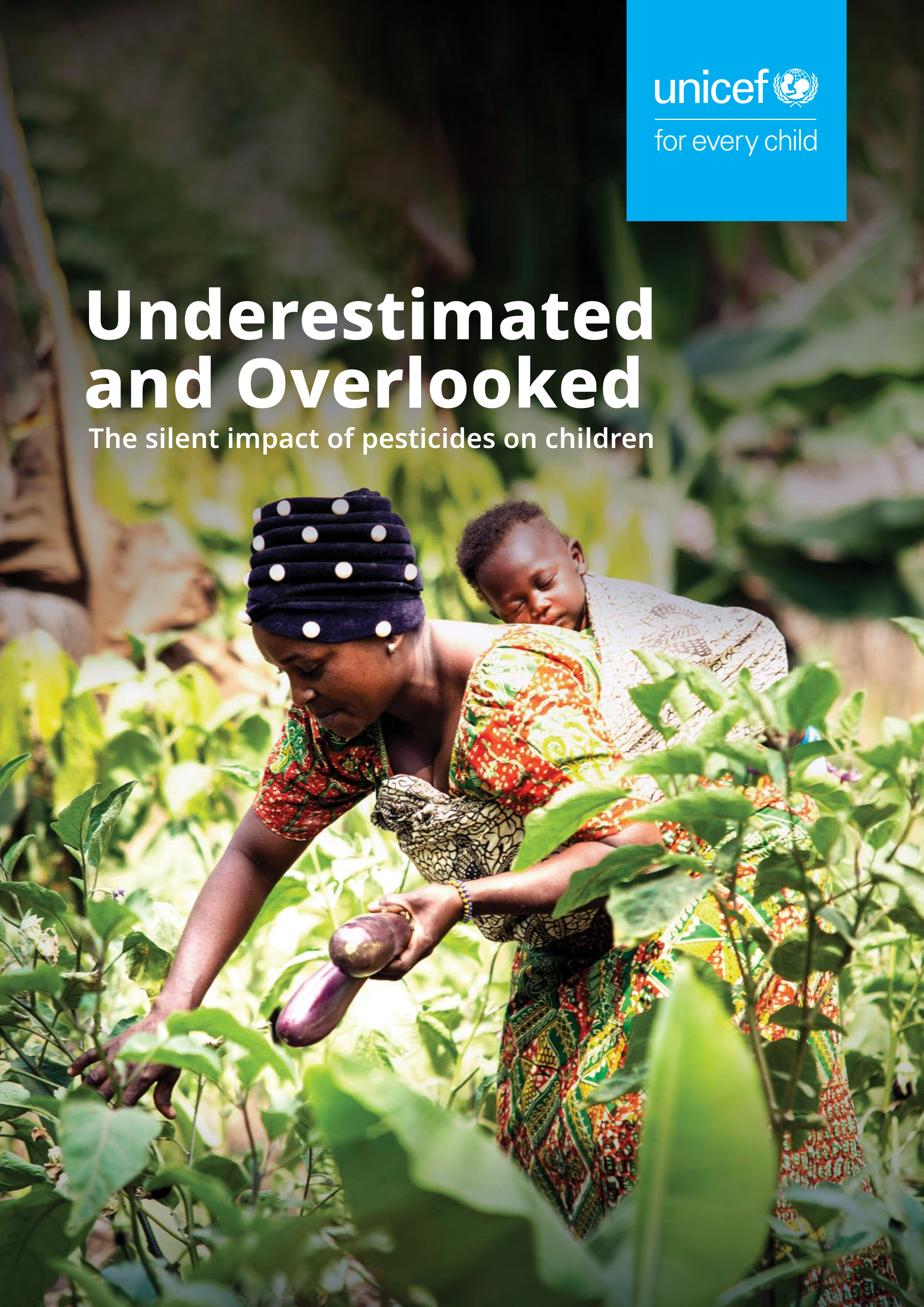

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Underestimated and Overlooked

The silent impact of pesticides on children

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The silent impact of pesticides on children

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Abbreviations

2,4-D	2,4-dichlorophenoxyacetic acid
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
AChE	acetylcholinesterase
ADHD	attention-deficit hyperactivity disorder
ADI	acceptable daily intake
AMR	antimicrobial resistance
ASD	autism spectrum disorder
CAC	Codex Alimentarius Commission
CDC	Centers for Disease Control and Prevention (United States of America)
Codex	Codex Alimentarius
COVID-19	coronavirus disease 2019
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
EDC	endocrine disrupting chemical
EPA	Environmental Protection Agency (United States of America)
ETU	ethylene thiourea
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GFC	Global Framework on Chemicals
HHP	Highly Hazardous Pesticide
HIC	high-income country
IARC	International Agency for Research on Cancer
IHME	Institute for Health Metrics and Evaluation
ILO	International Labour Organization
IPM	integrated pest management
IRS	indoor residual spraying
ITN	insecticide-treated net
IVM	integrated vector management
JMPM	FAO/WHO Joint Meeting on Pesticide Management
JPMR	FAO/WHO Joint Meeting on Pesticide Residues
LMICs	low- and middle-income countries
MRL	maximum residue limit
NHANES	National Health and Nutrition Examination Survey
PAN	Pesticide Action Network
PEST-CHEMGRIDS	Global Pesticide Grids (database)
PPE	personal protective equipment
UNEP	The United Nations Environment Programme
WHO	World Health Organization

Glossary

This report uses the United Nations definitions of child and adolescent:

Child: 0–18 years
Adolescent: 10–19 years

Exposure: Concentration or amount of a particular agent that reaches a target organism, system or (sub) population in a specific frequency for a defined duration (IPCS/OECD). Contact between a living organism and a pesticide, which may or may not lead to a poisoning.

Acute exposure to pesticides includes contact with pesticides for up to 14 days.
Chronic exposures take place for longer than one year.

Hazard: the inherent property of a substance, agent or situation having the potential to cause undesirable consequences (e.g., properties that can cause adverse effects or damage to health, the environment or property).

Poison: a substance that can cause disturbance of structure or function, leading to injury or death when absorbed in relatively small amounts by human beings, plants or animals.

Poisoning: occurrence of damage or disturbance caused by a poison, and includes intoxication.

Risk: the probability and severity of an adverse health or environmental effect occurring as a function of a hazard and the likelihood and the extent of exposure to a pesticide.

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Foreword

George Laryea-Adjei,
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Around the world, children are born into a landscape where the doubling of pesticide use since 1990 has made these chemical substances ubiquitous in our soil and food. This report reveals a reality that is as urgent as it is 'silent': the profound impact of pesticides on the health and rights of the world's most vulnerable citizens: children.

The title of this report – *Underestimated and Overlooked* – is not just a description of the current evidence; it is a call to action to address the massive gaps in our global protection systems.

Underestimated refers to the scale of the crisis that remains largely hidden from view. For too long, our understanding of pesticide poisoning has been based on incomplete data that represents only the 'tip of the iceberg'. While global databases record roughly 375 fatal child poisonings annually, country data and reports suggest that the true global toll is significantly higher. Beyond these acute tragedies, we systematically underestimate the risk of chronic, low-level exposures. Biomonitoring reveals that in some regions, 80 to 90 per cent of children have detectable pesticides in their bodies. Our current regulatory models often fail to account for the cumulative impact of these 'chemical cocktails' on children's developing bodies.

Overlooked speaks to the historical neglect of children's unique biological and behavioural vulnerabilities. For nearly a century, the production and application of synthetic pesticides proceeded without adequate consideration of the long-term legacy effects on child health. We have overlooked the fact that, kilo for kilo, children may breathe more air and consume more food and water than adults, leading to a much higher relative intake of toxicants. We have also ignored the 'silent' nature of these impacts; exposure in early life or even before conception can trigger neurodevelopmental delays, childhood cancers, and endocrine disruption that may not manifest for years or even decades.

This neglect extends to the millions of children working in agriculture – the sector accounting for 61 per cent of all child labour – where they are frequently exposed to Highly Hazardous Pesticides (HHPs) while performing tasks that are legally prohibited for minors. Additionally, 490 million children and adolescents may face potential exposure to agricultural pesticides given their proximity to pesticide use.

UNICEF remains committed to ensuring every child grows up in a clean, healthy, and sustainable environment. To achieve this, we must shift from a 'business-as-usual' approach to one that puts children first. This means phasing out the most toxic HHPs, strengthening primary health-care training to recognize poisoning, and establishing pesticide-free buffer zones where children live, learn and play.

It is time to bring these silent impacts out of the shadows. We must ensure that the health of our children is never again underestimated or overlooked.

Executive summary

Children are uniquely vulnerable to environmental hazards, including those resulting from the triple planetary crises of biodiversity loss, pollution and climate change. The doubling of pesticides usage since 1990 is undermining children's right to a clean, healthy and sustainable environment. This global report on pesticides and children's health examines the evidence and proposes essential actions to protect children.

Pesticide use: A growing and pervasive problem

Pesticides are used by farmers to protect crops from pests and diseases that might affect yields and threaten global food security. However, when used inappropriately, pesticides can pose risks to human health and the environment. Pesticides are chemical products that not only control specific pests but also affect non-target organisms, including humans. Their toxicity extends beyond active ingredients to other components and formulations. By-products of manufacturing can also be toxic.

Agricultural, vector control and domestic pesticide use continues to rise. This widespread use significantly threatens children's health, as exposure-prevention measures have not kept pace with increasing inapproriate use. Children face exposure through food and water, environmental contamination from spray drift, improper management, and pesticide residues on clothing. The continued use of Highly Hazardous Pesticides (HHPs), which present particularly severe acute or chronic hazards, intensifies these risks.

Antibiotics and fungicides can contribute to the development of resistance in target organisms, making infections increasingly difficult to treat and posing a growing global health challenge.

Children’s heightened vulnerability

Exposure to pesticides can begin from conception, via transfer from the mother. Prenatal exposure is associated with adverse birth outcomes including low birth weight, preterm birth and congenital defects, and increased risks of neurodevelopment issues, including cognitive delays and behavioural disorders in children.

Children’s developing bodies face greater risks than adults from pesticides in food, water and air because of their higher intake relative to body size. Growing organs are particularly sensitive to pesticide effects, which can be profound and long-lasting. Normal childhood behaviours such as exploring their environment with their hands and mouths, combined with their inability to read or understand warnings, further increase exposure risks. Their bodies’ detoxification mechanisms are still developing and therefore cannot easily get rid of toxicants from their bodies.

Research links pesticide exposure to respiratory problems, immune dysfunction, and childhood cancers such as leukaemia and brain tumours. Many pesticides disrupt endocrine function, affecting growth, thyroid function, metabolism and reproductive health. Chronic exposure, most commonly from food, damages multiple organ systems. Genotoxic effects may cause hereditary defects if reproductive cells are impacted.

Scale of exposure and poisoning

Pesticide exposure occurs through inhalation, ingestion or skin absorption, with effects depending on the toxicity of the pesticides and the level and duration of exposure. Biomonitoring studies in high-income countries show 80–90 per cent of children have detectable pesticide in their bodies, with dietary exposure identified as a major pathway.

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The dose and duration of exposure is heightened in proximity to heavy pesticide use. Children living near agricultural areas face increased risks because pesticides can spread beyond their intended application sites through air, water and soil.

Analysis using the Global Pesticide Grids database indicates that 490 million children and adolescents may face potential exposure to agricultural pesticides, with significant regional and urban–rural variations. This number represents only a crude proxy for a limited number of pesticides, which does not account for various exposure routes and environmental factors. Consequently, the relationship between pesticide application rates and the actual magnitude of human exposure or health risk remains uncertain and unmeasured.

Child labour in agriculture and exposure to pesticides also puts children at risk. Handling and applying pesticides are considered hazardous work and are not allowed below the age of 18. Although child labour is a serious human rights violation, around the world many vulnerable families have no choice but to engage their children in hazardous work or prevent them from going to school, as a survival strategy. The vast majority of child labour occurs in agriculture, the sector that accounts for more than 61 per cent of child labour worldwide. Currently, 83.4 million children are found in child labour situations in crop farming, fisheries and aquaculture, livestock, and forestry and post-harvest activities.

Pesticide poisoning manifests in acute or chronic health symptoms ranging from nausea, respiratory distress, organ damage to death. The ability to detect and manage pesticide poisonings worldwide is inadequate, with only 47 per cent of World Health Organization (WHO) Member States having poison centres. WHO mortality data from 2017 onwards report that there are 375 reported cases of fatal pesticide poisonings in children globally each year, including 130 from unintentional acute poisonings, leading to a loss of 7,686 life-years. The remaining 245 deaths are from intentional pesticide poisoning, accounting for 14,039 life-years lost (*see Annex 2 for calculation*).

Systematic management failures

Globally, pesticide management faces challenges in regulation, implementation and oversight. Weak or fragmented regulatory frameworks persist at national and international levels, with inconsistent enforcement of both binding and non-binding mechanisms. There are gaps in legislation for formulated products, consideration of metabolites, poisoning management, regulation of non-food applications, and occupational safety. Of particular concern is continued use of highly hazardous pesticides (HHPs) despite known risks.

Implementation of regulations is limited by monitoring and enforcement capacity, particularly in low- and middle-income countries. Poor controls on waste, drift and contamination compound these problems. Alternatives to synthetic pesticides are not available in sufficient quantities for scaling up. Although promising alternatives to synthetic pesticides—such as biopesticides and plant-based compounds—are increasingly being developed, their large-scale availability and adoption remain limited by production, regulatory

and market barriers. At the same time, industry messaging often emphasizes the effectiveness and cost-efficiency of chemical pesticides, which can contribute to misconceptions about the viability of alternatives. Meanwhile, investment in research and development for sustainable pest management strategies has not kept pace with the urgency of reducing chemical pesticide reliance. At the same time, there is not enough research into sustainable pest management.

Dangerous retail practices, inadequate health-system capacity, and economic barriers to safer alternatives further endanger children's health.

Recommendations to protect children from pesticide exposure

1. Strengthen pesticide standards and regulations to specifically account for children's unique vulnerabilities and prioritize their safety.
2. Phase out Highly Hazardous Pesticides where the risks have not been managed and where safer and affordable alternatives are available by 2035 as specified in the Global Framework on Chemicals.
3. End child labour in agriculture and protect children from the risk posed by pesticide exposure. Urgent and holistic actions are needed to eliminate child labour in agriculture. The Durban Call to Action on the Elimination of Child Labour outlines key strategies that states can take to protect children.
4. Reduce pesticide risks through promotion of agroecological practices, implementation of integrated pest and vector management, limitation of non-essential applications, and development of sustainable alternatives.
5. Reduce impacts on children by enhancing environmental monitoring, establishing pesticide-free buffer zones around places where children live and learn, improving drift management, strengthening food safety standards, and implementing rigorous occupational safety measures.
6. Expand education about exposure risks, safe storage and handling, take-home exposure prevention, dietary exposure reduction, and proper use in vector control programmes.
7. Strengthen health systems through the establishment of poison centres, poison hot lines, enhanced health worker training, improved mental health services, and comprehensive surveillance and monitoring.

This report presents compelling evidence of an urgent need to protect children from increasing pesticide exposures while maintaining essential agricultural and public health functions. The current trajectory of rising pesticide use poses an immediate threat to children's health and development. Success requires swift, coordinated action from international bodies, national governments, industry and civil society to implement these recommendations and create more protective systems.

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Introduction

Children are uniquely vulnerable to environmental hazards emanating from the triple planetary crises: biodiversity loss, pollution and climate change. The increasing use of pesticides in this more dangerous and challenging world is undermining children's right to a clean, healthy and sustainable environment. This global report on pesticides and children's health examines the evidence and proposes essential actions to protect children.

Children bear a unique and disproportionate burden from the harmful effects of pesticides, as their developing bodies and behaviours amplify their susceptibility compared with adults.

The report provides a stocktake of the latest science on children's vulnerabilities to and health effects from pesticides. It identifies the major gaps in understanding the scope of the pesticide problem and provides an analysis of the potential scale of pesticide exposure among children. Finally, it examines the complex legal, social and industrial factors (manufacturing, transport, storage, distribution, use, disposal) that perpetuate pesticide use and outlines key recommendations and actions needed to protect children from pesticides.

Children are uniquely vulnerable to the effects of pesticides

Pesticides

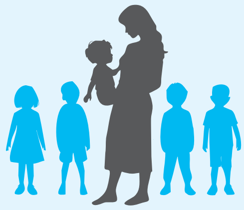
Insecticides | Rodenticides | Bactericides/ disinfectants | Fungicides | Herbicides

Child exposure

Most children are exposed to pesticides

80–90% of children in high-income countries have been **exposed to pesticides,** primarily from dietary exposure

490 million children, including 124 million under 5, **face potential exposure to agricultural pesticides**



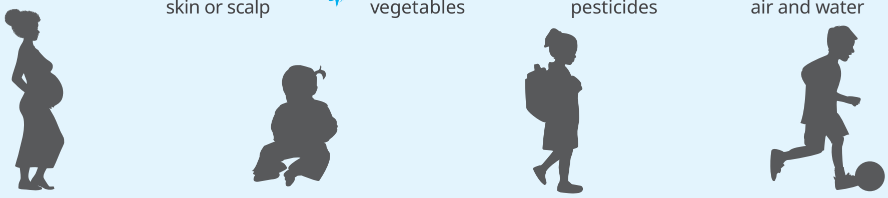
83.4 million children who work in agriculture are likely exposed to pesticides from direct spraying and drift. Agriculture accounts for **61% of all child labour.**

From mother to child

- Through blood, placental tissue and breastmilk

Exposure at home or at play

- Application of insect repellents on skin or scalp
- Ingestion of contaminated fruits and vegetables
- Directly or indirectly working with pesticides
- Environmental exposure through soil, air and water
- Chemicals stored near the home or dumped in public areas



Consequences for the child's health

Prenatal	0–4 years / 5–14 years		5–14 years
Fetal death and birth defects: • Stillbirths • Increased risk of fetal death • Risk of spontaneous abortion	Cancer: Childhood hematopoietic cancers and increased chances of brain tumours	Neurodevelopment: • Delays up to two years • Deficits in motor speed, coordination and visual memory	Endocrine-system disruption: Prenatally or during crucial stages of development

Public Health

375 children are reported to die annually from intentional and unintentional pesticide poisoning globally, leading to a loss of 7,686 life-years.

Source: UNICEF. Understanding the Impact of Pesticides on Children: A Practical Guide to Preventing Exposure and Protecting Children's Health. UNICEF, 2018, <www.unicef.org/childrightsandbusiness/media/356/file/Understanding-the-impact-of-pesticides-on-children.pdf>. Accessed 29 July 2025.

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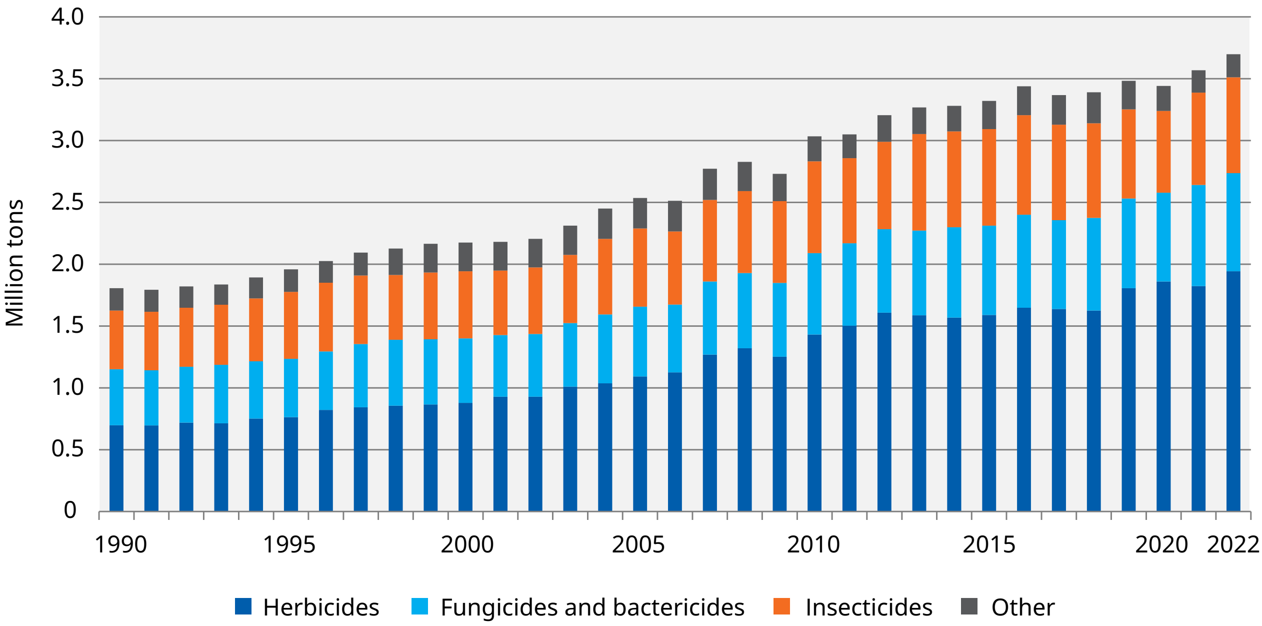
1 Overview of pesticides and their global use

1.1 Pesticides: definition and history

Pesticides are substances, or mixtures of substances, of chemical or biological ingredients that repel, destroy or control any pest, or regulate plant growth.[1] Pesticides are intended to protect people, crops, land, trees and property, and are used in many contexts, including agriculture, homes, yards and gardens. They are potentially toxic substances applied intentionally, including to the places where we live, work and play,[2, 3] thus posing risks to humans and other non-target organisms.[4] Following World War II, production of synthetic organic chemicals increased exponentially. In 2022, total pesticide use in agriculture was 3.7 million tons of active ingredients, having doubled since 1990.[5]

Figure 1. Global pesticides use by category



Source: FAO (2024).[6] CC BY 4.0.

For essentially the first century of synthetic pesticide use, impacts on children and the environment were not adequately considered and the longevity of chemicals and the legacy effects on health they would have decades later were not understood. Examples of past pesticide use continue to have widespread effects on people today. For instance, homes built on former orchards where lead arsenate was used still have lead and arsenic in the surrounding soil, presenting a potential risk to children.[7] DDT exposure in adolescent girls and young women in the 1950s has been shown to have increased their risk of breast cancer later in life.[8] Arsenic, a known carcinogen used as a herbicide and wood preservative, increases the environmental burden of arsenic in the ground, contaminating rice which is used to make infant cereal, and which serves as a dietary staple in many cultures.[9, 10, 11] Infants may still be exposed to DDT and its metabolites through breastmilk, even in countries where the use of DDT was banned decades ago.[12]

1.2 Functional classification of pesticides

Pesticides can be classified based on the pests they target. The most well-known categories of pesticides are insecticides, herbicides, fungicides and rodenticides. There are many other categories, which are less well known or less frequently considered to be pesticides, but which are also used in various settings.[13] Categories of pesticides are listed in *Annex 1*.

It is important to note that there is no standard definition of what is considered a pest worthy of killing by a pesticide. The risk–benefit ratio of use may be subject to individual interpretation, potentially exposing children and the environment to unnecessary chemicals. The application, for instance, of pesticides for cosmetic use in yards and gardens has little value beyond personal aesthetics to the property owner but poses risks to local waterways, groundwater, air quality and the environment at large. Similar risks occur when pesticides are used for cosmetic purposes on fruit, done to meet consumer preferences. Conversely, pesticides used to reduce the risk of exposure to malaria-carrying mosquitoes have high benefit in some countries.[14] Whatever benefits individual pesticides may have, pesticide use can subject children to unintended exposure through environmental contamination, drinking water and the food chain. Therefore, pesticides should only be used when the benefits clearly outweigh the risks of use, and efforts to mobilize safer alternatives have been exhausted.

1.3 Chemical composition of pesticide formulations

A pesticide formulation contains both active and inactive ingredients.[15] All ingredients may be potentially harmful but can be even more toxic when combined in a pesticide product formulation.

1.3.1 Active ingredients

Within each functional group of pesticides, such as insecticides or herbicides, classes of pesticides can be organized by chemical structure or mode of action of the active ingredients. Active ingredient means the part of the product that provides the pesticidal action.[16]

Active ingredients are the primary substances that target and eliminate or repel pests, such as insects, weeds, fungi or bacteria. Active ingredients are typically listed on the product label and are often followed by a statement of the percentage concentration in the formulation. Other components of the pesticide, known as inert ingredients, help to stabilize, dilute or improve the application of the active ingredient but do not directly affect pests.

Broadly, while having different mode of action, insecticides act primarily on four nerve targets, all of which are shared by children.[17, 18] Herbicides are designed to act largely on plant-specific pathways that are essential in plants but not animals.[19] Herbicides can, however, still cause toxicity to humans at the cellular level.[20] The International Agency for Research on Cancer (IARC) has concluded that some commonly used herbicides, which children may be exposed to, are either possibly or probably carcinogenic.[21, 22]

Fungicides target many pathways that kill fungi but, because these pathways are shared by humans and found in the brain, they can cause neurotoxicity in exposed people.[23] The use of metal-based fungicides has been particularly problematic for human health and the environment, but toxicity was overlooked because of the increased crop productivity with their use.[24] After a tragic outbreak of mercury poisoning resulting from seed treated with a methylmercury fungicide in the 1970s in Iraq, most countries banned mercury-based fungicides in the 1970s and 1980s.[25, 26]

In summary, humans and other non-target organisms may be harmed via the very same mechanism of action that is designed to kill the pest. Harm can also occur from unintended side effects of the active ingredient and other components of the formulated product. Children are particularly vulnerable to these effects.

1.3.2 Inactive ingredients and product formulations

'Inactive' or inert ingredients are chemicals or compounds added to pesticide formulations to improve their application, function and longevity.[27] The terminology 'inactive' is misleading as it refers only to a chemical's activity in relation to the target pest. Some 'inactive ingredients' may be more toxic than their 'active' counterparts.[28] Toxicity of 'inactive ingredients' is also not studied to the degree that toxicity of active ingredients is studied.

Globally, 'inactive' or 'inert' ingredients are often considered proprietary and therefore not disclosed on pesticide product labels.[29, 30]

When active and inactive ingredients are mixed together in proprietary pesticide formulations, toxicity is not always tested by regulators even though scientific evidence demonstrates that pesticide formulations may be far more toxic than their active ingredient acting alone.[31] Member States of the European Union are required to test one representative pesticide formulation before placing a pesticide on their national market.[32]

1.3.3 Unintentional by-products of pesticide manufacturing: An additional source of toxicity

Dioxins, persistent organic pollutants and known carcinogens, are an unintended by-product of the manufacturing process of some pesticides.[33] One example of dioxin contamination occurred with the herbicide Agent Orange used to defoliate areas in Viet Nam. Agent Orange consisted of a 50:50 mixture of 2,4-D and 2,4,5-T, but unknowingly became contaminated with 2,3,7, 8-tetrachlorodibenzo-*p*-dioxin (TCDD), the most toxic form of dioxin, during the production of 2,4,5-T.[34] In a 2018 report, the National Academy of Sciences concluded that exposure to TCDD and other chemicals in herbicides used in Viet Nam was associated with soft-tissue sarcomas, Non-Hodgkin's and Hodgkin's lymphomas, chloracne and hypertension.[35]

1.4 Categorization of pesticides by degree of hazard and criteria to identify Highly Hazardous Pesticides

While all pesticides are inherently toxic and designed to kill living organisms, some pesticides carry an especially high risk of acute or chronic harm to human health and the environment. These pesticides are known as Highly Hazardous Pesticides (HHPs).[36]

The latest version of The International Code of Conduct on Pesticide Management, which was endorsed and noted by the Food and Agricultural Organization of the United Nations (FAO) and the World Health Organization (WHO) in 2014, defined HHPs:

> Highly Hazardous Pesticides means pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as WHO[37] or Global Harmonized System (GHS) or their listing in relevant binding international agreements or conventions. In addition, pesticides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered and treated as highly hazardous.

The criteria for HHPs recommended by the FAO/WHO Joint Meeting on Pesticide Management (JMPM) are listed in *Table 1*.[38]

Table 1. Criteria for Highly Hazardous Pesticides

Criterion 1	Acute toxicity – WHO-recommended classification of pesticides by hazard: classes Ia and Ib
Criteria 2–4	Chronic toxicity • GHS Carcinogenicity categories 1A and 1B • GHS Mutagenicity categories 1A and 1B • GHS Reproductive toxicity categories 1A and 1B
Criterion 5	Stockholm Convention – pesticides listed in Annexes A and B
Criterion 6	Rotterdam Convention – pesticides listed in Annex III
Criterion 7	Montreal Protocol – pesticides listed
Criterion 8	High incidence of severe or irreversible adverse effects on human health or the environment

Source: FAO and WHO (2016).[39]

Although the criteria (Table 1) can be applied to identify whether pesticides are considered HHPs, WHO and FAO do not maintain an official list of HHPs.[40] Since these are sovereign decisions that vary from country to country, FAO and WHO cannot elaborate on a general list of HHPs. The Pesticide Action Network (PAN) International developed and maintains a list built on the JMPM criteria and based only on classifications by recognized authorities. The list is created by compiling information from international bodies (WHO), the European Commission, national agencies (the United States EPA, Japan), and the Pesticide Property Database.[41] This list, first published in 2009 and updated several times since, includes criteria not initially considered by JMPM, such as endocrine-disrupting properties, eco-toxicological properties and inhalation toxicity.[42] For children, a list of HHPs that reflects a broad view of harm is most protective.

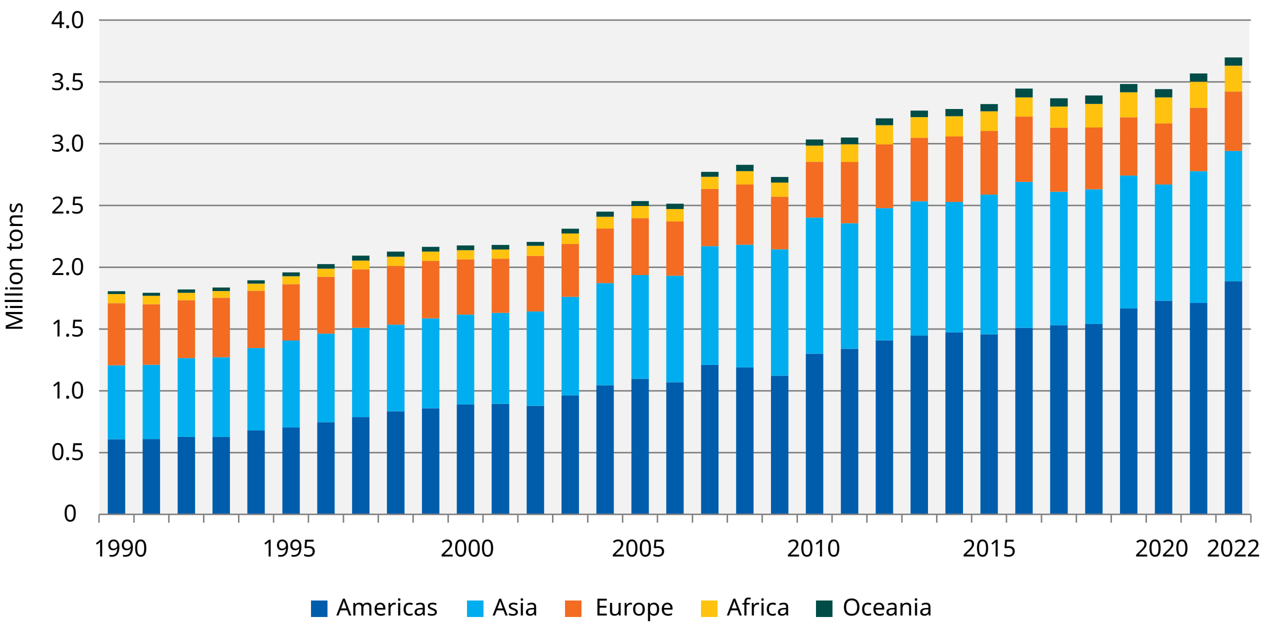
1.5 Drivers, actors, users and trends in pesticide use

Pesticide use has increased exponentially since World War II, after which synthetic pesticides such as DDT became widely available.[43] Pesticides used to control vector-borne diseases and protect crops were thought to promote public health. These uses are increasingly challenged as the human health and environmental costs grow, particularly in a changing climate.

1.5.1 Pesticide uses in agriculture

According to the World Bank Data Group, an estimated 85 per cent of the pesticides applied globally are used for agricultural purposes to protect crops from moulds, bacteria, invasive (native) plants and insects.[44] According to FAO, from 2000 to 2022, total global pesticide use increased by 70 per cent to 3.7 million tons, with most of this increase occurring between 2000 and 2016.[45] The highest contributions came from the Americas, followed by Asia, Europe, Africa and Oceania. The share of the Americas, the largest contributor, increased from 41 per cent to 51 per cent of global pesticide consumption, while that of Asia and Europe decreased by 5–8 percentage points to 29 per cent and 13 per cent, respectively. Africa and Oceania applied relatively small amounts of pesticides over time, but Africa nonetheless had the highest growth in pesticide applications (+185 per cent). In 2021, Brazil was the largest user with 22 per cent of the world total (0.8 million tons), far ahead of the United States of America (0.47 million tons).[46]

Figure 2. Total pesticides use by region



Source: FAO (2024).[47] CC-BY-4.0.

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The agrochemical industry asserts that pesticide use is necessary to achieve food security. However, food insecurity, defined as when a person lacks regular access to enough safe and nutritious food for normal growth and development and an active and healthy life, is a complex process.[48] Food insecurity is affected by inequitable production and distribution systems, poverty, conflict and climate change, which reduce access to food.[49, 50, 51]

In fact, many of the people who are food insecure are subsistence farmers engaged in agricultural work, particularly in lower-income countries. In 2023, an estimated 28.9 per cent of the world's population, or 2.33 billion people, experienced moderate or severe food insecurity.[52] Food safety can also be negatively affected by pesticide residues that may exceed the maximum residue limits in certain crops in certain markets.[53, 54, 55]

While pesticides can contribute to sustainable agrifood systems – defined as those that ensure food security by providing healthy, nutritious food for all without compromising the economic, social and environmental foundations of agriculture for future generations – their inappropriate use can harm ecosystems. This includes contributing to pollinator decline, degrading soil health, and harming or killing fish and wildlife that serve as food sources. Pollinators being essential to global food production,[56] such ecological damage can ultimately increase the risk of child malnutrition.

1.5.2 Pesticides for vector control

The use of insecticides to control vectors that transmit disease is based on a calculation about the benefits to global public health versus the risk to human health and the environment. Children are uniquely affected by both vector-borne diseases and potential acute and long-term effects of exposure to insecticides deployed to control vectors.

Vectors include mosquitoes, flies, ticks and other living things that transmit viruses, parasites and bacteria that infect millions of people globally.[57] Major diseases caused by vectors include malaria, dengue, Zika virus disease, yellow fever, Japanese encephalitis, lymphatic filariasis, Chagas disease, onchocerciasis, leishmaniasis, chikungunya and schistosomiasis.[58] These diseases are associated with approximately 17 per cent of the estimated global burden of communicable diseases and disproportionately affect poorer populations.[59] Other diseases, including tick-borne diseases such as Lyme disease, may be present in specific areas.[60]

UNICEF reports that 600 million children, more than 1 in 4 children globally, have high exposure to vector-borne diseases.[61] Globally, malaria is the most important vector-borne disease.[62] WHO estimates that in 2023, there were almost 263 million estimated malaria cases and 597,000 people died of malaria.[63] The WHO Africa Region carried 94 per cent (246 million) of all malaria cases and 95 per cent (569,000) of all deaths in 2022.[64] Children under 5 years of age accounted for 76 per cent of deaths in the region.[65]

600 million children, more than 1 in 4 children globally, have high exposure to vector-borne diseases[61]

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Since 1940, the primary method of vector control worldwide has been insecticides to kill or deter vectors.[66, 67] Methods of applying insecticides include insecticide-treated nets (ITNs), indoor residual spraying (IRS), space spraying, and control of larvae (the application of insecticides to aquatic habitats to kill mosquitoes in their immature stages).[68] These methods have had some success in malaria eradication in parts of the world. The WHO Global Malaria Eradication programme, initiated in 1955, used IRS with DDT and other residual insecticides and successfully eliminated malaria from Europe, North America, the Caribbean, and parts of Asia and northern Latin America.[69] The 14-year programme though failed because it left out tropical Africa, which continues to bear the largest burden of malarial disease.[70]

1.5.3 Non-essential uses of pesticides

While the judicious use of insecticides as part of an integrated vector control strategy can be regarded as indispensable to prevent or minimize the spread of vector-borne diseases, no arguments can be made in favour of pesticides used only to improve the aesthetic appearance of plants, lawns or produce. Pesticides are used for non-essential purposes in households, gardens and in agriculture settings without growing food.[71] Like all pesticides, these agents can potentially contaminate air, soil, food, drinking water and local waterways, and expose children who play on or near sprayed areas.

Advertisements by lawn-care companies reinforce the lawn as a social status symbol, a place where families gather, and where people can connect with nature.[72] The image of a pesticide-laden child-centric lawn is contradictory to the health threat that sprayed lawns pose to children and families. Pesticides may also be used for cosmetic purposes on golf courses and other recreational areas.

1.5.4 Home and garden use

While some pesticides are used for cosmetic purposes in gardens, pesticides are also used for other purposes in and around homes, such as to control unwanted insects, vectors or rodents. In Germany, pesticide use by non-professional users is only allowed for pesticides that are specifically authorized for home and garden uses.[73] In Belgium, non-licensed individuals, such as amateur gardeners, are no longer allowed to use glyphosate.[74]

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1.6 Climate change as driver for pesticide use

The relationship between climate change and pesticide use is complex and bidirectional.

Pesticides contribute to climate change throughout their life cycle from manufacturing, through packaging and transportation, to application and disposal. For instance, many pesticides are derived from fossil fuels, which when extracted and produced release greenhouse gases.[75] The United States EPA estimated that in 2019, some 29 per cent of emissions of methane, which has 25 times the global warming potential of carbon dioxide, were related to natural gas and petroleum systems and abandoned oil and natural gas wells.[76, 77] Other pesticides, such as sulfuryl fluoride, are themselves powerful greenhouse gases.[78]

Climate change will likely also increase the use of pesticides. Increases in temperature and precipitation are expected to alter the distribution of pests, influence the number of generations a pest can achieve each year, and affect the growth, reproductive rates and impacts of predators on pest species, among other effects.[79] Pest populations may include weeds, invasive species and insects.[80] These impacts of climate on pests can be beneficial or prejudicial to crops: for example, a changing climate can increase or shrink distribution ranges, can increase or decrease the numbers of pest generations, or could reduce or increase the impacts of natural enemies. Furthermore, growers confronted with greater variability in crop yields due to the direct effects of climate will likely increase pesticide use in an attempt to stabilize yields.[81] Therefore, it is predicted that pesticides will be used in greater quantities and more frequently, and that a greater diversity of chemical products will also be used.[82]

Because of the impacts of pesticides on natural enemy populations and behaviours, their increasing use could decrease the ability of agroecosystems to respond to pests and, thereby, exacerbate the effects of a changing climate. This can also affect ecosystem restoration in the face of climate change-related droughts and storms.[83] Although the exact impacts of climate change on vector-borne diseases are not clear, warmer temperatures have the potential to increase the transmission of diseases such as malaria in some locations.[84] When pesticides contaminate aquatic environments, they can harm key natural predators such as amphibians and fish, potentially leading to an increase in vector populations that would otherwise be kept in check. Increased vector-borne diseases may then contribute to increased use of pesticides for vector control, potentially resulting in a vicious cycle.

Climate change can also increase exposure to pesticide pollution. For instance, during storms and floods, pesticides may wash out into previously uncontaminated areas.[85] Higher temperatures can increase the volatility of pesticides, thereby driving increased releases during usage and from stockpiles.[86] Children in climate-vulnerable regions such as in flood-prone agricultural zones are doubly at risk due to pesticide spread during extreme weather events.

2 Children's unique vulnerability to pesticides and child-specific exposure scenarios

Children are uniquely vulnerable to pesticides, which have become ubiquitous in the environment and which contaminate our air, soil, food and drinking water. Exposure to and effects of pesticides are significantly different in children compared with adults. Children's developing bodies can be harmed by pesticides during critical windows of development that begin before conception. After birth and into childhood, children may take in relatively more pesticides than adults because of their growing bodies and unique behaviours such as hand-to-object and mouth-to-object behaviours that increase exposure. Children are cognitively immature and lack the capacity and skills to assess risks associated to pesticides, which puts them at risk of accidental exposures. Children may also have lower levels of pesticide-detoxification enzymes and have a relatively long remaining lifetime to experience health effects that may take decades to manifest.[87, 88, 89]

Pesticide exposures occur via ingestion, inhalation, dermal and transplacental routes.[90] Children are exposed to pesticides during routine activities such as eating meals, drinking, playing and attending school, and also through their work or involvement in agricultural activities.

Click here to learn more about children's unique vulnerabilities to environmental hazards at every stage of life.

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2.1 Children's inherent vulnerability to pesticides

2.1.1 Pre-conception and antenatal exposure window

Exposure to pesticides starts even before children are conceived and can continue during the antenatal period as some pesticides can cross the placenta.[91] These pre-conception and antenatal exposures pose significant health risks for children, notably including paediatric cancers and adverse neurodevelopment.

A recent meta-analysis of nine studies showed that neuroblastoma, the most common solid tumour seen in children under 1 year of age, is 1.6 times more likely with pre-conception/antenatal exposure to pesticides.[92] A 2017 systematic review and meta-analysis showed a statistically significant association between antenatal indoor insecticide use and childhood brain tumours.[93] A 2019 systematic review and meta-analysis showed a significantly increased risk of childhood leukaemia, the most common paediatric cancer, with antenatal exposure to residential pesticides including indoor insecticides.[94] International reviews and epidemiologic studies that included both urban and agricultural settings have clearly shown that antenatal exposure to organophosphate pesticides is associated with poorer cognitive, behavioural and social development.[95]

2.1.2 Developing physiology

Children also have potentially increased exposures to pesticides that contaminate food, water and air because they are growing. Children eat, drink and breathe more per kilogram of body weight than adults, making their relative exposure higher.[96] Children additionally may be picky eaters and have a less varied diet than adults, which may expose them to relatively higher pesticide residues if their preferred foods are high in pesticides.[97]

In addition to potentially higher exposures, children's organs are developing and may be particularly sensitive to the effects of pesticides. For instance, the developing brain and nervous system are targets of dangerous pesticides such as organophosphates.[98]

2.1.3 Developmentally appropriate childhood behaviours

Pesticides can continue to affect children throughout childhood. Developmentally appropriate childhood behaviours put children at increased risk of both acute high-dose and chronic low-level pesticide exposures during different life stages.

Children have more intimate contact with their surroundings. Active exploration of the environment is expected and often includes frequent hand-to-object, hand-to-mouth and object-to-mouth behaviours that can expose children to pesticides in their homes, schools and outdoor play areas.[99] Infants and toddlers crawl on the ground and have a lower breathing zone than adults. A 2017 review of six studies examined pesticide metabolite levels of children living in agricultural settings based on age. The review reported that most studies concluded that the greatest frequency of pesticide metabolite levels occurs in toddlers, is slightly lower in infants, and is least among older children.[100]

Children also spend more time outside than adults. Children especially enjoy digging and playing in soil, exposing them to any pesticides that may have been applied. Children can be exposed while playing in fields where pesticides have been applied or exposed to pesticide drift. Children may be in contact with pets that have been treated with pesticides to eliminate fleas or ticks.[101] In rural areas, children may be exposed while touching and playing with colourful empty containers of pesticides incorrectly disposed of or when containers are unsafely stored at home.

2.1.4 Cognitive immaturity

Children may accidentally consume pesticides and suffer acute poisoning as they may be unable to read or fully understand warning labels. Younger children are not able to assess pesticide exposure or remove themselves from hazardous situations.[102]

Children may also play on lawns with flags that warn 'Caution: no children or pets for 48 hours' because they are not yet able to read.

2.2 Children's pesticide exposure scenarios

2.2.1 Dietary exposure

Pesticide residues on and in food can be an important source of pesticide exposure for children; in the general population, those residues are thought to be the largest source of pesticide exposure.[103] This has been corroborated for several classes of pesticides, including organochlorines,[104] organophosphates[105] and pyrethroids.[106] For instance, in a 2018 study using data from the French National Nutrition and Health Survey, 87 per cent of exposure to the pyrethroid permethrin came from food.[107]

Given that diet is the major source of pesticide exposure, and children and adolescents typically consume more food per kilogram bodyweight than adults, it is not surprising that pesticide exposure as assessed by urinary biomarkers is considerably higher in this demographic group. This was demonstrated for different pesticides or their metabolites in studies conducted in Poland,[108] in five other European countries,[109] and in the United States.[110, 111]

There is also documentation that pesticide intake by children exceeds acceptable intake levels. For example, in a study from Argentina, the Theoretical Maximum Daily Intake (TMDI) of pesticides was compared with the Acceptable Daily Intake (ADI), a benchmark of toxicological risk assessment.[112] The comparison was based on real-world consumption data and the legal maximum residue limits of the different food items. It turned out that for babies and toddlers, the TMDI of 27 pesticide active ingredients exceeded the ADI, and for young children (2–5 years old) 22 pesticide active ingredients exceeded the ADI. This shows the special burden that children can be exposed to by residues in food alone. It is reasonable to assume that such exceedances can be encountered in other low- and middle-income countries (LMICs). In China, the risk arising from residues in citrus fruits was more than double in children (6 years or younger) compared with the general population.[113]

It is a well-known phenomenon that pesticide-free diets can reduce the body's burden of pesticides in children and in adults.[114, 115, 116] As a result of such interventions, urinary levels of pesticides and their metabolites always decreased significantly. It should be noted that choosing pesticide-free food may be a challenge for children living in LMICs and low-income communities in high-income countries (HICs).

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2.2.2 Drinking water exposure

Children, who consume more water per kilogram of body weight than adults, are at risk of pesticide exposures when drinking water is contaminated with pesticide residues. The increased and wide use of pesticides has clearly caused pesticide run off into ground and surface water, and thus contamination of drinking water sources with pesticide residues in many countries, although few reviews have addressed this issue globally.[117] A 2021 study reviewed almost 40 reports that evaluated pesticide residues in 31 countries around the world, primarily from the years 2000 to 2021, and found 113 pesticide residues in drinking-water samples.[118] The most frequently detected pesticide was DDT.

WHO publishes the *Guidelines for Drinking-water Quality*, which serve as an international reference point for the establishment of national or regional regulations and water safety standards. The Guidelines derive 'guideline values' for constituents of water, including many pesticides.[119] Guideline values are considered to be protective to cover all life stages, including childhood, up to a lifetime of exposure.

In some countries, it is a common risky practice to re-use empty pesticide containers to store water and this represents another exposure scenario for children.[120]

2.2.3 Non-occupational exposures in rural agricultural settings

Children in agricultural settings face increased pesticide exposure risks beyond dietary and residential uses, including dermal and inhalation risks from pesticide drift and 'take-home' exposure pathways, where family members who work in agriculture inadvertently bring residues home on their clothing, footwear, skin and vehicles.[121] Insufficient awareness, inadequate agricultural practices and improper disposal of empty containers can heighten the risk of health complications during childhood due to prolonged exposure to pesticides.[122]

85% of pesticide use globally is in agriculture[286]

This exposure can occur from the antenatal stage through infancy and into adulthood.[123, 124]

Common childhood behaviours such as playing on the ground, mouthing objects, and being drawn to colourful empty containers further elevate their risk of exposure to pesticides, especially in rural environments. Inadequate storage of pesticides at home, repurposing containers for food or water storage, and seemingly innocuous activities such as washing clothes used for agricultural tasks and pesticide handling can result in exposure. Residues of pesticides may also be present in gardens and school playgrounds. Additionally, children may come into contact with domestic animals treated with pesticides.

Dermal exposure emerges as a significant concern, notably for children living in areas where pesticides are applied, and the strong and odorous fumes blanket and affect the nearby community.

Furthermore, inhalation of pesticide spray drift or vapours poses a risk, particularly in agricultural communities where pesticides are extensively deployed across diverse farming and ancillary operations, involved in crop cultivation, livestock husbandry and aquaculture.

Ingestion represents another worry, as children might unwittingly consume pesticide residues present in beverages and on fruits, vegetables or other contaminated surfaces due to inadequate disposal practices or touching contaminated surfaces and putting their hands to their mouths. Moreover, absorption via eyes is a potential route of exposure, particularly for children who may encounter pesticide-contaminated air, water or soil.[125] Research indicates that, in general, children living in agricultural communities face higher levels of pesticide exposure compared with children not living in agricultural communities. Notably, studies have shown associations between closer proximity to pesticide-treated fields and higher pesticide residues in household dust and pesticide metabolites in children's urine samples.[126]This study primarily focused on data fromthe United States.

Children of farmers and agricultural workers are particularly at risk, with exposure potentially beginning antenatally and continuing through living in close proximity to agricultural settings. In LMICs, where farmers and agricultural workers often reside within or in close proximity to fields, children may be especially vulnerable to pesticide drift and environmental residues.

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2.2.4 Indirect and direct occupational exposure

Although no child under 18 years of age should be involved in the direct use of pesticides because the health risks they face are too high, in many countries children are involved in agricultural activities whether as child labour, young workers of legal age for employment or helping out their families.

Children working in the agriculture sector may be exposed to pesticides both directly and indirectly from a variety of sources. The agriculture sector includes farming, livestock keeping, forestry, fisheries and aquaculture, and post-harvest crop handling (including fish and aquatic-sourced foods). For example, they can be exposed by planting treated seeds, dipping livestock, re-entering fields where pesticides have been applied, and washing clothing and equipment of other workers who apply pesticides. Exposures are also affected by limited access to personal protective equipment (PPE), inadequate training in pesticide handling and disposal, insufficient awareness about pest management alternatives, and issues such as illegal repackaging or labels not being comprehensible to users.[127, 128]

Data from national programmes provide valuable information on children's occupational exposure to pesticides, including the tasks that children were undertaking at the time of acute pesticide poisoning.[129] Tasks reported at the time of poisoning included the following: cutting recently fumigated leaves; using spraying equipment; applying fumigants in a closed environment; cutting grass; planting fumigated seeds; mixing and preparing pesticides; applying pesticides and/or fertilizers by hand; entering recently sprayed fields; supervising agricultural tasks; harvesting fruits, vegetables and fish; packing contaminated produce; and carrying pesticide containers.

Among globally traded agrifood commodities, cotton and cocoa sectors have faced scrutiny and criticism for putting children at risk of child labour. According to the most recent assessments for 2020, some 1.56 million children work on cocoa farms in Côte d'Ivoire and Ghana, where almost 60 per cent of the world's cocoa is produced. Of these, 43 per cent engaged in dangerous activity, including the use of agrochemicals.[130]

Child labour is also a serious concern in the aquaculture subsector. A 2023 FAO study found that in small-scale aquaculture operations, farmers often rely on children for tasks such as feeding fish, cleaning ponds and harvesting fish, seaweed drying, shrimp pond management, and finfish bathing.[131] Many of these activities expose children to pesticides and chemicals, which can pose significant health risks. Despite legal protections, challenges persist in safeguarding children from hazardous work, particularly in vulnerable households where economic pressures push children to work in hazardous conditions.

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Although an enormous number of children are at risk from pesticides when they work in agriculture (including livestock, fisheries and aquaculture), there has been relatively little research to evaluate pesticide exposure among child workers in agriculture. A 2021 study evaluated 180 Latinx child farmworkers in North Carolina in the United States, using silicone wristbands worn for one day to assess exposure to 70 pesticides.[132] Most of the children were exposed to multiple pesticides, including pyrethroids, organochlorines, organophosphates, fungicides and herbicides. Of note, children under 15 years of age, and migrant rather than non-migrant workers, had more pesticide detections. Also, children who were not currently engaged in farm work had greater detections for some pesticides, suggesting that environmental pesticide residues in farming communities pose a risk to children.

A 2008 study evaluated the effects on male children between the ages of 9 and 18 years in Egypt, where cotton, heavily dependent on pesticide application, was the main agricultural product.[133] The children were hired as seasonal workers to spray pesticides in cotton fields with backpack applicators. While some PPE was available, there were no regulations requiring its use and so it was not commonly worn by applicators. Acetylcholinesterase activity was measured. Children and adolescents who applied pesticides had lower activity levels of serum acetylcholinesterase than controls. They also had lower neuro-behavioural performance and reported more neurological symptoms, including blurred vision, dizziness, headache and difficulty concentrating. Neurologic performance and symptoms were also dose-dependent in children who had chronic history of spraying over a period of years.

2.2.5 Urban exposures

Children living in urban areas are also at risk of pesticide exposure because pesticides play a large role in controlling pests in a variety of urban settings including homes, gardens, parks, commercial buildings, schools and roadways. Pesticides are applied by both homeowners and pest control professionals. Pesticide residues can contaminate the place of use but also offsite from dispersal, pesticide drift, leaks from storage sites and improper disposal.[134] Pesticide residues can be present in urban air, water and soil. The presence of pesticides creates hazards for residents who maintain urban farms. Furthermore, household rodenticides and other granular poisons are frequently associated with accidental ingestion and poisoning among children.[135]

Children living in crowded urban housing and in poverty may be exposed to pesticides applied either legally or illegally to control a wide variety of insects and rodents.[136] Of note, in New York State in the United States, more pesticides were applied in the 1990s in the dense areas of New York City, where approximately 1.4 million children under 15 years of age lived, than in the rural agricultural counties in the state.[137, 138] Particularly problematic was that chlorpyrifos was the most heavily used pesticide in 1997 in New York City, where usage included application around and into baseboards. Because it is a potent neurodevelopmental toxicant, chlorpyrifos was banned in 2001 in the United States for residential use. A 2001 study done before the ban showed that children from New York City highly exposed to chlorpyrifos antenatally had at age 3 lower scores on tests on motor and mental development, and also were more likely to show symptoms of attention-deficit hyperactivity disorder (ADHD) and pervasive developmental disorder.[139] The European Union banned chlorpyrifos in 2020, but chlorpyrifos is still used in most other countries globally.[140]

2.2.6 Exposures in schools and childcare settings

Infants, toddlers and preschool children may spend a significant amount of their time in childcare centres. Childcare settings located in old or poorly maintained buildings may have problems with pests and children may spill food which attracts pests.[141] Specific sources of pesticide exposures in childcare settings include residues from indoor or outdoor pesticide use, treatment of head lice, pets treated with flea dips in a home-based setting, food residues, treated playground structures, lawn and garden products, and insect repellents.[142] In the United States, the first National Environmental Health Survey of Licensed Child Care Centers in 2006, found that approximately 63 per cent of the centres reported using pesticides and at least one pesticide was detected in over 89 per cent of the centres.[143] Although the findings are not generalizable to unlicensed centres or centres outside the United States, they suggest that pesticide use may be common in settings that care for children under 6 years of age.

School-age children spend a large portion of their waking time in school. Pests can be present in many areas of school property including cafeterias, classrooms, gyms, locker rooms, dumpsters, school athletic fields and grounds.[144] Pesticides may then be used in schools to control various pests, creating potential acute and chronic exposures for children.

Children can also be exposed to pesticides on their way to school, as pesticides are used in both public and private transportation, and their application in publicly accessible places—such as roadsides, parks, golf courses, and school play areas—can also create exposure risks. In addition, pesticide drift from nearby agricultural areas, can further increase the likelihood of exposure. For example, one of the largest fruit plantation areas of Europe characterized by intensive heavy pesticide use is located in South Tyrol (northern Italy). A study monitoring the contamination of grass samples from nearby playgrounds and schoolyards revealed frequent contamination by pesticides and, in a significant number of cases, multiple residues.[145, 146]

2.2.7 Accidental exposures as a result of improper storage

Pesticides may be improperly stored and accessible to children or may be unlabelled or mislabelled. In some developing countries, pesticide solutions in soft drink bottles and other unlabelled liquid containers have been sold at open stands.[147] Pesticide containers may be reused to store water and food.

2.2.8 Intentional self-exposures and poisoning

Children can also be exposed to pesticides intentionally. Specific studies of childhood intentional pesticide poisonings are limited but the data available show that pesticides are being used by children to inflict self-harm.[148]

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Pathways of exposure to pesticides by age

Pathways of exposure		Prenatal	0–4 years	5–14 years	14–18 years
Through mother/ father	Father's sperm at time of conception	■			
	Trans-placental exposure through the mother	■			
	Breastmilk		■		
	Children carried on the back or being nearby, while caregivers work in fields that have recently sprayed by pesticides		■	■	■
	Caregivers' clothing laden with pesticides		■	■	■
	Caregivers not washing themselves after working with chemicals and picking up their children		■	■	■
At home or school	Children using discarded pesticide			■	
	Application of insect repellents directly on skin or scalp		■		
	Storage of pesticides inside the home and within the reach of children		■		
	Pesticides sprayed on school lawns or gardens, or inside schools to treat rodents and insects		■	■	■
	Pesticide residues on food or toys		■	■	■
	Indoor application of pesticides to treat rodents, insects or bedbugs		■	■	■
	Indoor air laden with pesticides		■	■	■
	Accidental ingestion of pesticides stored in the home		■	■	■
	Wood preservation pesticides in public and school playgrounds		■		
	Washing pesticide laden clothing			■	
	Purposeful ingestion of pesticides (suicide)			■	
	Caregivers not washing themselves after working with chemicals and touching their children				■
Environment	Pesticides in nearby water sources where children play		■	■	
	Improper disposal of pesticides in public areas		■	■	■
	Pesticides in drinking or swimming water		■	■	■
	Long-range transport of pesticides		■	■	■
	Environmental exposures of pesticides through water, air and soil		■	■	■
	Walking barefoot in or near agricultural runoff		■	■	■
	Direct contact or exposure through labour in agricultural fields or runoff areas, either applying pesticides directly or working to pick up leaves shortly after they have been sprayed			■	■

Source: UNICEF. Understanding the Impact of Pesticides on Children: A Practical Guide to Preventing Exposure and Protecting Children's Health. UNICEF, 2018, <www.unicef.org/childrightsandbusiness/media/356/file/Understanding-the-impact-of-pesticides-on-children.pdf>. Accessed 29 July 2025.

3 Health effects of pesticide exposure in children

3.1 Overview

Pesticides negatively affect a wide array of organ systems in children. Children can be affected by accidental or intentional acute poisoning but also from chronic low-level exposure. Pesticide exposure during childhood has been associated with impaired neurodevelopment, paediatric cancer, reduced lung function, disruption of the endocrine and immune systems, and adverse birth effects. Causal evidence connecting pesticides and health effects in children is difficult to obtain for several reasons. Apart from interventional studies that test risk reduction and outcomes, obtaining experimental evidence as a 'gold standard' is unethical in studying pesticides and all environmental contaminants. Additional challenges in studying the effects of chronic pesticide exposure include difficulty obtaining accurate exposure assessments and a long period of latency between exposure and development of symptoms. Despite these difficulties, evidence is increasingly mounting for broad health implications of pesticides in children.

The duration of exposure is important when delineating health effects from pesticides. Acute exposure to pesticides includes contact with pesticides for up to 14 days. Chronic exposures take place for longer than one year.[149]

3.2 Acute pesticide poisonings

Children are affected by both acute accidental and intentional pesticide poisonings, and health impact is dependent on the stage of the child's development. Even the smallest amount of some pesticides, such as paraquat, which is acutely toxic with one small sip, can be potentially lethal.[150]

Symptoms from acute pesticide poisonings can vary by dose and type of pesticides and cause an array of multi-system symptoms and death. Some pesticides, such as organophosphates and carbamates, are associated with known constellations of symptoms.[151] Health workers should have a high index of suspicion when children present with an acute change in physical or mental status that could be due to pesticide ingestion.[152] While a small dose of a highly toxic pesticide can be lethal, it is important to note for children that one dose at a particularly vulnerable period of development could be more toxic than at another stage. When during one's life the exposure occurs matters as well as dose. Treatment consists largely of symptomatic and supportive care – intensive care may be necessary for severe poisonings.[153] Health workers can work with staff at poison centres to determine the type of treatment needed.

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3.3 Chronic health effects of pesticides

3.3.1 Neurodevelopmental effects

While insecticides are intended to target the nervous systems of pests, the negative effects of pesticides on children's neurodevelopment are clear and well documented globally. Scientists, medical experts and children's health advocates have sounded the alarm that many environmental chemicals, including pesticides, contribute to neurodevelopmental disorders.[154, 155] These disorders can manifest as decreased performance in tests of cognitive and motor development in addition to neurological problems.[156, 157]

The evidence for an association of organophosphate pesticides with decreased performance on cognitive and motor tests is substantial. A 2018 paper advocating the urgent need to reduce organophosphate exposures in children cited three systematic reviews that included children in both urban and agricultural settings, as well as the risk assessment from the United States EPA. The paper found that antenatal organophosphate exposure was associated with poorer cognitive, behavioural and social development.[158] A 2019 systematic review of 50 studies done between 1973 and 2019 concluded that antenatal exposure to organophosphates contributes to neurodevelopmental disorders in toddlers, preschool and school-aged children.[159] A 2021 review of exposure to environmental neurotoxins in children from Latin America and the Caribbean concluded that studies suggested exposure to organophosphate and organochlorine pesticides was associated with neurodevelopmental delays in infants, toddlers, preschool and school children.[160]

An area of high clinical concern is the relationship between chronic low-level pesticide exposure and autism spectrum disorder (ASD) and ADHD.[161] A recent global survey noted that the rate of ASDs is increasing, rising from one in 160 in 2012 to one in 100 in 2021.[162] While the reasons for the increase are multifactorial and include better diagnosis and awareness of the condition, these explanations are not thought to account for the entirety of the increased prevalence, and environmental factors are also considered contributory.[163, 164] A 2019 review of the relationship between chronic low-level pesticide exposure and ASD and ADHD concluded that both laboratory and human epidemiologic data support that pesticides may play a role in the development of ASD and ADHD, and highlighted the role of gene–environment interactions.[165]

Another important area for consideration in countries where malaria is endemic, is the effect of insecticides for malaria control on neurodevelopment. A 2018 study of a large birth-cohort (752 mother–child pairs) in South Africa was the first known study to examine the neurodevelopmental effects on toddlers of antenatal indoor residual spraying with DDT and pyrethroids. While DDT and its metabolite DDE were unexpectedly not associated with negative neurodevelopmental outcomes in this study, pyrethroids were associated with decreases in social–emotional and language development in infants and toddlers and lower motor function scores in girls but higher function in boys.[166] While pyrethroids may be preferred over DDT (a well-known persistent organic pollutant), they are not without toxicity and demonstrate a common occurrence in the chemical market called 'regrettable substitution' where substitute chemicals also display toxic effects.[167]

Finally, the relationship between pesticides and mental health is also under investigation. For instance, in Ecuador, more than 500 adolescents participated in a study that matched erythrocytic acetylcholinesterase (AChE) with psycho-behavioural scores for depression and anxiety. Lower AChE activity (reflecting greater exposure to cholinesterase-inhibiting insecticides) was associated with greater depression symptoms.[168]

3.3.2 Genotoxicity

Genotoxicity refers to a substance's ability to damage genetic material, which can lead to hereditary defects if reproductive cells are impacted.[169] Genotoxic substances can also play a role in carcinogenesis.[170]

A review of publications from 2007 to 2021 of studies performed in Latin America identified 11 papers investigating the genotoxic effects of pesticides in children.[171] Eight of these papers demonstrated an association between pesticide exposure and cytogenetic or DNA damage. Countries covered were Mexico (4 publications), Argentina (2), Brazil (1) and Paraguay (1). Three studies, conducted in the Plurinational State of Bolivia, Colombia and Mexico, reported no associations, one of them based on analyses of organochlorine pesticides in blood.[172] In contrast, in two of the eight studies mentioned above, which also measured organochlorine pesticides in human matrices (hair or blood), genotoxic effects were demonstrated.[173, 174] The remaining six publications used questionnaires to estimate exposure and demonstrated DNA or cytogenetic damage (mostly assessed using buccal cells [cells inside the cheek]). Based on the questionnaires, exposures to organophosphate pesticides, pyrethroids, herbicides or 'multiple pesticide classes' were identified as being associated with genotoxic effects.[175]

Two studies from Malaysia demonstrated significant associations between organophosphate insecticide exposure and two different genotoxicity assays performed on buccal cells. One study was conducted with children aged 9 to 11 years in an area of paddy farming.[176] In this study, blood cholinesterase was measured to assess exposure. A depression of the activity of this enzyme indicated inhibition by organophosphates. The other study was conducted with children aged 7 to 12 years living on an island intensively used for palm oil production. Exposure was assessed by organophosphate metabolites measured in urine.[177]

Taken together, mounting evidence shows that children and adolescents living in agricultural areas or working in agriculture are at risk for genotoxic damage. This, in turn, may result in cancer as a long-term effect.

3.3.3 Cancer

The diagnosis of cancer in children is devastating to families.[178] Cancer treatment is arduous, painful and expensive, and drastically alters the family dynamic. Preventing unnecessary environmental childhood exposures that are associated with cancers is essential.

The International Agency for Research on Cancer (IARC) is the specialized cancer agency of WHO, and the IARC Monographs programme, which identifies environmental factors including chemicals that are carcinogenic hazards to humans, has classified many pesticides as either carcinogenic, probably carcinogenic or possibly carcinogenic.[179] Included in this list are commonly used pesticides such as glyphosate, which was deemed as probably carcinogenic in 2015.[180]

There is ample epidemiologic evidence of the association of pesticide exposure and childhood cancer. Studies have connected pre-conception/antenatal exposures to pesticides with neuroblastoma,[181] antenatal indoor insecticide use with childhood brain tumours,[182, 183] and antenatal exposure to residential pesticides, including indoor insecticides, with statistically significant increased risk of childhood leukaemia, the most common paediatric cancer.[184]

Postnatal pesticide exposures in childhood are also important for their association with child cancer. In a 2015 meta-analysis of 16 studies of residential exposure to pesticides, childhood exposure to indoor residential insecticides was associated with increased risk of childhood leukaemia and lymphoma, and herbicide exposure was associated with increased risk of leukaemia.[185] A 2017 systematic review and meta-analysis concluded that postnatal and antenatal residential exposures to pesticides were associated with increased risk of childhood brain tumours.[186] Another meta-analysis, published in 2021, demonstrated some evidence for an association between pesticide exposure in childhood and acute leukaemia, although the strength of the association was less than that for antenatal exposures.[187] Another systematic review and meta-analysis published in 2021 showed an association with childhood residential pesticide exposures and increased risk of childhood brain cancer.[188] The first and only systematic review published on the association between exposure to pesticides among non-farmer residents living near treated fields showed increased risk of blood cancers in both children and adults.[189]

Beyond the childhood cancers discussed, childhood exposures can also potentially be associated with adult cancers. Critical windows of exposure for certain tissues can be of importance in carcinogenesis, as was found in a study of the association of DDT and breast cancer, where exposure to DDT in adolescent girls in the 1950s has been associated with an increased risk of breast cancer later in life.[190]

Finally, in epidemiologic studies of cancer and environmental exposures to agents such as pesticides, exposure assessments, long latency periods and heterogeneity of diseases can be limiting.[191] Despite the difficulty and expense of doing such studies, the evidence accumulated is supportive of a significant association of pesticides with childhood cancers, warranting increased vigilance to prevent exposures as much as possible in children.[192]

3.3.4 Respiratory system effects

Evidence on the relationship between pesticides and respiratory and allergic disease has been considered limited and without consensus.[193] In a number of publications, the need for more research is emphasized, particularly in LMICs.[194, 195] In a 2020 systematic review, 15 of 19 studies (79 per cent) identified positive associations between exposure to agricultural pesticides in children and childhood respiratory and allergic effects, primarily asthma.[196] The review did not include studies that exclusively focused on residential pesticide exposures. Nevertheless, this meta-analysis had to deal with a huge variety of study designs which likely explains inconsistencies between the studies reviewed. Moreover, this review covered only studies published up to September 2019. Among the studies reviewed was a study from the California-based Center for the Health Assessment of Mothers and Children of Salinas (CHAMACOS), the oldest ongoing longitudinal birth cohort study of pesticides and other environmental exposures in children living in a farmworker community.[197] This study was the first to show that non-occupational early life exposure to organophosphate pesticides, assessed using urinary metabolites as the reliable biomarker measured from birth to the age of 5 years, was associated with decreased lung function objectively measured at 7 years of age.[198]

Confirming earlier results,[199] organophosphate insecticides exacerbated asthma in 16 school-age children (6 to 16 years) monitored for four months.[200] Higher urinary concentrations of dialkylphosphates (degradation products of these pesticides) were associated with asthma exacerbation as measured by the urinary asthma biomarker leucotriene 4E, suggesting an increased risk of asthma morbidity in children after short-term exposure.

Other chemical groups of pesticides recently reported to be involved in respiratory problems of children were pyrethroid insecticides and dithiocarbamate fungicides (exposure measured by their common metabolite ethylene thiourea [ETU]). Higher urinary concentrations of pyrethroid metabolites were associated with lower lung function in children and adolescents of a Canadian population.[201] In Costa Rica, a significantly increased risk of wheeze was observed for five-year-old children that had high urinary concentrations of pyrethroid metabolites.[202] Also, pyrethroid exposure was associated with asthma and an increased risk of respiratory tract infections in this study. In a study conducted in Ghana, an increased risk of respiratory infections was observed in children below 5 years of age when they had higher urinary concentrations of deltamethrin and bifenthrin (two pyrethroid insecticides), but also of the DDT-metabolite p,p′-DDE.[203]

The observation in French children (3 to 10 years old) of a significantly increased risk of asthma and rhinitis was associated with higher urinary concentrations of ETU.[204] This was complemented by a recent report of more frequently occurring respiratory tract infections in association with higher urinary ETU concentrations.[205]

Another aspect, respiratory problems after antenatal exposure to pesticides, is discussed in section 3.3.7 Birth outcomes and birth defects.

In summary, accumulating evidence demonstrates an exacerbation of asthma and an increased risk of other adverse effects on the respiratory system in children after exposure to pesticides, in particular to organophosphate and pyrethroid insecticides. Findings of asthma and respiratory tract infections also indicate an impact of pesticides on the immune function of the lung.

3.3.5 Endocrine system effects

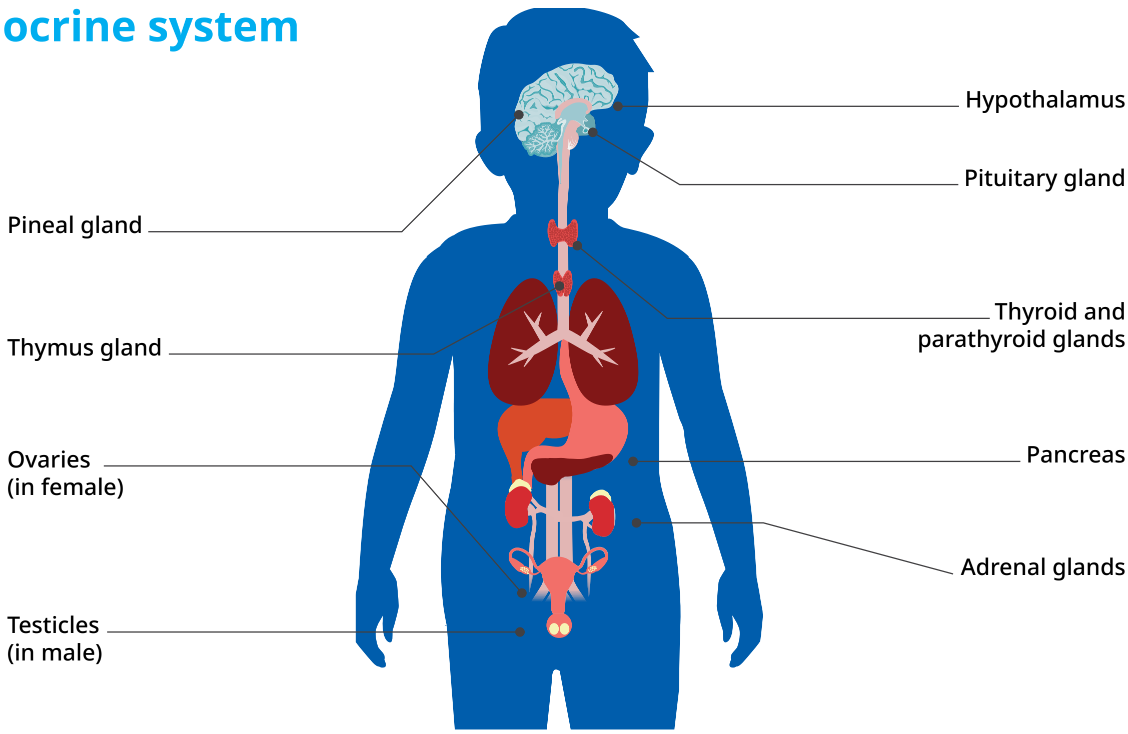
The endocrine system is made up of glands that produce, store and release hormones – chemicals that regulate vital body functions.[206] Components of the endocrine system include the testes, ovaries, hypothalamus and pancreas, as well as the adrenal, parathyroid, thyroid, pineal and pituitary glands.[207]

The endocrine system in humans and other organisms is responsible for regulating a large number of biological processes in the body, including those in early life, such as cell differentiation and organ formation, along with most tissue and organ functions throughout adulthood.[208] Pesticides are known endocrine-disrupting chemicals (EDCs) – exogenous substances that can change the function of the endocrine system, causing adverse health effects.[209]

EDCs are an urgent and serious threat to public health. Many EDCs show effects at very low doses and/or non-monotonic dose–response relationships, meaning that low doses can have a greater effect than higher doses.[210, 211] There are over 1,000 synthetic chemicals, including certain pesticides, which are known or potential EDCs; this is an enormous number and may be an underestimate.[212] The European research project EDC-MixRisk, which studied the effects of antenatal exposure to mixtures of suspected EDCs on the development and health of children, concluded that current regulations of synthetic chemicals systematically underestimate health risks associated with combined exposures to EDCs or potential EDCs.[213]

The effects of EDCs can depend on the timing of exposure, especially critical when exposure occurs during early life-stage development.[214] The early life stages (from conception to age 2 years) are critical windows of growth and development. During this period, there is maturation and epigenetic programming of neuronal, metabolic and immune pathways, as well as endocrine, reproductive and renal systems.[215] The endocrine disrupting effects

Endocrine system



are of concern in children, particularly because of their potential influence on neurologic and sexual development.[216] For example, chlorpyrifos, one of the world's most common organophosphate insecticides, is toxic to reproduction and has also been associated with endocrine disruption.[217]

The Endocrine Society, a global organization representing physicians and scientists from 120 countries,[218] reviewed the latest science and data and developed a comprehensive Second Scientific Statement in 2015, pointing out the gaps that still exist in research of EDCs, including pesticides. The report concludes that there is strong and mounting evidence for adverse outcomes in areas such as neuroendocrine and thyroid function, sexual development, obesity, metabolism and insulin resistance.[219]

Human epidemiological studies suggest that EDCs in children affect antenatal growth, thyroid function, glucose metabolism, obesity, puberty and fertility. Further research is needed to clarify which EDCs can primarily act on epigenetic processes.[220]

A 2021 review points to significant evidence suggesting that pesticides that are widely applied in farming have disrupting effects on the reproductive system.[221] An example of abnormal sexual development in males can be seen with cryptorchidism, commonly called 'undescended testis', which occurs in 1 to 4 per cent of full-term newborn males. Cryptorchidism is a risk factor for infertility and testicular cancer,[222] and requires surgery to relocate the testicle into the scrotum.[223] A 2018 review of pesticide exposure and congenital abnormalities examined the association of pesticides with urogenital abnormalities, including cryptorchidism.[224] A 2006 nested case–control study in Denmark and Finland examined the relationship between pesticides in breastmilk, used as a proxy for maternal exposure, and congenital cryptorchidism. While only one organochlorine, trans-chlordane, showed a positive association, the combined analysis of the eight most abundant pesticides of the 27 samples, showed that pesticide levels in breastmilk were significantly higher for boys with cryptorchidism.[225, 226]

For countries with endemic malaria, children can be exposed to DDT used for vector control. DDT is a known EDC with oestrogenic effects.[227] A 2009 study in South Africa showed that mothers who lived in a village that was sprayed five to nine years before the study had a 33 per cent increased chance of having a child with any external urogenital birth defect.[228]

Globally, the ages of onset of puberty for girls and boys have been decreasing during recent decades, likely partly due to excess body fat accumulation. There is also a growing body of literature that suggests EDCs may play an important role in this global trend, but the association has not yet been fully established.[229] Epidemiological research has mainly been conducted in geographical areas where accidental exposure to specific chemicals occurred and suggests that EDCs can affect the timing of puberty (both advanced and delayed puberty).[230] Pyrethroids for example, found in most common commercial household insecticides, show association with late onset of puberty and effects of maturation in girls.[231, 232] Exposure to EDCs during puberty is associated with the risk of developing breast cancer later in life.[233, 234] Some pesticides may also interfere with the function of female hormones, causing negative effects on the reproductive system.[235]

Another endocrine effect of concern is the disruption of thyroid function, important for many metabolic processes as well as neurodevelopment. A 2020 review, which examined the association with antenatal exposure to organochlorine compounds, found that some organochlorines, including DDT, DDE, hexachlorocyclohexane and hexachlorobenzene, may possibly alter foetal thyroid function.[236]

Associations of pesticides with many other endocrine effects are still under investigation. While the evidence is sometimes still inconclusive, such as the association of pesticides and obesity,[237] given the enormous number of EDCs children are exposed to, including pesticides, a precautionary approach is still warranted.[238]

3.3.6 Immune system effect

Epidemiologic studies showing the association of pesticides and immune function in children and adults are lacking. In-vitro and in-vivo animal and human studies show impairment of many important immune cells, including T cells, B cells, neutrophils, macrophages and natural killer cells.[239, 240] Some pesticide test guidelines include developmental immunotoxicity (DIT) assessments, such as OECD Test Guideline 443 (Extended One-Generation Reproductive Toxicity Study), which allows optional cohorts to evaluate immune system development and function. Further research is needed to determine how this impairment manifests clinically in children.

3.3.7 Birth outcomes and birth defects

A growing number of studies demonstrate effects of pesticides on preterm births and other birth outcomes and an increased risk of congenital abnormalities. A 2018 systematic review summarizing the literature from 1990 to June 2017 found a trend towards a positive association between environmental or occupational exposure to some pesticides, but cautioned that the 'recall bias' may have influenced the results of studies that solely relied on self-reported exposure. However, several studies have confirmed consistency between exposure measurement by chemical analyses and the self-reported use of pesticides.[241, 242] If certain groups of pesticides or individual compounds are identified as the potential cause, a 'weight of evidence' approach (considering experimental and epidemiological studies) strengthens the argument for the correctness of the conclusions.

According to a 2018 study, urogenital anomalies, including hypospadias, cryptorchidism and others, were the most thoroughly investigated category of anomalies associated with exposure to pesticides.[243] These findings were corroborated by other investigations.[244, 245, 246] Because organochlorines as well as a larger number of non-persistent pesticides are known to have endocrine disrupting properties,[247] this is considered the common mechanism for causing these effects.[248] (*See also section 3.3.5 Endocrine system effects).*

Other adverse birth outcomes associated with antenatal exposure to pesticides were oral clefts,[249, 250] cardiovascular abnormalities,[251] and neural tube defects for which two recent meta-analyses reported a high prevalence in African countries and demonstrated an association with pesticides.[252 253] A finding that should receive more attention is the potential occurrence of respiratory problems in children after maternal exposure to pesticides.[254, 255]

Finally, an important birth outcome is birthweight. Some, but not all, studies have shown that pesticide exposure is associated with risk of decreased birthweight.[256]

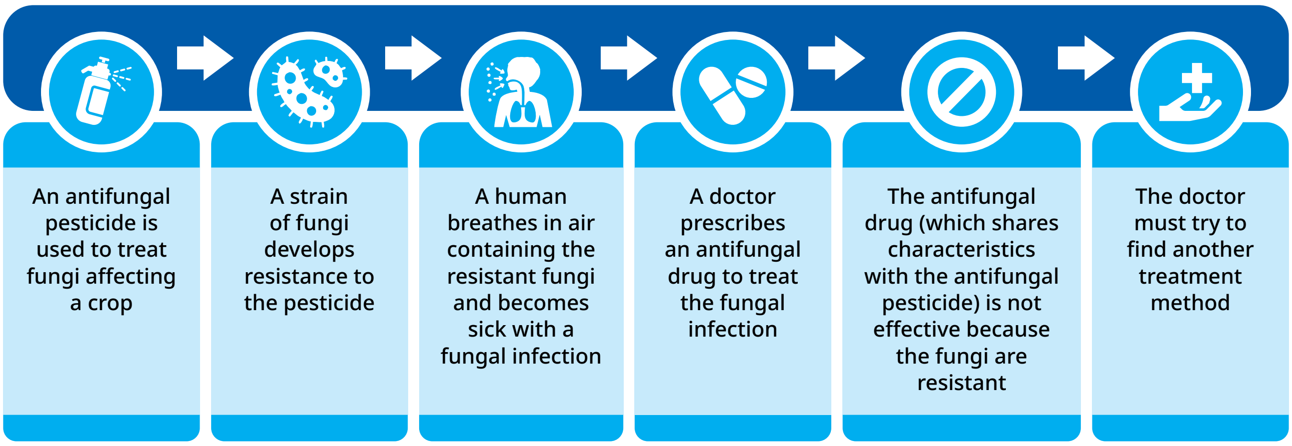
3.3.8 Antimicrobial resistance

Antimicrobial resistance (AMR) is a major global health concern, mainly driven by the inappropriate use of antimicrobials in human, animal and plant health.[257] Antimicrobial pesticides, including bactericides and fungicides, can contribute to the development of drug-resistant pathogens through several key mechanisms. They can cause the horizontal transfer of resistance genes between microorganisms and select for resistant strains of human, animal and plant pathogens.[258] Children, especially in LMICs, often receive more antibiotics than other groups.[259, 260] The misuse of fungicides can also increase resistance to antifungal agents, posing a particular threat to people at risk of fungal infections, including those who are immunocompromised or have other chronic diseases such as asthma.[261, 262]

The United States EPA outlines the potential clinical problem of antifungal resistance that can result from pesticide use (*see Figure 3*).[263]

According to WHO, addressing AMR requires coordinated action across human, animal and environmental sectors.[264] The One Health approach underscores the importance of such cross-sectoral collaboration. Reducing pesticide use, where appropriate, may mitigate AMR that threatens children's and public health.

Figure 3. Process of pesticide-initiated antifungal resistance



Source: US EPA (2024).[265] Reproduced with permission.

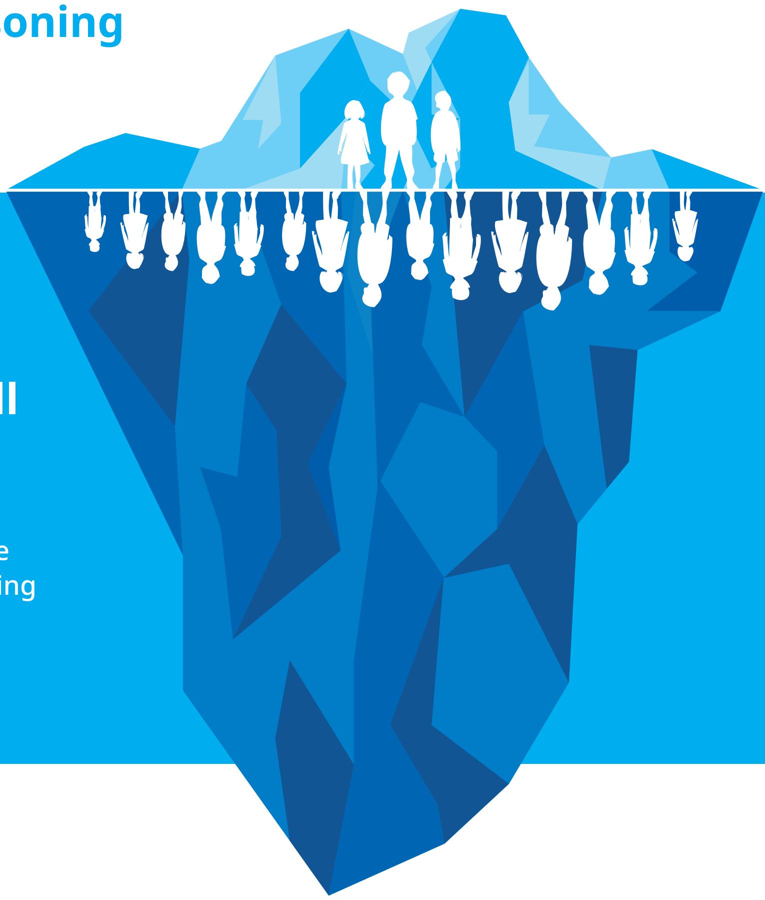
4 The scale of children's exposures to pesticides

The true scale of children's exposures to pesticides globally is largely unknown for several key reasons. First, acute poisonings are not adequately tracked globally. Second, biomonitoring data of pesticides in children are scant and the clinical significance of pesticide levels is difficult to establish, particularly given the array of pesticides to which children are exposed. Unlike toxicants such as lead, for which health outcomes are reported to occur at various levels of exposure, the understanding of the scale of pesticide exposure and the associated population-based health outcomes in children is in its infancy, particularly in LMICs.

It is likely that the data we do have on children's pesticide poisonings represents the tip of the iceberg. The available biomonitoring data suggest more widespread chronic exposure and sound the alarm for further study to determine the implications of children having low levels of numerous pesticides in their developing bodies. What lays underneath the iceberg will only be revealed with dedicated resources, strategies and technologies for monitoring and reporting children's exposures and health outcomes.

In this chapter, we describe a novel approach to assessing children's global pesticide exposures developed by experts from the University of Washington and the Institute for Health Metrics and Evaluation. Using a model of global agricultural pesticides, scientists estimated potential exposure in global child populations to pesticides applied on harvested land.

More than one child a day dies from pesticide poisoning annually – 375 deaths reported globally.



But the true global toll is likely much higher

The lack of data means we must take a precautionary approach in protecting children from pesticides.

4.1 Tip of the iceberg: Acute pesticide poisonings

4.1.1 Unintentional pesticide poisonings

The global number of unintentional acute pesticide poisonings is a severe public health problem, but limited data for children make understanding the scale of pesticide poisonings in children difficult at best, with the known data representing the tip of the iceberg.

Fatal pesticide poisoning is documented by the WHO mortality database, which comprises deaths registered in national civil registration systems. National authorities of the reporting countries transmit their data to WHO on an annual basis. Where national reporting systems are not in place, mortality data are neither recorded nor transmitted.

In the WHO mortality database from 2017 onwards, 130 deaths annually are documented due to unintentional acute pesticide poisoning in children, leading to a calculated loss of 7,686 life-years (a measure of premature mortality that considers both the frequency of deaths and the age at which it occurs). The highest number of fatalities occurred in Egypt, which employs children routinely in cotton farming. The highest rates per million children are seen in Guatemala, Peru and Ecuador.

As only a limited number of countries inform the database, the poisoning numbers highly underestimate the global mortality from pesticide poisoning in children. Data from studies in individual countries and regions such as south-western China, the Republic of Korea, the United Republic of Tanzania and the United States show that accidental acute pesticide poisoning in children is prevalent.[266, 267, 268]

For example, in 2021, a national report of India gives 178 fatal cases of accidental pesticide poisoning in children below 14 years and 583 cases in the age group of 14–17 years. This is six times the number of annual cases documented in WHO data for all countries together.[269] Consequently, India has reduced its numbers of registered HHPs.[270]

4.1.2 Intentional pesticide poisonings

Intentional pesticide self-poisoning is also a significant global public health problem. A 2017 systematic review evaluated the global burden of fatal self-poisoning with pesticides in the general population. Using data primarily from the WHO mortality database, the study estimated that globally almost 110,000 deaths, 13.7 per cent of suicides, occurred by self-poisoning with pesticides annually from 2010 to 2014.[271] There is large geographic disparity in suicide deaths from pesticide self-poisoning, with 0.9 per cent of suicide deaths by pesticide self-poisoning occurring in LMICs in the European Region compared with 48.3 per cent in LMICs in the Western Pacific Region. Despite the large number of suicides by pesticides found, the authors noted that high-quality data were lacking in populous countries, especially in the African and Eastern Mediterranean regions, so that true suicide incidence may have been underestimated. Children were not analysed as a separate group in this study.

The WHO mortality database from 2017 onwards shows that there are 245 deaths annually due to intentional acute pesticide poisoning in children. This amounts to a loss of 14,039 life-years (*Table 2*). Females accounted for 58 per cent of all intentional cases of pesticide poisoning in children and adolescents. The greatest number of fatalities occurred in Colombia, whereas the highest rates per million children are seen in Nicaragua and El Salvador. Only two cases of fatal intentional pesticide poisoning occurred in children younger than 10 years, in contrast to unintentional pesticide poisoning where this age group accounts for 41 per cent of all cases.

Table 2. Global annual cases of fatal pesticide poisoning according to WHO mortality database and calculated years of life lost in children and adolescents

	Accidental	Intentional	Total
Cases of fatal pesticide poisoning	130	245	375
Years of life lost	7,686	14,039	21,725

Source: WHO Mortality data,[272] see ICD-10 for classification of poisonings.[273] *(See Annex 2 for methodology).*

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In conclusion, the assessment of the amount of pesticide poisoning in children is hampered by the incomplete data and limited number of studies. Figures derived from mortality data and published single studies lead to a certain underestimation of cases, especially in countries of the global South where a particularly large number of children work in the agricultural sector or grow up in its vicinity.

4.2 Getting beneath the surface: children's pesticide exposures

Given the paucity of data on fatal pesticide poisoning in children, it is critical to estimate the scale of pesticide exposure in children. Data from the poison centres in the United States for 2021 show a total of 32,535 pesticide exposure cases in children and adolescents. This would result in a rate of 39 per 100,000, given a United States child population of approximately 84 million in 2021. If all countries had the same poisoning rate as the United States, that would mean about 1 million poisonings in children. However, this estimation would be based on poison centre data, which often comprise all exposure calls, including those without severe symptoms.

The most precise measure of recent pesticide exposure is through biomarkers – measurement of pesticides or their metabolites in urine, blood or other biological materials. However, biomarker collection and measurement is time- and resource-intensive, resulting in sparse data at a global scale – particularly in LMICs.

The United States Centers for Disease Control and Prevention (CDC) reports biomonitoring data using a nationally representative sample from the National Health and Nutrition Examination Survey (NHANES).[274] Studies published using NHANES data show widespread exposure to pesticides in children in the United States. For instance, a 2018 study of 2,295 children aged 6–19 years detected urinary metabolites of pyrethroids in almost 80 per cent of them.[275] In another study, 87 per cent of 685 children evaluated had glyphosate in their urine.[276] Additionally, NHANES data have shown that children aged 6–11 years had higher urinary levels for metabolites of several pesticides, including chlorpyrifos and other organophosphates, compared with adults aged 20–59 years.[277]

Large-scale national biomonitoring studies of pesticides are also conducted in a limited number of countries. The European Human Biomonitoring Initiative (HBM4EU) conducted a human biomonitoring survey (2014–2021) in 23 European countries to generate EU-wide comparable human biomonitoring data. The HBM4EU Aligned Studies looked specifically into the exposure of children and young people to environmental chemicals and included a total of 10,795 participants in three age groups: 6–12 years, 12–18 years and 20–39 years (young adults). Pesticide exposure was assessed by measuring substance-specific biomarkers. The pesticides included were chlorpyrifos, dimethoate, pyrethroids, glyphosate, polyethoxylated tallow amine and fipronil. Higher biomarker concentrations were observed in younger age groups, indicating that all of the pesticides monitored under HBM4EU were detected in higher concentrations in children than in adults.[278]

In Japan, a study examining urine samples from diapers (nappies) documented exposure levels of organophosphate pesticides in more than 1,000 Japanese toddlers. Associations were found between concentrations of common organophosphate metabolites (dialkylphosphates) in the toddlers' urine and food selection/preparation as well as household habits of using pesticides, indicating wide exposure of Japanese toddlers to organophosphate pesticides.[279]

In Australia, a cross-sectional biomonitoring study using pooled urine samples in Queensland was carried out in 2016. While overall there was no association of most of the pesticide metabolites in the study with age, both age less than 5 years and age over 60 years were significantly associated with concentrations of five organophosphate metabolites.[280]

Finally, smaller biomonitoring studies have shown similar results. One United States analysis showed that almost all of the 110 children in the study had measurable organophosphate metabolites in their urine, and children whose families reported garden pesticide use had a significantly higher level of one metabolite than families who had gardens but did not use pesticides.[281] A smaller-scale study conducted in Luxembourg on 264 children under 13 years of age examined biomarkers of different chemicals in children's hair, testing for 153 compounds, including 140 pesticides. The results showed children's long-time exposure to various chemicals, including pesticides. It also showed that if pesticides are persistent in the environment, they can lead to children's exposure decades after their use had been banned. There was frequent detection of pesticides with endocrine disruptive properties (organochlorine insecticides and azole fungicides). Additionally, the study demonstrated that consuming organic food could reduce children's exposure to pesticides.[282]

Overall, although biomonitoring data are inadequate, particularly in LMICs, the data that are available suggest widespread exposures in children to many commonly used pesticides.

4.3 Novel approach to quantifying children's pesticide exposure using PEST-CHEMGRIDS

Experts from the University of Washington and the Institute for Health Metrics and Evaluation have done a preliminary evaluation of the global scale of pesticide exposure in children living close to agriculturally applied pesticides, which account for 85 per cent of the pesticides used globally.[283]

The study used the Global Pesticide Grids (PEST-CHEMGRIDS) dataset, which was recently developed as the first global harmonized model of agricultural pesticide application.[284, 285] Leveraging PEST-CHEMGRIDS,[286] researchers estimated global child populations at risk of 'exposure' to 12 commonly applied pesticides among children (and adolescents) aged 0–4 and 0–19 years living within a 10 km grid cell from where pesticides were applied. (*For more details of population data, refer to Annex 3.)*

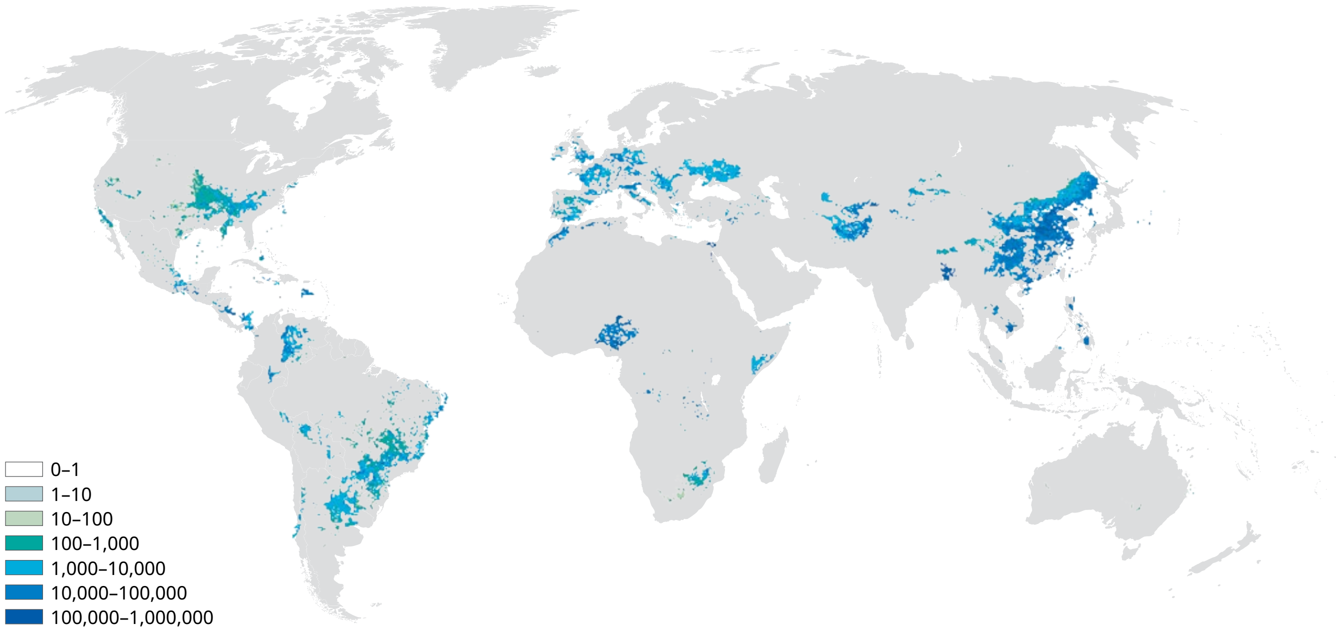
Findings suggest that children living within 10 km of the applied pesticides are potentially exposed to numerous harmful pesticides. The pesticide active ingredient with the highest rate of potential exposure (5.3 per cent in children under 5 years old) was glyphosate, which has been designated by IARC as probably carcinogenic to humans.

Researchers also evaluated the percentage of children exposed to combined pesticide active ingredients, finding that 124 million children under the age of 5 (18.5 per cent) and 490 million children and adolescents (18.8 per cent) may face potential exposure to pesticide active ingredients. Both urban and rural children were potentially exposed, possibly because as populations grow, agricultural areas may lay closer to highly populated urban areas. In fact, a 2014 global assessment of urban and peri-urban agriculture found that 40 per cent of irrigated croplands were located within 10 km of urban areas.[287]

124 million children under the age of 5 (18.5%) and 490 million children and adolescents (18.8%) may face exposure to pesticide active ingredients[6, 7]

As is common for many environmental toxicants, disparities in exposure were found. 'Potentially exposed' populations were located throughout Asia, Europe, the Midwestern United States, South America and sub-Saharan Africa (*see Figure 4*).

Figure 4. Estimated number of children and adolescents potentially exposed to pesticides applied to harvested land under the base exposure scenario for proximal combined pesticide application rates



Note: Estimates were calculated using high PEST-CHEMGRID application rates estimates (APR) for all (i.e., urban and rural) global children and adolescents.
Base exposure scenario (50 per cent crop coverage; 1 lb per acre–year)

Source: Institute for Health Metrics and Evaluation. Reproduced with permission.

This assessment of 'potential exposure' to pesticides is constrained by several significant limitations. The core issue lies in the use of proximity and application rates as a crude proxy for actual exposure, which fails to account for specific routes such as diet and residential use, as well as various lifestyle and housing factors that influence exposure levels. The analysis is further limited by the coarse 10 km resolution of the pesticide data, making it difficult to determine meaningful exposure for children within that grid, and an annual temporal resolution that misses seasonal population changes. Additionally, the assessment's focus on only the 12 most common pesticides and excludes other potentially significant chemicals and those used heavily in specific regions. Finally, the assessment does not account for the complex and variable relationships between pesticide type, environmental conditions, application methods, and the actual exposure and health risks to nearby populations, nor does it establish a clear link between the studied application rates and real-world exposure biomarkers. For these reasons, conservative estimates were applied.


EXPLORE

5 Pesticide life-cycle management: Remaining risk of pesticide exposure for children

To protect human health and the environment from the risk of pesticides, sound pesticide management is needed. Proper pesticide management is even more crucial to protect children.

5.1 Overview of pesticide life-cycle management

The pesticide life cycle includes all stages from production to disposal. Pesticide life-cycle management involves legislation, protocols and norms applied during each stage. Each stage of the pesticide life cycle needs to be managed appropriately with assessment of any risks to the environment and human health, especially for children and other vulnerable populations.[288] Surveillance and monitoring can be especially helpful to determine the effectiveness and implementation of regulations.[289, 290]

Progress on effective life-cycle management and pesticide risk reduction has been uneven across nations and regions.[291, 292] Evidence suggests that progress in risk mitigation in LMICs often lags behind that in HICs, disproportionately affecting poor and marginalized communities.[293, 294] Legal, technical and social challenges underlie the lack of progress in effectively managing pesticides at all stages of the pesticide life cycle.

Main elements of pesticide lifecycle management

Policy and legislation
to regulate and control each element of lifecycle management

Manufacturing
to produce pesticides safely

Packaging
to avoid any leakage and related unwanted exposure

Labelling
to lead to better application and improve safety

Registration
to control and increase the safety of the pesticide market

Transport
to promote safe distribution

Storage
to control necessary conditions in places of supply

Handling, application and use
to avoid exposure of sprayers and to reduce environmental impacts

Disposal of pesticide waste
to destroy residues in an environmentally sound manner

Monitoring of pesticides and pesticide residues
to assure food safety for both domestic consumption and export

Source: FAO (2023).[295] Adapted with permission.

5.2 Legal challenges regarding pesticide management

5.2.1 Weak or non-existent national legislation

In general, the registration and use of pesticides are governed by national legislation. These types of legislation vary greatly from country to country and region to region. Registration requires infrastructure and personnel and can be costly for the regulator and the producer/importer.[296] It also requires effective intragovernmental coordination and ideally will involve the ministries of health, environment, agriculture and others. However, many countries – particularly LMICs – have very few staff employed in pesticide registration, and registration facilities can become overwhelmed with requests.[297] A lack of human and technical capacity can ultimately undermine pesticide legislation and weaken regulations in an attempt to accelerate the registration process.

5.2.2 Non-legally binding mechanisms in global governance of pesticides

The global governance framework for pesticides contains legally binding and non-binding mechanisms, codes and instruments. Legally binding mechanisms include, for example, international chemicals and waste conventions such as the Rotterdam, Basel and Stockholm conventions.[298] Other important mechanisms, such as the FAO/WHO International Code of Conduct for Pesticide Management and the 2023 Global Framework on Chemicals, are not legally binding.

5.2.3 Continued use of Highly Hazardous Pesticides

The Global Framework on Chemicals targets the phasing out of HHPs in agriculture where the risks have not been managed and where safer and affordable alternatives are available by 2035. Until this Framework is implemented, HHP use continues, putting children at risk, especially in LMICs where HHPs, including those banned in HICs, may still be in use.[299] Elimination of the most toxic pesticides has been shown to rapidly reduce pesticide-related poisoning and fatalities, without any consequences for agricultural productivity.[300, 301] Ending HHP use can also be a potentially cost-effective intervention for reducing suicide deaths in countries with a high burden of suicides attributable to pesticides.[302]

5.2.4 Other key gaps in legislation

The legal framework for the safe production of pesticide products should include industrial safety standards, proper management of industrial wastes, quality control, transparency around active ingredients and compliance related to product packaging and labelling, among others. Failures to comply with international standards have led to tragedies and the loss of human lives, including those of children.[303] Although many countries have improved standards for pesticide manufacturing, the accelerated production of pesticide products, especially in South and South-East Asia, requires increased attention from authorities with already stretched resources.[304]

Key gaps in pesticide legislation include the following.

- Ingredients in pesticide formulations other than the active ingredient are not regulated. They are also often regarded as trade secrets and protected by intellectual and commercial property laws without requirements for transparency and disclosure.[305, 306]
- Levels of pesticide breakdown products (metabolites) in the environment are not regulated.
- No legal requirements for labels regarding the management of poisonings.[307, 308, 309, 310]
- There are relatively weak regulations and restrictions around pesticide use in non-food commodities such as cotton. This can result in exposures for children who work in these industries in many LMICs.
- Clear and practical guidelines for end-users on application procedures and risk mitigation measures are also lacking. Retailers and operators sometimes refuse to comply with trade or health and safety regulations, particularly if these represent trade-offs with potential profits or with averting perceived pest-related risks.[311, 312, 313, 314]
- Some national regulatory frameworks are weak and fail to adequately address pesticide safety standards and labelling requirements. This can lead to a false sense of security among farming communities.[315]
- Many agricultural workers are excluded from general labour legislation and/or occupational safety and health legislation. There is also poor application and enforcement of existing legislation. Labour inspectorates often have insufficient resources and training. Inspectors also rarely visit rural enterprises such as farms.[316]

5.2.5 Gaps in enforcement of legislation

Pesticide risk mitigation guidelines that are in place in most countries and for most products aim to minimize the potential harm pesticides can cause to human health, non-target organisms and the environment. However, they are seldom implemented or sufficiently enforced.[317] For environmentally persistent pesticides that are easily transported through air and water, mitigation measures are unlikely to be effective. Prevention of exposure is thus a preferred mitigation measure.

Poor infrastructure and limited personnel hinder the enforcement of regulations, including restrictions on the cross-border movement of hazardous pesticides and compliance with pesticide bans. Sadly, banned pesticides continue to poison children, even many years after national bans.[318] This can be compounded where governments institute pesticide bans without liability on obsolete pesticide stock.

A lack of adequate laboratory and digital infrastructure also hinders many countries in their abilities to monitor pesticide impacts and assess pesticide-related risks.[319] Limited government budgets and the prioritization of other government functions, including the promotion of industry and trade, can perpetuate poor infrastructural support to pesticide risk reduction programmes.

In some cases, scientific and public scrutiny of specific pesticide products can be subject to threats of legal action from producers, thereby delaying advances in policies that protect the environment and human health.[320]

5.2.6 Inadequate data and regulation for aesthetic uses of pesticides

While there are global data reported by Member countries to FAO on the use of pesticides in agriculture, there are no comparable data on the sales and usage of pesticides outside agriculture, making it impossible to define the scope and scale of use in places where children spend significant amounts of time. There are, for example, no data on pesticides used in schools or childcare centres. Once purchased, there is little regulation of the non-professional use of pesticides for aesthetic uses, such as around homes and in gardens to kill weeds. Unprofessional applicators are less experienced with chemical use and so may be more prone to unsafe use.

5.2.7 Inadequate control of pesticide waste and containers

Infrastructural deficiencies affect the potential for countries to secure the technical capacity and functions required for pesticide life-cycle management. Consequently, the private sector, including the pesticide industry and related advocacy groups, assume roles in monitoring and training for pesticide management including disposal of empty pesticide containers.[321]

Legislation regarding the management of pesticide-related waste is also inadequate in many countries, and often guided only by recommendations.[322, 323] Operators wash their spray equipment in streams and rivers and discard empty pesticide containers on farms or in wastelands, resulting in environmental contamination.

5.3 Technical challenges regarding adoption of less hazardous pesticide alternatives

Despite clear recommendations for a transition away from chemical-intensive agriculture, there are several challenges and barriers that affect the wide-scale adoption and use of biopesticides, biological, cultural and other alternatives.[324]

5.3.1 Limited availability and challenges to scaling up use

When alternatives are available, access may be limited, particularly for small-scale farmers in remote or resource-constrained regions.[325] Scaling up pesticide alternatives to meet the needs of large commercial farms or industrial agriculture presents challenges due to high initial investment costs, the complexity of managing diverse agroecological systems on a large scale, and the lack of infrastructure to support such practices. This emphasizes the importance of tailored approaches to scaling, considering the local context and the needs of smallholder farmers. The scalability challenge requires targeted interventions that address knowledge gaps, improve access to resources, strengthen supportive policies, and foster enabling environments for sustainable agriculture.[326]

5.3.2 Misconceptions on efficacy

Farmers may be hesitant to adopt alternatives if they perceive that chemical pesticides have resulted in good yields and productivity in the past.

However, several long-term studies that compared the performance of alternative and conventional pest management systems have provided evidence for the efficacy of alternatives and disproved misperceptions about comparatively lower yields.[327]

5.3.3 Uncontrolled pesticide drift

Pesticide drift is the movement of pesticide through the air at the time of application or soon afterwards, from the target site to any non- or off-target site. Pesticide drift excludes pesticide movement by erosion, migration, volatility or on wind-blown soil particles after application. Pesticide applicators are guided by the recommendations on pesticide labels and by advice received from government or agri-supply extensionists.[328 329, 330] However, even with regulations that prohibit the use of pesticides near waterways, dwellings and built environments, children are continually exposed to multiple pesticides.[331] Applications are often made during unsuitable weather conditions (hot and windy days), or by using aircraft or other methods without properly controlling drift.

5.3.4 Inadequate implementation of integrated pest management (IPM)

Integrated pest management (IPM) is the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations. It combines biological, chemical, physical and crop-specific (cultural) management strategies and practices to grow healthy crops, with pesticides considered only as a last option. This reduces the risks posed by pesticides to human health and the environment while providing more sustainable pest management.[332] Despite several successes, the concept of IPM has been eroded in recent years and, therefore, its implementation faces increasing challenges.[333]

5.4 Socioeconomic challenges regarding pesticide management

5.4.1 Lack of awareness on pesticide hazards and risks

Pesticides have become a prominent feature of rural and urban lives, and industry has failed to communicate and train farmers on pesticide hazards and risks. The familiarity with pesticides can cause complacency and lead to lack of sufficient care during the transport, storage, use or disposal of pesticide products. Also, users may be unaware of pesticide adverse effects or may choose to overlook them due to concerns about agricultural productivity, or because they have no knowledge of or access to alternatives. Without knowledge of risk, users may apply pesticides in higher doses than recommended. Low literacy rates and difficulty interpreting technical language, pictograms or colour codes present additional challenges. In some cases, labels may be in a foreign language or script.[334]

5.4.2 Perceived higher costs

Pesticide alternatives are often perceived to have higher costs than chemical pesticides, which sometimes are economic choices, especially where they include off-patent active ingredients. In contrast, alternatives may include additional labour costs (e.g., for manual weed or pest control), more expensive biopesticides, the costs of monitoring tools, and training programmes for farmers to recognize and manage pests and their natural enemies effectively.[335] It has to be highlighted that these considerations do not include any external costs, such as, for example, doctor's fees or costs for medical treatment in case of poisonings, or loss of working days in case of illness due to pesticide exposure.

5.4.3 Insufficient research on sustainable pest management

Research investments into non-chemical pest management options continue to lag behind investments into pesticides. Collaborative research initiatives involving universities, research institutions and private sector partners are necessary to drive innovation and knowledge exchange in sustainable pest management. Priority research areas may include the development of novel biopesticides, the optimization of biological control methods, and the integration of digital technologies for pest monitoring and decision-making.[336]

5.4.4 Misleading marketing

Agro-chemical suppliers invest substantial resources into marketing that promotes or exaggerates the benefits of their products while omitting or downplaying related environmental and health concerns. They also market their products as safe if used properly. However, due to prevailing conditions, including often incomprehensible labelling, economic and climatic conditions, or cultural norms, handling as prescribed by the manufacturers is often not possible. This is a significant problem given the scale of pesticide use and the pressures on farmers to consistently increase yields.[337]

5.5 Factors that directly increase risk of exposure for children

5.5.1 Child labour in the agricultural sector

Nearly 138 million children – 59 million girls and 78 million boys – are in child labour, accounting for almost 8 per cent of all children globally. Agriculture accounts for 61 per cent of child labour. Around 83.4 million children work long hours and often perform hazardous tasks, including the handling, preparation and application of pesticides, in farming, livestock keeping, forestry, fisheries and aquaculture, as well as post-harvest handling of crops (including fish and aquatic-sourced foods).

Agriculture accounts for the largest share of children in child labour, at 61 per cent globally.[338] Most of this takes place on smallholder farms and involves family subsistence activities such as farming, collecting firewood and fetching water. In sub-Saharan Africa, child labour in agriculture is especially dominant, with 7 out of every 10 children working in farming. Some 68 per cent of child labour among children aged 5–11 years, both boys and girls, is in the in agricultural sector, often in informal and family-based settings.[339]

About one third of children in child labour in agriculture are engaged in hazardous work, including pesticide application, which is classified as one of the worst forms of child labour under International Labour Organization (ILO) Convention No. 182. Children in child labour in agriculture face some of the most dangerous threats to their health and well-being, including exposure to pesticides.

Since handling, preparing and using pesticides is classified as hazardous work and prohibited for those under 18, addressing this issue is critical.[340]

It is frequently suggested that children are simply helping their families or learning skills that will be useful on the farm as adults. International law recognizes this and permits children to lend a ‘helping hand’, but it requires that the child be at least 13 years old (12 in some developing economies), work for a limited time each week, only in non-hazardous work, and attend school. However, for far too many children, work in agriculture exceeds these boundaries and becomes child labour.[341]

Child labour in rural areas is triggered by a series of factors including low family incomes, few livelihood alternatives, inadequate access to education, limited labour law enforcement, weak management of aquatic resources and environmental degradation. The seasonal nature of agriculture, as well as the variations in labour demand, also contribute to the use of children as workers. Low-income families in rural areas are under financial pressures and may see no other option other than to engage children to supplement the family’s income. Children may be pulled out of school, lowering their potential to earn higher income later in life and creating a cycle of poverty.[342] One key problem in reducing child labour in agriculture is that national labour legislation may not adequately cover, or may explicitly omit, the work that children perform in family businesses. Traditional labour inspection may have difficulty accessing children working in isolated, remote and rural communities. Workers’ organizations are less likely to record instances of child labour in agriculture, particularly in family farming, compared with other child labour situations.

5.5.2 Challenges in implementing regulation of pesticide residues in foods

Maximum residue limits (MRLs) are the highest level of a pesticide residue that is legally tolerated in or on food when pesticides are applied correctly in accordance with good agricultural practices.[343]

61% of child labour is in agriculture, potentially exposing 83.4 million children to pesticides[338]

Child labour and hazardous work

The definition of child labour is set by the ILO Minimum Age Convention, 1973 (No.138) and the ILO Worst Forms of Child Labour Convention, 1999 (No.182). Additional guidance is provided in the related Minimum Age Recommendation, 1973 (No.146) and the Worst Forms of Child Labour Recommendation, 1999 (No.190). Protecting children from economic exploitation is also included in the Convention on the Rights of the Child, 1989, Article 32.

ILO Convention No.182 defines hazardous work as any task that, by its nature or circumstances in which it is carried out, is likely to harm the health, safety or morals of the child.

While both conventions 138 and 182 prohibit hazardous work for individuals under 18 years of age, member states have discretion in identifying specific hazardous tasks through national legislation, in consultation with employers' and workers' organizations. These identified hazardous tasks are recorded in what is commonly referred to as the "Hazardous Work List" or "Hazardous Child Labour List".

ILO Recommendation No.190 provides guidance on types of work that should be prohibited, including activities such as the application of and exposure to agrochemicals and pesticides, particularly within agricultural settings.

Source: FAO (2020).[344]

Pesticide residues include the residues of both active substances and their toxicologically relevant breakdown products (metabolites).

MRLs are set as international standards by governments and international risk managers such as the Codex Alimentarius Commission (CAC). CAC considers input from the FAO/WHO Joint Meeting on Pesticide Residues, which establishes limits for safe intake to ensure that the amount of pesticide residue to which people are exposed through eating food over their lifetime will not result in adverse health effects.[345]

MRLs may be adequately protective in many settings, but implementation challenges remain. Although much effort has been made and success achieved in harmonizing test guidelines and assessment methods for the evaluation of dietary risks, a key factor of whether the human health risks in relation to dietary risks are acceptable in a particular country or region is the local use pattern and the local population food consumption data. With different local agricultural practices, the MRLs set by individual countries or regions can differ from Codex MRLs. Also the conduct of dietary risk assessment is complex as it may consider exposure sources other than food, such as drinking water. It may also require special consideration of risks to infants and children in some countries.[346]

International standards related to pesticide MRLs are set for the purposes of international trade.[347] According to WHO, currently there are more than 1,000 pesticides used around the world to protect food.[348] There are Codex standards for more than 100 pesticides.[349] Meanwhile, local capacity to adopt and enforce pesticide residue standards remains a key challenge, resulting in a chequered regulatory landscape.[350]

A 2018 study evaluated the ability of MRLs to protect public health globally using data from 16 countries (both HICs and LMICs) and found that many countries lack pesticide MRLs for some common agricultural foods.[351] Also, many theoretical maximum daily intake values were greater than the acceptable daily intake (ADI) values.

Minimizing pesticide residues in the foods specifically intended for infants and young children is critical. The European Food Safety Authority has established that the legal limit for these types of food products should generally be set at a low level (the limit of quantification), which generally means a default MRL of 0.01 mg/kg.[352] Countries outside the European Union do not regulate baby foods using this low level; they are regulated in the same manner as foods intended for the general population.[353]

5.5.3 Lack of access to adequate and affordable personal protective equipment

High-quality PPE is often costly or unavailable in remote rural communities. Farmers may also be reluctant to wear PPE due to discomfort, especially in hot climates. Agri-suppliers seldom discuss PPE and rely on government extension officers to relay safety issues.[354] When adults lack proper PPE, or when PPE is not cleaned and properly stored, take-home exposures to children can occur. PPE for children working in the fields should be available. However, PPE is typically not designed for children and may not provide the same protections.

5.5.4 Unsafe storage of pesticides and uses of pesticide containers

Numerous farmers lack the proper storage facilities for pesticides and some often keep pesticides and applicators (sprayers) on the farm, which can be accessed by members of the public. Pesticides should never be stored in a manner that poses risks to children. The dangerous re-use of empty containers for food or water storage, a common practice in some LMICs, can lead to pesticide poisonings.[355] *(See also section 2.2.7).*

5.5.5 Dangerous retail practices

Before purchase by the end-user, pesticides pass through several levels of retail that should be regulated to protect retailers and staff, and end-users and their families. To minimize risks to children, pesticide packaging should be not compromised or illegally altered for distribution. Pesticide packaging should also have adequate safety features and labelling.[356, 357]

Pesticides are also sometimes displayed on shop counters next to household and food products that are prone to contamination, particularly in remote rural regions of several LMICs.[358, 359] Although legislation that prohibits such commercialization and repackaging generally exists in affected countries, implementation is often difficult – particularly where pesticide distribution is mainly through informal channels.

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In some LMICs, including Ghana, vendors who commercialize pesticide products operate mobile vans, carts and trucks in communities where they sell their products at residences or marketplaces. These products are used for residential, agricultural and other purposes, during which children may be involved and/or exposed. Most of these vendors do not apply or educate their buyers on product safety measures. Though mobile retail of pesticides is prohibited by law, it is still commonplace because enforcement has been challenging.

Source: Northern Presbyterian Agricultural Services and Partners (2012).[360]

5.5.6 Potential exposure from pesticides used for vector control

When communities, homes and gardens are sprayed for public health purposes, there is potential for unintended direct exposure to children. Currently, there is a lack of research on the adverse effects on children from the use of insecticides for vector control.

In many countries, regulation of the use of pesticides for vector control is lacking. In a survey of 194 countries, around half of responding countries in the African, Asia–Pacific, and Latin America and Caribbean regions and 20 per cent of European and other regions had an integrated vector management (IVM) policy.[361] Some countries also do not have legislation regulating the use of pesticides in homes.[362] Lack of appropriate legislation for vector control may put children at increased risk of pesticide exposure.

5.6 Public health challenges

5.6.1 Lack of national poison centres

Poison centres are specialized units that advise and assist health workers on the prevention, diagnosis and management of pesticide poisonings.[363] Despite their importance, as of 2019, only 47 per cent of WHO Member States had a poison centre, with notable gaps in the African and Eastern Mediterranean regions and in small island states in the Western Pacific Region.[364]

Without poison centres, there is reduced capacity to adequately record pesticide poisonings, leading to unreliable estimates of exposure, poisoning rates and the types of pesticides involved. The lack of poison centres also results in delayed responses to pesticide poisonings, heightening the risk of adverse effects that could otherwise be promptly addressed.

Even where centres are available, standardized case definitions and disaggregation by age, sex and sector are often absent, which makes it difficult to trace poisonings in the informal sector. Furthermore, financial and technical constraints often hinder their efficiency, with significant consequences.[365] Often there is inconsistent and incoherent guidance and advice from different poison centres regarding pesticide-related incidents that may lead to confusion among health-care providers and the public.

5.6.2 Lack of primary health-care services and training

According to WHO, approximately half the world's population lacks access to essential health care,[366] reducing capacity for preventive actions that health workers could take with families to reduce and manage pesticide exposures. There is a well-documented knowledge gap for paediatric health providers on environmental toxicants, including pesticides, yet few providers receive training in environmental health.[367]

Data also exist specifically related to knowledge gaps for acute pesticide poisonings. Paediatric health providers have not historically accurately recognized acute pesticide poisonings and indicate that they lack education and efficacy in this area.[368] Poor recognition of acute pesticide poisoning by health providers has occurred in HICs such as the United States[369] and LMICs such as the United Republic of Tanzania.[370]

5.6.3 Lack of mental health services and suicide prevention programmes

Intentional pesticide poisonings due to mental health disorders are a risk to both children and the adults in their lives. Unfortunately, most people, 75 per cent in many low-income countries, do not have access to the mental health services they need.[371] People at risk of suicide require early assessment, management and follow-up.[372] Suicide prevention programmes require coordinated efforts across stakeholders and can be hindered by complex social and resource-related factors such as lack of acknowledgement of suicide as a problem and lack of data collection on suicide method.[373]

5.6.4 Lack of education on public health risks and strategies to reduce pesticide exposure

Public health communication and education on pesticide risks, essential for families to be able to know when and how to reduce exposures, is fragmented and inconsistent. Challenges of risk communication include public understanding of science, the underestimation of the threats posed by chronic or familiar exposures, and the disparity in information provided by industry versus public health officials.[374, 375, 376] The increasing use of social media can also influence the accuracy of the public's understanding of pesticide risk.[377]

There are limited data on public knowledge of the risk of pesticide residues in and on food. Consumers have been shown to have limited access to and availability of information on pesticide residues. A study on consumer risk perception of pesticide-stained tomatoes in Uganda showed that even when consumers had a negative attitude towards pesticide residues on tomatoes, their risk perception of these tomatoes was low. Consumers also bought tomatoes stained with pesticide residues due to lack of alternative products.

Source: Sekabojja *et al*. (2023).[378]

There are no international standards that require foods that contain pesticide residues to be labelled as such. Families purchasing produce are not then afforded information that can help them make educated food purchases. Foods that are grown organically, without the use of agricultural inputs such as synthetic pesticides,[379] may be certified according to standards in various countries; but there is no coordinated certification of non-organic foods grown without pesticides.[380]

The application of household and public health pesticides is often associated with child poisoning, but household pesticides are sometimes outside the jurisdiction of relevant authorities[381] and measures to specifically protect children are difficult to enforce.

6 Recommendations to protect children from pesticide exposure

Around the world, children and the environment are harmed every day by pesticides. The current increasing level of global pesticide use is not sustainable and a business-as-usual approach to pesticide use and management is not an option.[382] Efforts need to be ramped up by all stakeholders at a rapid pace to protect children and the environment on which they depend to lead healthy and productive lives. The overarching goals should be to phase out HHPs, minimize other pesticide use when possible and protect children from pesticide exposure.

The mobility of pesticides in the environment and international trade of pesticides create a global pesticide problem that requires international solutions. All stakeholders have a role to play in protecting children from harmful pesticides, including international agencies, national governments, industry and civil society.

In prioritizing certain recommendations and approaches over others, this report focuses on strategies that provide the most immediate and effective protection for children's health while also considering broader environmental impacts. The rationale is based on a holistic assessment of the risks associated with different practices, the feasibility of implementing changes, and the potential for sustainable long-term solutions. Through these proposed recommendations, solutions and actions at multiple levels, the report aims to create a comprehensive framework that encourages collective action and fosters a safer environment for children.

6.1 Prioritize pesticide standards that put children first

According to the United Nations Committee on the Rights of the Child, when environmental decisions are adopted and implemented, full consideration of all children's rights under the Convention on the Rights of the Child is required.[383] This includes decisions involving laws, regulations, policies, standards, guidelines, plans, strategies, budgets, international agreements and the provision of development assistance.[384]

Children's unique vulnerabilities to pesticides should also be considered, especially as they relate to human health risk assessments, which are used to determine limits for pesticide residues in foods and drinking water.[385]

The United Nations Committee on the Elimination of Discrimination against Women also calls on states to provide special protection of pregnant women, which would include minimizing the risks of maternal and foetal pesticide exposure.[386]

6.2 Prioritize phasing out Highly Hazardous Pesticides

A focus on phasing out HHPs and reducing environmental toxicity by eliminating pesticide-associated hazards has been recognized at international levels and is now policy under a series of binding and non-binding international instruments, including the 2023 Global Framework on Chemicals (GFC). The GFC advocates the phasing out of HHPs in agriculture where the risks have not been managed and where safer and affordable alternatives are available by 2035, notes the prevention of illegal trade in chemicals and waste, and advocates implementation of national legal frameworks. It also encourages the transition to safer production systems, safer chemical alternatives, and improved transparency and access to information about chemicals and associated risks.[387]

WHO and FAO are developing guidelines to assist countries to phase out HHPs.[388] Concerns should be raised about pesticides that adversely affect the health and development of children, including their cognitive development. Once identified, such chemicals can be addressed using the same guidelines as for HHPs. Safer alternatives to HHPs already exist and need to be supported and scaled up.[389, 390]

UNEP's *Guidelines on Alternatives to Highly Hazardous Pesticides* is a useful resource in identifying the roles of the different stakeholders in the process of replacing HHPs and suggest how they can support one another to maintain agricultural productivity while protecting people's health and the environment.[391]

6.3 End child labour in agriculture and protect children from the risk posed by pesticide exposure

The Fifth Global Conference on the Elimination of Child Labour (5GCCL), held in May 2022 in South Africa, emphasized the urgent need to address child labour in agriculture, which makes up 61 per cent of global child labour. The conference concluded with the adoption of the Durban Call to Action, urging collaboration among governments, United Nations entities, civil society, and international organizations to eradicate child labour in agriculture, fisheries and aquaculture.[392] It also supported the 2020 *FAO Framework on Ending Child Labour in Agriculture*[393] and the International Partnership for Cooperation on Child Labour in Agriculture (IPCCLA).[394]

Child labour in agriculture, particularly involving exposure to hazardous pesticides, is a multifaceted problem that requires a comprehensive approach. To address the root causes that force children to work in agriculture at a young age and be exposed to hazardous pesticides, it is crucial to involve a wide range of stakeholders, including agricultural workers, educators, labour representatives, and pesticide control boards, at multiple levels.[395] The goal is to carry a common effort to promote sustainable agricultural practices to reduce hazardous child labour, and build global, regional and national commitment.

Pesticide risk reduction and safer practices for workers involve multiple strategies. These include raising awareness and building capacity, applying risk mitigation measures and restrictions, promoting alternative pest and chemical management strategies, and enforcing international controls governing pesticides and national legislation. Specific actions involve non-registration or cancellation of registrations and phase-out of harmful pesticides, gathering data on children's occupational exposure to pesticides, and preventing child labour in hazardous conditions. National regulations should contain hazardous work lists to protect children under the age of 18 years from pesticide exposure, as well as tasks that are not permitted for children.[396]

6.4 Promote safer alternatives

6.4.1 Promote agroecological practices

The United Nations Special Rapporteur on the right to food has stated that the promotion of agroecological practices, which replace chemicals with biological processes, is key to sustainable agriculture. Accomplishing this requires changing the current industrial agriculture framework and addressing the ecological, economic and social factors that are embedded in agricultural policies.[397] It also requires overturning the myth that pesticides are essential to feed the world[398] and challenging the current interests, incentives and power relations that promote industrial agriculture.[399]

Increased research and development of sustainable pest management is needed, including the development of novel biopesticides, the optimization of biological control methods, and the integration of digital technologies for pest monitoring and decision-making.[400]

6.4.2 Implement integrated pest management

Integrated pest management (IPM) is a holistic approach to crop protection that prioritizes the use of non-chemical pest management methods and encourages producers to apply available pest control options only after consideration of the economic, environmental and social impacts. IPM promotes crop health with the least possible disruption to agro-ecosystems thereby protecting, enhancing or restoring natural pest regulation mechanisms. It contributes to food safety and reduces harmful residues in food, water and the environment; but also enhances biodiversity and soil health. Economically, IPM lowers production costs and boosts farmer income by improving crop quality and market value. Moreover, it empowers farmers with deeper ecological knowledge tailored to their local conditions, fostering long-term stewardship and resilience.[401]

IPM can be used in both agricultural and non-agricultural settings, including homes, gardens and workplaces.[402] In non-agricultural settings, residues (including organic wastes) and moisture can be managed to avoid conditions that favor pests, and weeds can be removed by hand or other physical means (e.g., weed burners) rather than using herbicides. In childcare centres and schools, IPM is a proven strategy to minimize pesticide exposure.[403]

6.4.3 Implement integrated vector management

Sustainable vector control protects children from vector-borne illnesses, while minimizing adverse effects from pesticides. IVM is a rational decision-making process that emphasizes optimal use of resources for efficient, cost-effective and sustainable vector control.[404] In 2017, WHO published the *Global Vector Control Response 2017–2030*, which provides a strategy to strengthen vector control through increased capacity, improved surveillance and coordination of actions across sectors and diseases.[405] The World Health Assembly adopted resolution WHA 70.16, which calls on WHO Member States to develop or adapt national vector control strategies and operational plans to align with this strategy.[406]

6.4.4 Limit non-essential uses of pesticides

The non-essential uses of pesticides, such as to improve the appearance of a lawn or garden ('cosmetic use') should be limited. Incentives must be provided to limit the use of pesticides for cosmetic purposes. There is scant legislation globally regarding these uses, with only a few country examples. For example, the Canadian province of Ontario banned the cosmetic use of pesticides in 2009.[407] In the United States, only one jurisdiction in the state of Maryland has been successful in creating a similar ban.[408] Another example of restriction of 'plant-protection chemicals' to a wider range of environments including private gardens, hotels, campsites, theme parks, health-care establishments, sports facilities and cemeteries came into force in July 2022 in France.[409]

6.5 Reduce the impact on children when using pesticides

To protect children, the first priority should be to eliminate or reduce the use of pesticides. When pesticides are used, the next priority should be to minimize collateral damage to children and the environment. Following recommendations during the manufacture, transport and application of pesticides can reduce risk.

6.5.1 Minimize pesticide drift and environmental contamination in agricultural communities

The agricultural industry has an obligation to people living, working or playing in the vicinity of fields and plantations. This includes avoiding pesticide drift and environmental contamination of all sorts. Precision spraying can hinder or significantly reduce spray drift. Consistent access to this tool is necessary, especially in LMICs. When applicable, other engineering controls such as ventilated tractor cabins are also important.[410] Pesticide-free buffer zones around schools, housing, playgrounds and sports fields can also reduce children's exposures.

6.5.2 Reduce occupational exposures

Reduction of occupational exposures can mean fewer potential exposures for children and family members of agricultural workers.

The agricultural industry should ensure that pesticides are only passed from the factory gate of the production facility to users who have received training or education in the handling of pesticides. Industry should also ensure that the origin and course of pesticides can be traced in international trade and especially ensure the end of the marketing of HHPs.

Additionally, farmers should be educated on pesticide risks, economic feasibility of reduced use, and IPM strategies.[411] Workers should minimize their own exposures when possible, know what pesticides they are working with and their associated risks, and wear PPE.

6.5.3 Increase capacity for surveillance and monitoring of pesticide management

Building technical capacity is essential to ensure effective pesticide life-cycle management. This includes deploying trained and skilled personnel to perform key regulatory and enforcement functions. Insufficient staffing limits the ability to enforce regulations, monitor compliance with pesticide bans, and control the cross-border movement of hazardous pesticides. Targeted capacity-building initiatives can address these gaps, improving the overall effectiveness of pesticide monitoring and surveillance systems.

Surveillance should be both human (biomonitoring) and monitoring of environmental pesticide residue in air, water and soil near schools, childcare centres and agricultural communities – to better estimate actual exposure pathways affecting children. Development or expansion of tools is also needed to compile, track and present the data in quantifiable indicators and reports. The quantitative measures indicate trends and can identify the areas and pesticides that most need monitoring in the future.

The pesticide-producing industry should also collaborate with governments in post-registration surveillance and conducting monitoring to determine the fate of pesticides and their health and environmental effects under operational conditions. Improved systems of monitoring and enforcing legal pesticide residue limits on foods should be in place. In addition, industry should establish services to collect and safely dispose of used containers and small quantities of left-over pesticides.[412]

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6.6 Prioritize community education

The public needs increased education on the risks of pesticide exposure and access to strategies to protect children from pesticides. Strategies include the following:

6.6.1 Reduce take-home exposures

Agricultural workers and other pesticide handlers should change from work clothes and shoes before entering their homes or cars, store and wash work clothes separately from other clothes, wash their hands before leaving work and eating, and avoid hugging or carrying children until they have changed from their work clothes and showered. Employers of agricultural workers should provide all necessary cleaning equipment and supplies for their workers.[413, 414]

6.6.2 Store pesticides and other chemicals safely

Pesticides should always be stored safely out of the reach of children, not in proximity to food, and never in unlabelled, improperly labelled or easy-to-open containers.[415]

6.6.3 Reduce harm from drift and environmental contamination

In agricultural communities, families should close their windows and stay indoors when pesticides are sprayed on nearby fields.[416] Other actions include preventing children from playing in sprayed fields, washing children's hands after they come in from the outside and before eating, keeping the home clean, and frequently washing children's toys and blankets.[417] It is also crucial to avoid using empty pesticide containers to store or transport drinking water or food to prevent contamination and accidental poisonings.

In the event of a pest infestation in the home that poses a problem to the health or safety of the family, families should seek help from professional pest controllers if they are available and affordable rather than take action themselves. If indoor pesticide use does occur, re-entry times should be strictly observed to avoid exposure.

Children's exposures should also be minimized during indoor residual spraying for vector control. WHO has an updated operational manual that outlines strategies to protect children when pesticides are used for vector control in homes.[418]

6.6.4 Reduce dietary exposure to pesticides

Organic diets have been shown to reduce pesticide levels in children,[419] but certified organic foods produced without the use of synthetic pesticides are generally far more expensive than conventionally produced foods and may not be an affordable option for low-income families.[420]

There are other strategies families can take to minimize dietary exposures. If data are available in their countries, families can learn which produce might have the highest levels of pesticides. Families can also peel and wash produce to minimize residues on foods and trim skin and fat from fish, meat and poultry,[421] as many pesticides are lipophilic and can be stored in fat.[422, 423] The American Academy of Pediatrics recommends that while families should try to limit pesticide exposure, they should not avoid consuming conventional produce, as fruits and vegetables are a necessary part of children's diets.[424]

When possible, families can also consider growing their own pesticide-free produce.

Companies that produce and market baby food should only use raw materials from organic farming, as these are less contaminated by pesticides or free from pesticide residues. To protect young children, the EU has set specifically low maximum residue levels for foods that are intended for infants and young children (e.g., processed baby food).[425]

In state institutions such as schools, kindergartens and nurseries, governments and municipalities can also lead by example and provide measures for sustainable procurement, ensuring that pesticide-free food is made available. They may also set incentives for other providers to do so in similar non-state facilities.

6.6.5 Protect children from treated pets

Families should keep children away from pets that have been sprayed with flea-control medication or treated with antiparasitic medication as advised on the pesticide label.[426]

6.6.6 Increase public access to accurate information on pesticide risks

Governments are also responsible for ensuring the right to information (labelling, data safety sheets, etc.) for the public and to raise awareness of professional users, the general public, health providers and others on where and how to find information such as hazard information, hazard pictograms, risk and safety phrases. Governments should also develop clear, accessible communication tools that translate technical information into practical guidance, enabling communities to understand and reduce pesticide risks – not merely access information. Existing legal instruments should be constantly updated with newly identified hazards, safety rules and risk mitigation provisions.

6.7 Strengthen surveillance and primary care services

6.7.1 Establish national poison centres

WHO recommends that all countries establish and strengthen poison centres, which play a crucial role in managing and preventing pesticide poisoning cases by offering immediate and accessible medical advice to health workers and the public.[427] Poison centres provide invaluable expertise, cost-effective management strategies and health data that enable the early detection of emerging threats and support targeted prevention efforts.

Poison centres play an important role in collecting and providing data on acute and chronic pesticide poisoning cases. The important role of poison centres and the need to overcome their unequal distribution and to increase their number was recognized by the fifth session of the International Conference on Chemicals Management (ICCM5).

Source: United Nations Environment Programme (2024).[428]

Poison centres rely on the availability of information on the toxicological properties of substances and benefit from cooperation at national and international levels. Legislation can require companies that market hazardous chemicals to provide this information in a standardized way, as is the case in the EU for some chemical mixtures.[429]

Finally, poison centres, especially those in LMICs, should be set up with mechanisms within appropriate institutions or ministries to ensure their sustainability, and should consider institutional collaborations for research, training, financing and surveillance operations. The poison centre in Ghana, one of only two poison centres in the West Africa subregion, was set up in response to increasing cases of accidental poisoning and mishandling of pesticides, including accidental poisonings due to unsafe storage methods in homes.[430]

6.7.2 Strengthen the primary health-care workforce with training on the recognition, diagnosis and management of pesticide poisoning

Health professionals who care for children should be informed about the sources and routes of pesticide exposures and their health effects, resources for management of acute and chronic exposures, hazard pictograms and risk phrases on pesticide products, and anticipatory guidance for minimizing pesticide exposures.[431] They should also develop skills to take a paediatric environmental history that targets pesticide exposures.[432]

Increasing health worker education requires concerted efforts by medical institutions, hospitals, clinics, poison centres, medical professional societies, and individual health workers. Government agencies, public health departments and non-governmental organizations can also support such efforts. Effective educational options include interactive, web-based learning[433] and community-based learning with education tools such as the FAO–ILO *Visual Facilitator's Guide*.[434]

6.7.3 Increase mental health services to prevent suicide and other intentional pesticide poisonings

According to WHO, the most effective way to reduce deaths by pesticide poisonings is to first ban the most toxic pesticides.[435] WHO also advocates for fostering socio-emotional life skills in adolescents as adolescence is a period of risk for the onset of mental health conditions. WHO also promotes the early identification, assessment, management and follow-up of anyone affected by suicidal behaviours.[436] Health systems should ensure suicide prevention is a core component of clinical care.

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Annex 1
Types and examples of commonly used pesticides

Table A1.1 Pesticide category, target pest and method of destruction

Pesticide category	Target pest and method of destruction
Algicides	Kill algae
Antifoulants	Kill or repel organisms that attach to underwater surfaces
Antimicrobials	Kill microbiological organisms (bacteria, viruses, fungi and protozoa) in can preservatives, film preservatives, wood preservatives, protective coatings, disinfectants, sanitizers and others
Attractants	Lure pests to trap or bait
Defoliants	Selectively kill plants; cause leaves or foliage to drop from a plant
Desiccants	Promote drying of living tissues
Disinfectants and sanitizers	Kill or inactivate disease-producing microorganisms on inanimate objects. Also used for human and veterinary hygiene purposes.
Fungicides	Kill fungi (blights, mildews, moulds and rusts)
Fumigants	Produce gas or vapour that destroys pests
Herbicides	Kill weeds and other plants
Insect growth regulators	Disrupt insect life processes
Insecticides	Kill insects and other arthropods
Miticides	Kill mites that feed on plants and animals
Microbial pesticides	Target microorganisms that kill, inhibit or out-compete pests, such as insects or other microorganism pests
Molluscicides	Kill snails and slugs
Nematicides	Kill nematodes
Ovicides	Kill eggs of insects and mites
Pheromones	Disrupt insect mating behaviours
Plant growth regulators	Alter plant growth, flowering or reproduction rate
Repellents and attractants	Repel or attract pests, including insects, birds or rodents
Rodenticides	Kill mice, rats and other rodents

Source: Adapted from the United States Environmental Protection Agency (EPA, 2023)[1] and European Chemical Agency (2012).[2]

Table A1.2 Insecticides organized by chemical class

Chemical class	Examples	Notes
Organophosphates	Chlorpyrifos, malathion	Significant source of acute pesticide poisonings
Organochlorines	DDT,[A] aldrin, endosulfan, lindane	Persistent organic pollutants; many banned under Stockholm Convention
Carbamates	Aldicarb	Similar to organophosphate pesticides
Pyrethroids[B]	Permethrin, cypermethrin	Increasingly used in some countries in residential and agricultural settings to replace organophosphates and organochlorines
Neonicotinoids[C]	Imidacloprid, clothianidin, acetamiprid	Increasing use; persistent in environment; higher affinity for insect rather than mammalian nicotinic acetylcholine receptors; threat to pollinators

Source: American Academy of Pediatrics Council on Environmental Health (2019),[3] except for: [A] use of DDT in malaria vector control (WHO, 2011);[4] [B] use of pyrethroids in Canada (van Balen *et al*., 2012)[5] and the United States of America (EPA, 2022);[6] [C] neonicotinoid use (Bakker *et al*., 2020; Simon-Delso *et al*., 2015; EPA, 2023).[7, 8, 9]

Table A1.3 Commonly used herbicides

Chemical class	Examples	Notes
Organophosphorus herbicides	Glyphosate	Active substance also available in ready-to-use products for non-professional users; declared by International Agency for Research on Cancer (IARC) in 2015 to be probable human carcinogen; low but pervasive contamination globally
Triazine herbicides	Atrazine	Although banned in the European Union and 17 other countries (44 countries total), atrazine is still used widely globally; threatens drinking water due to widespread agricultural use
Bipyridyl herbicides	Paraquat	Acutely toxic; has no antidote and leads to a painful death when consumed; one of the most used pesticides for suicides over the past five decades; globally, one of the most used herbicides
Phenoxyacetic herbicides	2,4-D	Phenoxyacetic herbicides are widely used and can be found in surface and groundwater; global use is expected to increase worldwide

Source: Glyphosate technical information sheet (National Pesticide Information Center, 2010);[10] Glyphosate basic information (EPA, 2022);[11] Herbicides basic information (EPA, 2022);[12] Pesticides sales and usage (EPA *et al*., 2017);[13] Contamination of croplands with glyphosate (Maggi *et al*., 2020);[14] IARC classification of glyphosate (IARC, 2015);[15] Atrazine (PAN, 2021; Brovini *et al*., 2021);[16, 17] Facts about paraquat (CDC, 2022; Gawarammana and Buckley, 2011; Bonvoisin *et al*., 2020);[18, 19, 20] 2,4-dichlorophenoxyacetic acid (2,4-D) (Islam *et al*., 2018).[21]

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Annex 2
WHO mortality data analysis as basis for child fatal pesticide poisoning

This annex details how the World Health Organization (WHO) mortality data were analysed to report on child fatal pesticide poisoning (PP).

Methods

Data sources

Data of the WHO Cause of Death statistics to identify fatal PP in children were used. WHO mortality data comprise deaths registered in national civil registration systems. National authorities of the reporting countries transmit these data to WHO on an annual basis. The underlying cause of death is defined as 'the disease or injury which initiated the train of morbid events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury' in accordance with the rules of the International Classification of Diseases (ICD).[1] The database is made available online by WHO and contains the number of deaths by country, year, sex, age group and cause of death. Data for the years 2017 onwards were downloaded (as of 27 February 2023).[2]

The WHO database provides population data along with the mortality data. Some countries submit their own population data to WHO; for other countries, WHO takes population data from the population estimates of the United Nations Population Division. The WHO population data did not cover some countries and relevant years. To calculate PP fatality rates, United Nations population data for all countries were taken directly from the United Nations website. Data for the sex-specific population under 20 years of age by country and five-year age groups were extracted and matched to the years of reported deaths in the mortality database.[3]

Mortality

Most countries report cause of death data using the International Classification of Diseases revision 10 (ICD10). WHO allows reporting by either a 3-digit or a 4-digit code. PP is coded in ICD10 either under chapter XIX as 'T60 – Toxic effect of pesticides' or under chapter XX 'External causes of morbidity and mortality' as 'Accidental poisoning by and exposure to pesticides' (X48) and as 'Intentional self-poisoning by and exposure to pesticides' (X68). When reported by 4-digit code, a fourth digit added to X48 or X68 indicates the site where the PP incident occurred. According to ICD, a code from chapter XX should in general be used in addition to a code from another chapter. However, if only one code is tabulated then the code from Chapter XX should be used in preference.

Countries report only for ICD codes with incidents; therefore, a missing code was considered as zero incidents for our purposes. So, for example, if a country provided fatalities for a specific year not including codes X48, we set X48 = 0.

No codes T60 were found in the mortality data after 2017. Most countries also did not report site-specific X48 and X68. The analysis was therefore restricted to the ICD codes X48 (accidental) and X68 (intentional).

Years of life lost from mortality (YLL)

In addition to the number of fatal poisonings the potential 'years of life lost' (YLL) was calculated as a measure of premature mortality that takes into account both the frequency of deaths and the age at which it occurs.[4]

YLLs are calculated by summing up the number of deaths occurring at a specific age and multiplying this sum with the number of remaining years to live up to a selected age limit. In accordance with Organisation for Economic Co-operations and Development (OECD) Health Statistics, a standard age limit of 75 years was used.[5]

A group mean age was used for each fatal poisoning: 70 YLL for children aged 0–9 years, and 60 YLL for those aged 10–19 years. Using the United Nations population data, YLL rates per 100,000 were calculated.

Data analysis

The authors:

- summed the crude number of cases and YLL for countries by ICD code, year and sex;
- annualized the cases and YLL by dividing by the number of reporting years;
- calculated fatality (per 1 million) and YLL rates (per 100,000) by country, diagnosis, year and sex, by dividing the number of cases and YLL by the size of the respective population, and then averaged the specific rates for countries and diagnosis.

Results

Reporting countries

- The database provided entries from 119 countries reporting by ICD10. However, 10 countries could not be linked to population information in the United Nations database, e.g., 'Occupied Palestinian Territory' and 'UK Scotland' (a sub-division of a larger nation, United Kingdom of Great Britain and Northern Ireland).
- 26 countries reported (non-zero) cases for accidental and 25 countries for intentional PP.
- 32 countries of the WHO country-codes list are considered low-income countries by the World Bank classification. However, in the mortality database we found only one of them (Tajikistan) with a single record for 2017. So, all other low-income countries do not inform the WHO mortality database from 2017 onwards. Most of the reporting countries (82 per cent) belong to the 'High' or 'Upper middle' income groups.

Cases

- For the years 2017–2021, the WHO mortality data show 1,312 fatal pesticide poisoning among children, 433 of them accidental and 879 intentional.
- This gives an annual fatal PP of 375 cases: 130 accidental, 245 intentional.
- The annual YLL were calculated as 21,725, comprising 7,686 YLL from accidental and 14,039 from intentional PP.
- 55 per cent of all cases were female, with a larger share for intentional PP (58 per cent) compared with accidental PP (47 per cent)
- For intentional PP, only 2 cases in children younger than 10 were recorded, whereas 41 per cent of accidental PP happened in this age group.
- The overall rate of annual cases per 1 million children is 0.18 for accidental and 0.37 for intentional PP. Country-specific rates are presented in Table A2.1.

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Table A2.1 Fatal pesticide poisoning of children by descending annual rate per million

Accidental			Intentional		
Country	**Cases per million**	**Cases, annual**	**Country**	**Cases per million**	**Cases, annual**
Guatemala	2.40	19	Guyana	60.21	19
Peru	1.20	14	Nicaragua	7.97	22
Ecuador	1.12	7	El Salvador	5.96	14
Kuwait	0.86	1	Grenada	5.33	1
Republic of Moldova (the)	0.64	1	Guatemala	3.68	29
Egypt	0.57	25	Colombia	2.70	42
Mexico	0.52	23	Costa Rica	2.39	4
Belarus	0.47	1	Ecuador	2.38	15
Nicaragua	0.46	2	Panama	1.37	2
South Africa	0.41	9	Thailand	0.82	14
Costa Rica	0.34	1	Mexico	0.75	33
Mongolia	0.30	1	Brazil	0.44	27
Paraguay	0.29	1	Peru	0.43	5
Colombia	0.27	5	Paraguay	0.40	1
Uruguay	0.26	1	Switzerland	0.14	1
Lebanon	0.19	1	Philippines (the)	0.11	5
Kazakhstan	0.13	1	Cuba	0.10	1
Thailand	0.10	2	Chile	0.10	1
Cuba	0.09	1	Netherlands (Kingdom of the)	0.06	1
Romania	0.08	1	Egypt	0.06	3
Brazil	0.08	5	Türkiye	0.04	1
Türkiy	0.07	2	Republic of Korea (the)	0.03	1
Tunisia	0.07	1	South Africa	0.02	1
Philippines (the)	0.06	3	Argentina	0.02	1
Spain	0.02	1	United States of America (the)	0	1
United States of America (the)	0.01	1			

Source: WHO Mortality data, for details see text.

Annex 3
Assessing children's pesticide exposure using PEST-CHEMGRIDS

Background

As reviewed in previous sections of this report, children's exposure to pesticides occurs on a global scale. Children may be exposed from a variety of sources, including pesticide residues on food or in drinking water, dermal and oral contact with surfaces, and inhalation of volatile pesticides from residential and agricultural pest control.[1, 2] Children near farmed lands face higher exposure from pesticides tracked into homes, contact with farmworker family members and pesticide drift.[3, 4, 5] Despite widespread potential exposure, quantitative measures of child exposure to pesticides are limited and no assessment to date has estimated such exposure at the global level.

Given the challenges with biomonitoring in low- and middle-income countries (LMICs), metrics of agricultural pesticide use can provide a more readily available proxy for potential population exposure. The Global Pesticide Grids (PEST-CHEMGRIDS) data set was recently developed as the first global harmonized model of agricultural pesticide application.[6, 7] PEST-CHEMGRIDS provides estimates of pesticide application rates for the 20 most commonly applied pesticide active ingredients on 10 crops and crop classes at a resolution of 5 arc-minutes (approximately 10 km). The model was developed using spatial statistical methods, incorporating data from public pesticide inventories including the United States Geological Survey Pesticide National Synthesis Project (USGS/PNSP) and United Nations FAOSTAT pesticide database, along with global models of soil physical properties, hydroclimatic conditions, agricultural output and socioeconomic indices.

This analysis leveraged PEST-CHEMGRIDS to estimate global child populations at risk of potential exposure to pesticides applied on harvested land. While pesticide use data are an imperfect proxy for exposure, an assumption is made that children living in proximity to agricultural pesticide use are vulnerable to increased magnitude of exposure via inhalation (pesticide drift), contact with environmental pesticide residue, or occupational and take-home exposure in farmworker communities. This analysis does not consider children's exposure from dietary intake or from residential pesticide use.

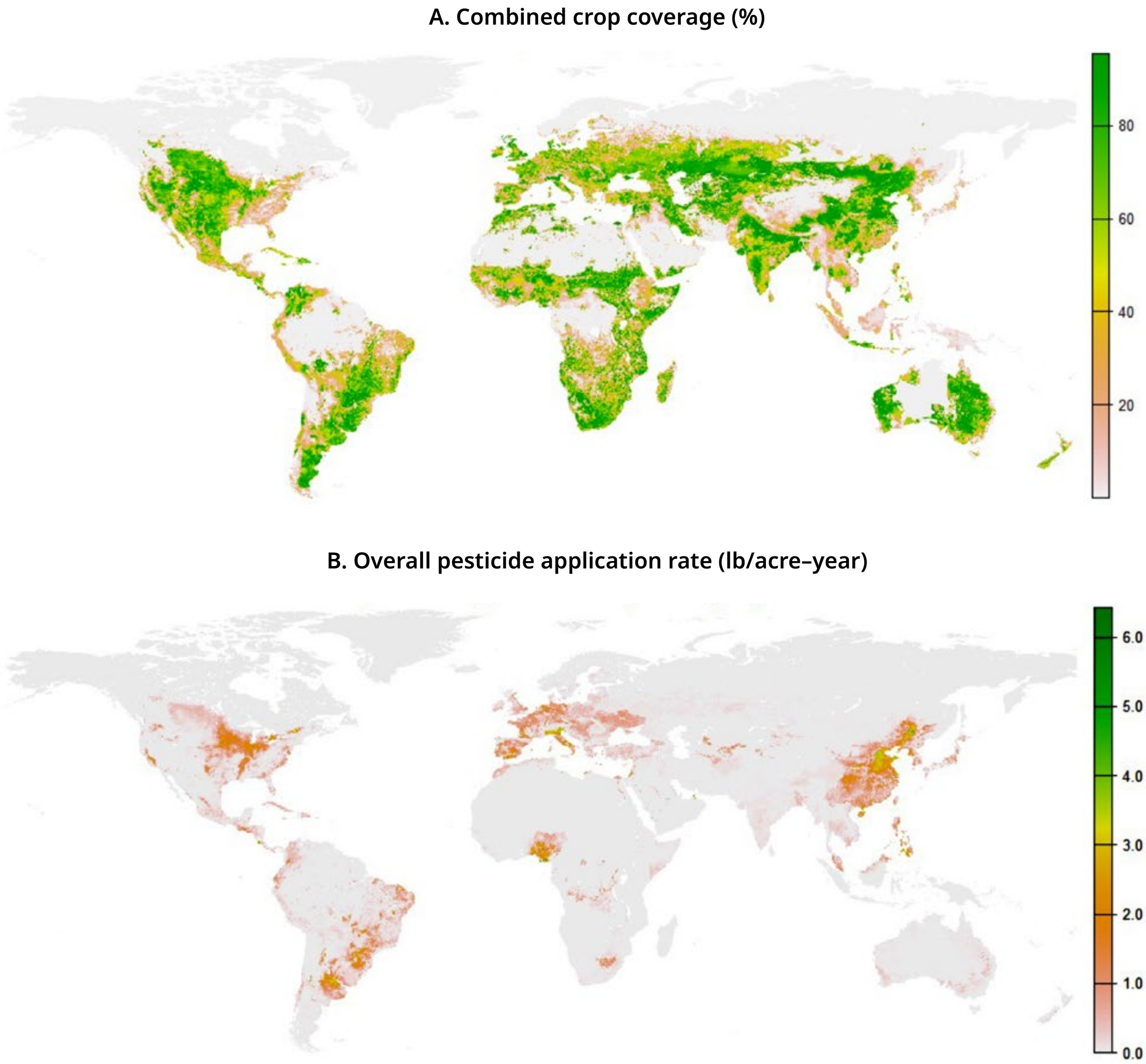
Methods

'Potential exposure' to 12 commonly applied pesticides among children aged 0–4 and 0–19 years was evaluated. PEST-CHEMGRIDS provides low and high estimates for application rates of each pesticide ingredient on each crop type in 2020. Crop-specific application rates for each pesticide active ingredient were combined to yield the overall application rate within each (~10×10 km) grid cell. The application rate for each pesticide was also summed to yield a combined application rate for all 12 index pesticides. PEST-CHEMGRIDS also includes quality index measures representing confidence in the estimates for each specific pesticide active ingredient on each crop type. An a priori decision was made to omit pesticide–crop combinations with a median quality index ≤0.5. None of the 12 index pesticides included in the analysis had median quality index below this threshold for any corresponding crops.

These data were merged with global population counts from Gridded Population of the World (GPW) Version 4,[8] adjusted to United Nations World Population Prospects (WPP) global estimates and country-specific age structures.[9] 'Potentially exposed populations of children' were determined by summing the global child population within grid cells meeting pre-specified exposure criteria and assumptions.

The exposure criteria were based on (a) the percentage of each cell area with harvested land to which the index pesticide was applied and (b) the magnitude of the application rate of the index pesticide on harvested land (*see Figure A3.1*). The scientific literature indicates that proximity to harvested land is associated with higher levels of pesticide biomarkers;[10] however, the specific relationships between crop cover, pesticide application rate and exposure risk are uncertain. Children's potential exposure under a range of exposure scenarios was therefore evaluated.

Figure A3.1 Global crop coverage (all crop types combined) and pesticide application rates (all active ingredients combined)



Source: Sherris, Allison. Global Crop Coverage (All Crop Types Combined) [Map] and Pesticide Application Rates (All Active Ingredients Combined) [Map]. Underestimated and Overlooked, UNICEF, 2025.

First, the potential exposure was evaluated under a 'base' scenario in which children were considered potentially exposed if they lived in grid cells with at least (a) 50 per cent harvested land and (b) an individual or combined pesticide application rate of at least one pound active ingredient per acre per year (lb per acre-year; 1 pound per acre = 1.1209 kg per hectare) on harvested land. The first criterion increases confidence that harvested land is in proximity to child populations within each (~10×10 km = ~10,000 hectares) grid cell. The second criterion was based on the recommended application rates of index pesticides on harvested land, which range from 0.5 lb per acre-year to 85 lb per acre-year (*see Table A3.1*). Pesticide application rates were based on 'high' estimates from PEST-CHEMGRIDS.

Table A3.1 Pesticide active ingredients and recommended application rates from US EPA pesticide labels (pounds active ingredient per acre per year)

Active ingredient	Approximate recommended application rate on crops (lb per acre-year)	Type
2,4-D	2.00	Herbicide
Acetochlor	3.00	Herbicide
Atrazine	2.50	Herbicide
Chlorpyrifos	4.00	Insecticide
Dicamba	2.00	Herbicide
Dichloropropene	85.00	Herbicide, nematicide
Diuron	6.40	Herbicide
Glufosinate	0.53	Herbicide
Glyphosate	0.75	Herbicide
Metolachlor	3.71	Herbicide
Paraquat	0.50	Herbicide
Pendimethalin	2.00	Herbicide

Note: Application rates for US EPA-regulated pesticides change regularly and can be checked at FederalRegister.gov.

To evaluate the influence of these assumptions on pesticide exposure estimates, estimates were compared under a range of harvested area thresholds (40 per cent, 50 per cent and 60 per cent) and application rate thresholds (0.2–1.5 lb per acre-year). The effect of using 'high' or 'low' application rate estimates provided by PEST-CHEMGRIDS was also explored. Finally, the numbers of 'potentially exposed' children living in rural areas, who are likely to live in closer proximity to harvested areas and have greater opportunity for exposure to pesticides applied on croplands, were determined. Rural areas were defined based on the Global Human Settlement Layer (GHSL) Settlement Model Grid.[11]

Findings

The pesticide active ingredient with the highest rate of potential exposure was glyphosate (*see Figure A3.2, Table A3.2*). Using PEST-CHEMGRIDS 'high' application rate estimates, 35.6 million children under age 5 (5.3 per cent of children in that age group) and 147 million children and adolescents (5.6 per cent) live in a grid cell with 50 per cent harvested land to which glyphosate is applied at a rate of least 1 lb per acre-year. Under different exposure thresholds, the estimated percentage of children exposed ranged from 0.3 per cent (cells with 60 per cent harvested land and application rates of at least 1.5 lb per acre-year) to 17.5 per cent (cells with 40 per cent harvested land and application rates of at least 0.2 lb per acre-year).

The pesticide ingredient with the second most common potential exposure was 1,3-dichloropropene, with an estimated 9.3 million children under age 5 (1.4 per cent) and 31.9 million children and adolescents under age 20 (1.2 per cent) potentially exposed (range: 0.8–5.5 per cent). The recommended application rate for 1,3-dichloropropene on crops is approximately 100-fold that of glyphosate at 85 lb per acre-year; 1,3-dichloropropene has higher average application rates but is used on a smaller area of harvested land than glyphosate. Other pesticide ingredients with measurable exposure included chlorpyrifos, diuron, paraquat, atrazine, acetochlor and metolachlor, with less than 5 per cent of children potentially exposed under all crop cover and application rate thresholds (*Figure A3.2*).

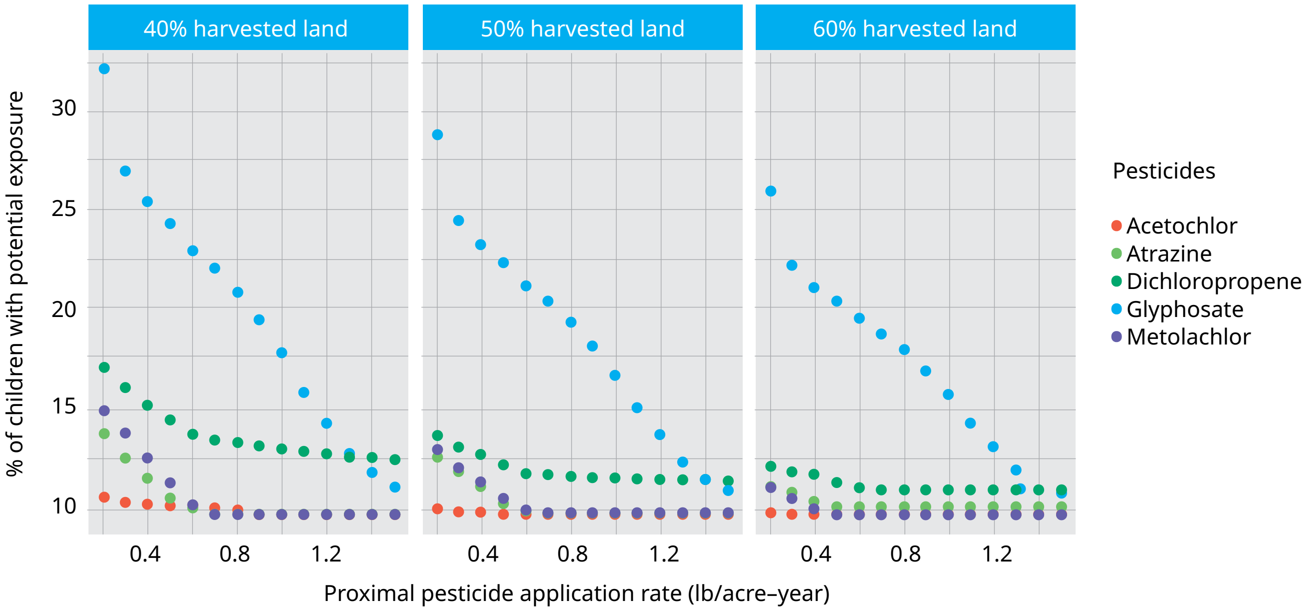
Table A3.2 Estimated population exposed under the 'base' exposure scenario (50 per cent harvested land with at least 1 lb per acre-year individual or combined pesticide active ingredient)

Pesticide	Children aged 0–4 years		Children and adolescents aged 0–19 years	
	All	Rural	All	Rural
2,4-D	0	0	0	0
Acetochlor	23,115 (<1%)	11,305 (<1%)	95,976 (<1%)	46,941 (<1%)
Atrazine	0	0	0	0
Chlorpyrifos	9,502 (<1%)	4,511 (<1%)	33,571 (<1%)	15,870 (<1%)
Dicamba	0	0	0	0
Dichloropropene	9,339,769 (1.4%)	4,874,757 (1.5%)	31,851,166 (1.2%)	16,494,418 (1.4%)
Diuron	603 (<1%)	579 (<1%)	2,137 (<1%)	2,054 (<1%)
Glufosinate	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Glyphosate	35,605,389 (5.3%)	10,759,194 (3.2%)	146,544,192 (5.6%)	44,412,169 (3.4%)
Metolachlor	0	0	0	0
Paraquat	4,988 (<1%)	2,783 (<1%)	17,596 (<1%)	9,755 (<1%)
Pendimethalin	0	0	0	0
Exposure to any individual pesticide active ingredient	44,357,694 (6.6%)	15,456,919 (4.6%)	175,916,633 (6.7%)	60,138,711 (4.8%)
Exposure to combined pesticide active ingredients	124,355,626 (18.5%)	53,406,164 (15.9%)	490,325,673 (18.8%)	205,969,792 (16.3%)

() percentage of all children and adolescents in the respective age group.

Figure A3.2 Estimated percentage of global child population (aged 0–4 years) potentially exposed to pesticide active ingredients applied to harvested land based on various thresholds for proximal individual pesticide application rates

As the threshold for what counts as harvested land increases, fewer areas meet the criteria for exposure — resulting in a smaller estimated number of exposed children.



Note: Estimates calculated using high application rate (APR) values from PEST-CHEMGRIDS and for all (i.e., urban and rural) children. Pesticides with exposure <1 per cent under all exposure scenarios are excluded.

Table A3.3 Potential exposure of children to combined pesticide active ingredients under three exposure scenarios

Exposure scenario	Number of children and adolescents (% global population)			
	Under 5		Under 20	
	All	Rural	All	Rural
Base 50% cropland; 1 lb/acre-year; high PEST-CHEMGRIDS APR rate	124 million (18.5%)	53 million (15.9%)	490 million (18.8%)	206 million (16.3%)
Conservative[A] 60% cropland; 1.5 lb/acre-year; low PEST-CHEMGRIDS APR rate	65 million (9.7%)	26 million (7.9%)	258 million (9.9%)	102 million (8.1%)
Least conservative 40% cropland; 0.2 lb/acre-year; high PEST-CHEMGRIDS APR rate	214 million (32%)	98 million (29%)	847 million (32%)	383 million (30%)

APR, pesticide application rate.

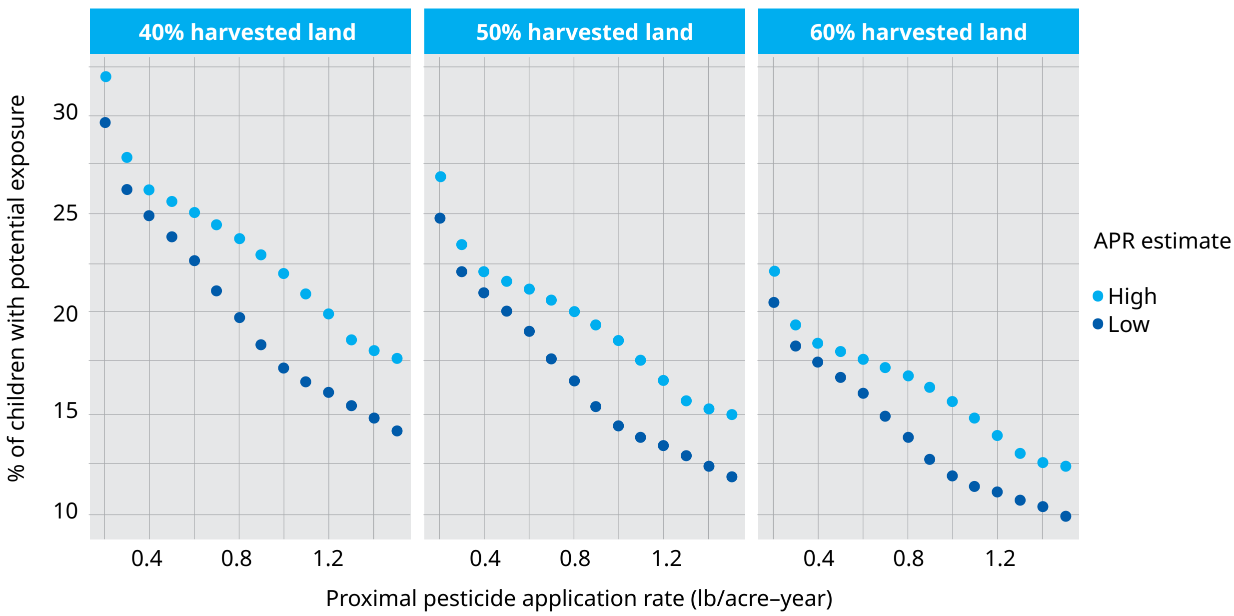
Note: [A]The conservative value required the highest APR to achieve the threshold of "exposure". PESTCHEM gives a high and a low estimate for each grid cell, so using the low estimate requires a "higher bar" to achieve this high APR.
1 lb/acre-year ~1.12 kg/ha-year; 1.5 lb/acre-year ~1.68 kg/ha-year; 0.2 lb/acre-year ~0.22 kg/ha-year.

Potential exposure to combined pesticide active ingredients was also evaluated (*Table A3.3*). Under the base exposure scenario, 124 million children under age 5 (18.5 per cent) and 490 million children and adolescents (18.8 per cent) were potentially exposed to pesticide active ingredients with a combined application rate of 1 lb per acre-year in grid cells with 50 per cent harvested land. The estimated global population of children and adolescents potentially exposed ranged from 258 million using more conservative estimates to 847 million using the least conservative exposure criteria; the comparative range for under-fives was 65 million to 214 million (*Table A3.3; Figure A3.3*).

However, the majority of this 'potentially exposed' population resides in urban areas. This likely reflects the coarse resolution of pesticide exposure grids; urban communities with crop coverage within 10 km may be considered exposed despite living in urban centres. We therefore evaluated the number of rural children 'potentially exposed', assuming that these children likely live in closer proximity to harvested land. The number of rural children under 5 years old with potential exposure ranged from approximately 26 million to 98 million under the different exposure scenarios; and for all children and adolescents the range was 102 million to 383 million (*Table A3.3*).

Figure A3.3 Estimated percentage of global child population (aged 0–4 years) potentially exposed to pesticides applied to harvested land based on various thresholds for proximal combined pesticide application rates, based on high and low PEST-CHEMGRIDS application rate estimates

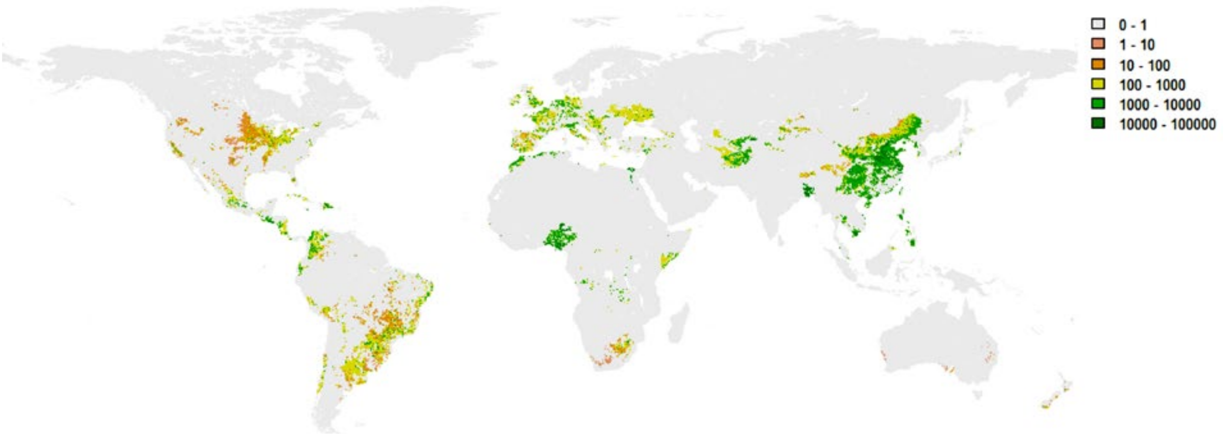
As the threshold for what counts as harvested land increases, fewer areas meet the criteria for exposure — resulting in a smaller estimated number of exposed children.



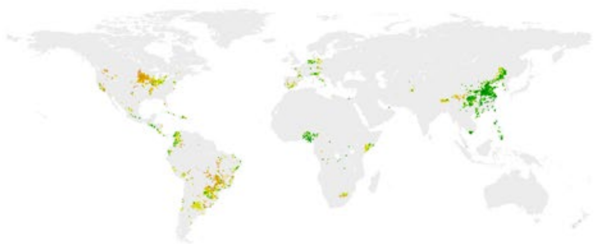
'Potentially exposed' populations were located throughout the Midwestern United States, Europe, South America, sub-Saharan Africa and Asia (*see Figure A3.4*). There was a high concentration of 'potentially exposed' populations in China, Bangladesh and Nigeria. In fact, over half of potentially exposed populations were located in China and South Asia.

Figure A3.4 Estimated number of children and adolescents (aged 0–19 years) potentially exposed to pesticides applied to harvested land based on various thresholds for proximal combined pesticide application rates

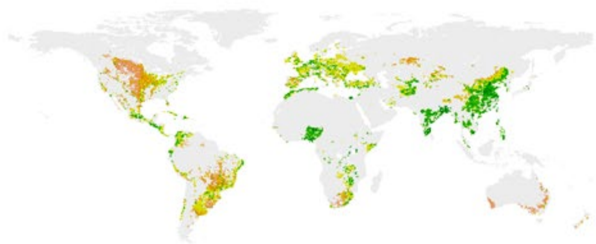
A. Base exposure scenario (50% harvested land; 1 lb per acre–year)



B. Most conservative (60% harvested land; 1.5 lb per acre–year)



C. Least coservative (40% charvested land; 0.2 lb per acre–year)



Note: Estimates calculated using high PEST-CHEMGRIDS application rate (APR) estimates for all (i.e., urban and rural) global children and adolescents.

Limitations

Researchers evaluated 'potential exposure' to pesticides based on proximity to pesticide application and pesticide application rates; this metric is a crude proxy that does not incorporate information on routes of exposure. Proximity to croplands with pesticide application may contribute to child exposure via inhalation (spray drift), contact with environmental pesticide residue, or occupational and take-home exposure in farmworker communities. Dietary exposure and residential pesticide use are likely important exposure sources that are not accounted for in our analysis.[12, 13, 14] Lifestyle factors (e.g., time spent outdoors, smoking), food intake (including organic food and self-production) and professional and housing characteristics (e.g., ventilation system, housing quality and pests, household cleaning practices and presence of a garden) also influence exposure to agricultural and domestic pesticides.

The PEST-CHEMGRIDS data are only available at a resolution of approximately 10 km. The location of applied pesticides within each cell (and therefore the proximity to child populations) is not known. Studies have generally identified higher levels of pesticide biomarkers among residents living proximal to agricultural lands relative to those living further away; however, the definition of proximity is variable and ranged from up to 250 m to up to 8 km in a recent review of the literature.[15] A recent meta-analysis found that the concentrations of pesticides in house dust decreased logarithmically with distance between home and treated fields.[16] The distances considered in the meta-analysis ranged from 3 m to 1,125 m, and the magnitude of the decrease was non-linear and varied according to pesticide type. Thus, children living within a 10 km grid cell with pesticide application may not be meaningfully exposed to the pesticides applied within that cell. On the other hand, our analysis underestimates potential exposure among populations in proximity to harvested land in grid cells not meeting our crop cover threshold criteria.

This analysis was limited to only the 12 most commonly applied pesticides (i.e. the pesticide ingredients applied on the most crop types), which may not represent the ingredients with the greatest application by mass. In particular, some fumigants with widespread global use on vegetable and fruit crops and generally high application rates are excluded (including metam potassium, metam sodium and petroleum oil). Specific pesticides that are used extensively in particular regions but which are not among the most commonly used globally are also not captured well in this analysis.

Agricultural drift and pesticide environmental fate may differ by pesticide ingredient (i.e., due to differences in volatility), mode of application, crop type, topography, season and meteorology.[17, 18] Active ingredients may also be applied in various formulations that can impact environmental fate and toxicity. Thus, the relationship between pesticide application and population exposure and health risk is not consistent across pesticides and regions.

There is also no standard pesticide application rate that can imply exposure to nearby populations. Current literature does not point to a consistent relationship between proximal pesticide application and biomarkers of exposure, as described above. We evaluate exposure for a range of application rates based on fractions of recommended pesticide application; however, the relationship between these rates and population exposure or health is not clear.

Conclusion

Estimation of children's global exposure to pesticides is incomplete, uncertain and limited in the extent of capturing exposure routes. In particular, estimates of global dietary exposure are not available. Furthermore, the PEST-CHEMGRIDS and population data were available only at annual temporal resolution, so we are unable to account for potential exposure among child populations with short-term or seasonal residence near agricultural pesticide application. As an initial estimation of the global exposure to commonly used agricultural pesticides via pathways related to proximity agricultural pesticide application, 26 million to 98 million children under age 5 and 102 million to 383 million children and adolescents living in rural areas were potentially exposed. Exposures to glyphosate and 1,3-dichloropropene were by far the most common. Estimates indicate rural population glyphosate exposures of 10.8 million children under age 5 and 44.4 million children and adolescents, and 4.9 million under age 5 and 16.5 million children and adolescents potentially exposed to 1,3-dichloropropene. These results provide an initial and coarse view of potential global pesticide exposure, suggesting large numbers of children potentially exposed. There is a need for more detailed investigations, including analysis of biomarkers of exposure, especially in LMICs, to better characterize exposure and potential health risks.

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Annex 4
Mechanisms in the global governance framework for pesticides

There are several mechanisms in the global governance framework for pesticides. Mechanisms can either directly or indirectly affect pesticide management. Direct mechanisms addressing pesticide management include international conventions, which are legally binding treaties created by the global community with the backing of the United Nations to support regulation of issues, such as hazardous pesticide use, that transcend national boundaries.[1]

Multiple international conventions exist for the regulation of hazardous chemicals and wastes throughout their life cycles.[2] However, the only binding global agreements to address pesticides in use are the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, and the Stockholm Convention on Persistent Organic Pollutants. According to Pesticide Action Network (PAN) Germany, which used data from the Stockholm and Rotterdam Conventions and the Montreal Protocol, together these cover only about 3 per cent of all pesticides on the market.[3] In addition, the Basel Convention concerns hazardous waste. Summaries of the major conventions and their pesticide-related actions and implications for children are provided in Table A4.1.

Additional legally binding conventions related to trade include: the World Trade Organization Sanitary and Phytosanitary Measures (SPS); the World Trade Organization Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS); and the Organisation for Economic Co-operation and Development Mutual Acceptance of Data (OECD-MAD).

Other direct mechanisms are not legally binding and are voluntary. Examples are included in *Table A4.3*.

Indicators and procedures for the evaluation of risk reduction achieved by both legally binding and voluntary mechanisms are inadequate overall.[4] For some conventions, there is evidence to support risk reduction from pesticide exposure, such as the decline in global DDT use as a result of the Stockholm Convention.[5] According to the World Health Organization (WHO) there is also evidence that suggests that bans of the most acutely toxic pesticides can prevent suicide deaths.[6] For instance, selected pesticide bans in Sri Lanka are estimated to have prevented 93,000 pesticide deaths over a 20-year period between 1995 and 2015.[7] Importantly, in the report, WHO notes that pesticide bans did not result in decreased crop yields in the respective countries.

Table A4.1 Legally binding direct mechanisms to address pesticide management

Instrument	Pesticide-related actions	Relevance to children
Rotterdam Convention	• Promotes shared responsibility and cooperative efforts among parties in international trade and environmentally sound use of certain hazardous pesticides[8] • Goal to support LMICs to better control imports of hazardous pesticides	• Reduction of hazardous pesticide imports to developing countries may reduce the quantity in use and, consequently, some harmful pesticide exposure for children
Stockholm Convention on Persistent Organic Pollutants (POPs)	• Global treaty that eliminates or restricts production, use and release of certain pesticides that remain intact and are widely distributed in the environment and which accumulate in humans and wildlife[9] • Examples of eliminated pesticides include endosulfan, aldrin and lindane; restricted pesticides include DDT[10]	• POPs are common contaminants of air, food and water, which children consume more of relative to their body weight than adults • POPs such as DDT can be contaminants of breastmilk
Basel Convention	• Aims to reduce hazardous waste generation and promote environmentally sound management of hazardous wastes • Restricts transboundary movements of hazardous wastes[11]	• Reduction of hazardous pesticide waste generation and transport may reduce environmental contamination and, therefore, some exposures for children via air, soil, food and water
Minamata Convention	• By the end of 2020, parties were required to cease the manufacture, import and export of many listed mercury-containing products, including mercury-containing pesticides[12]	• Reducing exposure to mercury is critical for children's health as mercury is a potent neurodevelopmental toxicant[13]
Montreal Protocol on Substances that Deplete the Ozone Layer	• Restricts certain applications of the pesticide methyl bromide, which is an ozone-depleting substance[14]	• Ozone layer protects children from ultraviolet radiation[15]
Kunming-Montreal Global Biodiversity Framework	• Commits parties to reducing the overall risk from pesticides and highly hazardous chemicals by at least half by 2030[16]	• Reduced risk will include reduced risk to children

There are also indirect legally binding and non-legally binding mechanisms in place for pesticide management. One indirect legally binding mechanism specifically related to children is the Worst Forms of Child Labour Convention, established in 1999.[17] This convention requires countries to eliminate the worst forms of child labour, including work that is likely to harm children's health, such as spraying pesticides.

Table A4.2 Legally binding international standards on occupational safety and health

Instrument	Pesticide-related actions	Relevance to children
Safety and Health in Agriculture Convention, 2001 (No. 184)[18]	• Recognizes the hazards posed by chemicals (including pesticides) in agriculture and aims to ensure the safe handling, storage and use of pesticides. Emphasizes the need for proper training, education and information dissemination regarding pesticide use to minimize risks to agricultural workers. Requires national system for chemical importation and regulation. Mandates compliance with safety standards. Provides for safe disposal of chemical waste.	• Indirectly addresses child safety by promoting safe working environments. Sets minimum age of 18 for hazardous agricultural work.
Occupational Safety and Health Convention, 1981 (No. 155)[19]	• Requires Member States to establish and implement national policies and programmes for occupational safety and health, which include regulations and measures related to the handling and use of chemicals and pesticides in various industries, including agriculture.	• Ensures the safety and health of adult workers in all sectors, including agriculture, and indirectly benefits children by promoting measures to create safer working environments and setting standards for occupational safety and health in workplaces where children may be employed.
Promotional Framework for Occupational Safety and Health Convention, 2006 (No. 187)[20]	• Provides a framework for promoting occupational safety and health practices at the national level. Encourages Member States to develop comprehensive strategies for improving safety and health in all sectors, which include measures related to the safe handling and use of chemicals and pesticides.	• Indirectly benefits children by promoting the creation of safer working environments for all workers, including children involved in hazardous occupations such as agriculture. Encourages Member States to address occupational safety and health issues comprehensively, which would include measures to protect child workers.

Table A4.3 Non-legally binding direct mechanisms to address pesticide management

Instrument	Pesticide-related actions	Relevance to children
International Code of Conduct on Pesticide Management	• Establishes voluntary standards of conduct for all public and private entities engaged in or associated with the management of pesticides.[21]	• Gives attention to vulnerable groups such as children. Standards related specifically to children include using containers that are not attractive to or easily opened by children and preventing the use of pesticides by and sale of pesticides to children.
International Code of Conduct on Pesticide Management – Guidelines on Highly Hazardous Pesticides (HHPs)	• Defines criteria to identify HHPs according to their acute toxicity, chronic health and environmental hazard classification and use situation. • Provides guidance to national or regional pesticide regulators wishing to address HHPs.[22]	• Banning HHPs as one of the mitigation options is protective of children's health and the environment, particularly in LMICs where resources may not be available to adequately manage risks.
Codex Alimentarius	• Establishes international food standards, guidelines and codes of practice that contribute to the safety, quality and fairness of the international food trade.[23] • Sets maximum residue levels (MRLs) for all food and animal feed.	• MRLs may reduce dietary exposures of pesticides. MRLs, however, do not factor in child vulnerabilities to pesticides and so may not be maximally protective.
Globally Harmonized System of Classification and Labelling of Chemicals (GHS)	• Aims to ensure that information on physical hazards and toxicity from chemicals is available during their handling, transport and use. • Provides a basis for harmonization of rules and regulations on chemicals at national, regional and worldwide levels.[24]	• Improved hazard communication elements, including labels and safety data sheets, may help to reduce pesticide exposure for children.
Strategic Approach to International Chemicals Management (SAICM) and its successor, the Global Framework on Chemicals – For a planet free of harm from chemicals and waste	• SAICM aimed at addressing HHPs with the common goal to eliminate the short- and long-term health and environmental impacts of HHPs, and the United Nation's fourth International Conference on Chemicals Management (ICCM) called for concerted action on HHPs. HHP risk reduction involves a set of policy provisions and recommendations under various frameworks and codes.[25] • In September 2023, the fifth meeting of the ICCM (ICCM5) adopted the Global Framework on Chemicals (GFC) as the successor instrument to the SAICM. Target A7 of the GFC commits stakeholders, including governments, to a path to phase out HHPs in agriculture. ICCM5 also adopted a resolution to establish a global alliance on HHPs to facilitate the HPP phase-out under Target A7.	• HHPs are considered an issue of concern under SAICM 2020 and beyond. Measures stipulated by SAICM and GFC may help to reduce future pesticide exposure and risk for children.
WHO pre-qualification of vector control products (VCPs)	• Process that assesses VCPs and public-health pesticide active ingredients to determine that they can be used safely and effectively and are manufactured to a high-quality standard.[26]	• Safe and effective vector control benefits children, who are vulnerable to morbidity and mortality from malaria and other vector-borne diseases.[27]

Children are part of a vulnerable group and, as such, they are individual rights holders who must be protected. While children are fully entitled to human rights, the United Nations has proclaimed that childhood is entitled to special care and assistance. After signing the United Nations Convention on the Rights of the Child in 1989, countries recognize 'the right of the child to the enjoyment of the highest attainable standard' and shall pursue full implementation of this right by 'taking into consideration the dangers and risks of environmental pollution'.[28] Harms caused by environmental pollution by pesticides prevent children from enjoying their rights.

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Annex 5
Methods of integrated pest management (IPM)

Preventive methods in IPM

Farmers are encouraged to apply preventive methods to avoid the build-up of pests, weeds and diseases, ensuring that they do not exceed established thresholds that represent economic losses. Preventive measures include the selection of pest- and disease-resistant crops or livestock and the avoidance of seed-borne diseases and weeds by using certified seed, avoiding crop or livestock stresses through proper husbandry – for example, by providing the correct nutrients, watering and space. Preventive measures will ensure that the farm promotes effective pest regulation by maintaining natural enemies such as predatory wasps and beetles, or seed-eating ants.[1]

Figure A5.1 Components of integrated pest management indicating necessary prerequisites for curative actions

Preventive actions

Maintains farm resistance and resilience against pests and weeds

- Seed quality
- Host plant resistance
- Promoting natural enemies
- Farm hygiene
- Soil health
- Plant/livestock husbandry
- Diversified habitats
- Physical barriers to pests
- Biological control
- Mulching
- Harrowing/soil preparation
- Trapping

Monitoring and decision support

Assesses farm health and requirements for action

- Establishing threshold pest/weed densities
- Weather-based decision support systems
- Livestock condition tables
- Crop colour indices
- Field monitoring/sampling
- Pheromone trapping
- Yellow sticky traps
- Certification and standards

Curative actions

Only applied as directed by decision support tools and monitoring

- Chemical pesticide applications
- Biopesticide applications
- Biological control
- Treatment of affected livestock
- Washing affected plant/livestock
- Hand weeding
- Removal of affected plants/branches
- Burning/steaming/physical removal of weeds

Curative methods in IPM

Curative methods are applied only if pests or weeds approach the threshold for economic damage (indicated by monitoring the crop or livestock). These can include chemical pesticides, but chemicals can also be avoided by using a range of alternative methods. Alternatives include the timely application of botanical or microbial biopesticides. Otherwise, farmers can use less toxic substitutes instead of toxic chemicals to reduce their risk of poisoning and environmental contamination.

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Annex 6
Additional resources on pesticides and children's health

Online learning opportunities

Rotterdam Convention

- The Rotterdam Convention website is a vital resource for understanding how countries around the world are working together to promote the safe trade and use of hazardous chemicals and pesticides.
<https://www.pic.int/>

From FAO

- E-learning course series *End Child Labour in Agriculture:* Designed to raise awareness and build knowledge among agricultural stakeholders about the importance of addressing child labour in agriculture, including livestock, forestry, fisheries and aquaculture
<https://elearning.fao.org/course/view.php?id=1021>

- FAO, E-learning – *Pesticide management and child labour prevention*, 2020: Available in English, French, Spanish, Russian, Arabic
<https://elearning.fao.org/course/view.php?id=299>

- FAO and ILO, *Protect Children from Pesticides: Visual Facilitator's Guide:* Helps agricultural extension workers, rural educators, labour inspectors, and producer organizations teach farmers and their families how to identify and minimize risks at home and on the farm. It also instructs learners on how to recognize and respond to signs of toxic exposure
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- FAO, *Protect Children and Young Workers from Occupational Safety and Health Risks in Agriculture*, 2022
<www.fao.org/documents/card/en/c/cb7512en>

From UNICEF–WHO

- Introductory Course on Children's Environmental Health: This interactive course has been developed from the WHO training package on children's environmental health for the health sector.[1] It is a comprehensive set of internationally harmonized and peer-reviewed materials on the most relevant and pressing issues in children's environmental health. Participants will increase their capacity to recognize, prevent, diagnose and manage children's conditions related to an array of environmental threats, including pesticides
<https://ceh.unicef.org/introduction-childrens-environmental-health-course>

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