209. https://doi.org/10.3390/ijerph191912209.

World Health Organization (WHO), (2004). Guidelines for drinking-water quality, fourth edition. Available at https://www.who.int/docs/default-source/wash-documents/wash-chemicals/chlorpyrifos-chemical-fact-sheet.pdf?sfvrsn=dd947a00_4. Accessed 19 February 2024