

Beyond Crop-Specific Restrictions: WHY PAKISTAN NEEDS A COMPREHENSIVE BAN ON CHLORPYRIFOS AND A TRANSITION TO AGROECOLOGY



By Nasira Habib

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Needs a Comprehensive
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Transition to Agroecology**

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*Cover: Garlic harvested
in school garden.*

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Introduction

Chlorpyrifos is widely used in Pakistan's agriculture and is also marketed for household insect control and termite management in residential environments. Despite growing international restrictions on the pesticide due to its neurotoxicity and environmental risks, imports and use remain significant. Trade data indicate that in May 2023 alone, Pakistan imported more than 16 tons of chlorpyrifos 40 % EC formulation and over 1,200 litres of formulations containing chlorpyrifos combined with cypermethrin (Volza, 2023).

Chlorpyrifos is an organophosphate insecticide widely used on major crops, including cotton, rice, vegetables and fruits for insect control. Although crop-wise data on its consumption are not publicly available, pesticide residue studies confirm its presence in a wide variety of crops across the country. These findings suggest that chlorpyrifos continues to be widely applied across Pakistan's agricultural systems. While chlorpyrifos is classified as an organophosphate insecticide, it has also been recognized as a persistent organic pollutant (POP) due to its persistence, long-range environmental transport, and harmful impacts on human health and the environment. In May 2025, the Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants agreed to list chlorpyrifos under Annex A, requiring its global elimination, with limited time-bound exemptions for certain specific uses.

Chlorpyrifos Use in Pakistan's Cropping Systems

Cotton Production Systems

Cotton is widely recognised as the largest consumer of pesticides in Pakistan. Sectoral assessments indicate that approximately 60–80 % of total pesticide use in the country occurs in cotton production systems, largely due to high insect pest pressure from bollworms, whiteflies and leafhoppers (Competition Commission of Pakistan, 2025; PACRA, 2021). Because chlorpyrifos is a commonly registered broad-spectrum insecticide used for controlling these pests, cotton production likely represents the largest share of national chlorpyrifos use.

Although official crop-wise pesticide statistics are not disaggregated, multiple scientific studies confirm the presence of chlorpyrifos residues in cotton-growing environments. Soil surveys conducted in Nawabshah (Sindh) detected chlorpyrifos in 16 of 19 top-soil samples, with a mean concentration of 0.486 mg kg^{-1} (Anwar, Ahmad, & Tahir, 2012). Monitoring studies in Punjab's cotton–wheat cropping systems similarly reported frequent contamination with chlorpyrifos alongside other insecticides (Rafique, Tariq, & Ahmed, 2016).

Additional microbiological studies provide further evidence of heavy pesticide exposure in cotton soils. Researchers have isolated chlorpyrifos-resistant bacterial strains from agricultural soils (Ajaz et al., 2005), and indigenous *Bacillus* strains capable of degrading high concentrations of chlorpyrifos have been recovered from contaminated cotton fields (Farhan

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et al., 2021). The presence of pesticide-degrading microbial populations suggests sustained environmental exposure to chlorpyrifos in these agroecosystems.

Together, these studies indicate that chlorpyrifos has been extensively used in cotton cultivation and that residues persist in soil ecosystems, with potential implications for environmental and human health.

Vegetable and Fruit Production

Chlorpyrifos is also widely used across vegetable and fruit crops in Pakistan. Although crop-wise pesticide use statistics are not available, residue monitoring studies reveal its presence in numerous vegetables.

Talat et al. (2023) reported high chlorpyrifos residue levels in cauliflower and brinjal (eggplant) samples. Approximately 65% of the cauliflower samples exceeded the maximum residue limits (MRLs) established by both the European Union and the Codex Alimentarius Commission, while 20% of the brinjal samples exceeded the EU limits. The researchers also conducted a dietary exposure risk assessment, estimating the amount of pesticide consumers could ingest from eating these vegetables. They found that consuming contaminated cauliflower could result in acute exposure to chlorpyrifos and lambda-cyhalothrin exceeding 200% of the Acute Reference Dose (ARfD)—the maximum amount considered safe to consume in a single meal or over one day, as established by the FAO/WHO Joint Meeting on Pesticide Residues. These findings raise concerns about potential health risks, particularly for children and other vulnerable populations.

Similarly, Alvi et al. (2024) detected chlorpyrifos residues in multiple vegetables and fruits, including okra, brinjal, spinach, cabbage, cauliflower, guava, and citrus, sold in wholesale markets in the Lahore region of Punjab, Pakistan.

In another study conducted in northern Pakistan, 38 % of peach samples from Swat and Peshawar (Khyber Pakhtunkhwa) exceeded EU residue limits for chlorpyrifos (Jan et al., 2022).

Chlorpyrifos Use in Paddy Systems

Chlorpyrifos has also been widely used in rice cultivation to control chewing and sucking pests such as rice stem borers and leaf-feeding caterpillars. In some cases, it has also been used in grain storage against insect infestations.

Because rice is grown in water-logged paddy systems, pesticide applications can facilitate the movement of residues into soils, irrigation water and aquatic ecosystems.

Residue studies conducted in Kasur, Sheikhpura, and Nankana Sahib (Punjab) detected chlorpyrifos concentrations in basmati rice exceeding maximum residue limits (Hamid et al., 2020).

A large international study analysing 306 rice samples from multiple countries reported that rice samples originating from Pakistan contained among some of the highest overall levels of pesticide contamination among the countries analysed. Dietary risk assessments indicated that chlorpyrifos, profenofos and lambda-cyhalothrin were major contributors to estimated health risks associated with rice consumption (Kong et al., 2026).

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Concerns about pesticide residues in exported rice have intensified in recent years, as several consignments from Pakistan were rejected by importing countries due to excessive pesticide residues. Chlorpyrifos residues have been identified as one of the major causes of shipment rejections (Wattoo & Ahmad, 2024).

In response, Pakistani regulators introduced stronger control measures in 2025, prohibiting the use of several pesticides—including chlorpyrifos—in rice cultivation to reduce residue levels and improve compliance with international food-safety standards.

Non-Agricultural Uses: Household and Termite Control

Chlorpyrifos is not limited to agricultural pest control. In Pakistan, it is also marketed for household pest management and termite treatment.

Commercial formulations containing chlorpyrifos are sold for controlling ants, cockroaches, fleas, bedbugs, and other domestic pests. Similar products have historically been used internationally in residential pest control.

Chlorpyrifos is also widely used in termite management, particularly for soil treatments around buildings and structures. Retail agrochemical listings show chlorpyrifos formulations marketed for termite control, along with other pests such as borers and bugs.

Because these applications occur in residential environments, they introduce additional exposure pathways for households through contamination of indoor air, dust, and surfaces. This is particularly concerning for children, who are more likely to come into contact with contaminated floors and household surfaces and are among the most vulnerable to the adverse health effects of chlorpyrifos exposure.

Environmental Implications of Chlorpyrifos Use

Soil Contamination

Agricultural soils represent a primary reservoir for pesticide accumulation because they receive repeated applications during crop production. Studies conducted in Pakistan have detected chlorpyrifos residues in soils from major agricultural regions, particularly in cotton production systems (Anwar et al., 2012; Rafique et al., 2016).

Soil contamination can have important ecological consequences. Chlorpyrifos exposure may alter microbial community composition and inhibit soil enzyme activity, potentially affecting nutrient cycling and soil fertility (Farhan et al., 2021).

Soil invertebrates such as earthworms and arthropods may also be exposed to pesticide residues through direct contact with contaminated soil particles.

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Because these organisms play essential roles in soil structure formation and nutrient dynamics, their decline could negatively affect soil ecosystem functioning.

Water Contamination and Aquatic Ecosystems

Pesticide applications in agricultural fields can lead to contamination of irrigation water, surface water, and groundwater through runoff and leaching.

Monitoring studies conducted in Pakistan have detected organophosphate pesticides, including chlorpyrifos, in surface water and groundwater near agricultural areas (Arain et al., 2018; Javaid et al., 2023).

Chlorpyrifos is highly toxic to aquatic organisms, including fish, crustaceans, and aquatic insects. Even low concentrations can disrupt nervous system function in aquatic species because the pesticide inhibits acetylcholinesterase.

Chlorpyrifos Residues in Meat and Milk

A study analysing pesticide contamination in cattle meat and organs from agricultural areas around Faisalabad (Punjab) detected chlorpyrifos residues in muscle and organ samples. About 13 % of muscle samples contained chlorpyrifos residues, indicating contamination of livestock raised near pesticide-sprayed fields (Muhammad et al., 2010).

Monitoring studies of dairy farms in Faisalabad detected pesticide residues in cattle milk, including chlorpyrifos, with approximately 40 % of samples contaminated and mean chlorpyrifos concentrations of 0.072 ppm, indicating that livestock feeding in agricultural areas may lead to pesticide contamination of milk (Muhammad et al., 2012).

Monitoring of milk samples from cows, buffalo, goats, sheep, and camels collected from dairy farms in the Lahore region detected residues of several pesticides, including the organophosphate insecticide chlorpyrifos, in approximately half of the analysed samples (Shahzadi et al., 2013).

Human Health Implications

The presence of chlorpyrifos residues in food and fibre crops, meat, milk, and agricultural environments raises serious concerns about human health in rural and urban communities. Although agricultural workers and rural communities often experience the most direct exposure to pesticides, the presence of chlorpyrifos residues in food crops, meat, milk and aquatic products indicates that the risks extend beyond farming areas to urban populations. Food produced in agricultural regions is transported through national food distribution systems and consumed widely in cities. Consequently, pesticide residues present in vegetables, fruits, grains, milk, meat and fish may contribute to dietary exposure among urban consumers. Studies of pesticide residues in food commodities have shown that chlorpyrifos residues can persist through harvesting, storage, and transport processes and may remain detectable in food sold in wholesale markets and retail outlets in urban areas.

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Urban residents may also be exposed through environmental pathways. Pesticide residues can contaminate rivers, canals, and groundwater used as drinking water sources for cities. In addition, chlorpyrifos applied in agricultural fields can be transported beyond the target area through spray drift and wind, with airborne pesticide droplets, dust, and particles capable of travelling several kilometres under suitable weather conditions. This may expose people well beyond the application site, including residents, workers, commuters, and children, who are particularly vulnerable to the adverse health effects of chlorpyrifos. Supporting this concern, a study conducted in Lahore identified chlorpyrifos and diazinon as the most prominent organophosphate insecticides in airborne dust and found evidence of exposure among both rural and urban residents, demonstrating that airborne transport can contribute to human exposure beyond the sites where pesticides are applied (Waheed et al., 2017). Chlorpyrifos has also historically been marketed for household pest control and termite treatment, creating potential indoor exposure through contaminated dust and surfaces. These multiple exposure pathways indicate that pesticide contamination originating in agricultural production systems can affect the entire food supply chain and urban living environments. Therefore, the public health implications of chlorpyrifos use extend beyond rural farming communities and may affect the broader population through dietary, environmental, and residential exposure pathways (Eaton et al., 2008; WHO, 2019; PAN International, 2024).

Chlorpyrifos is an organophosphate insecticide that exerts toxicity primarily through inhibition of acetylcholinesterase, an enzyme essential for normal nerve transmission. When this enzyme is inhibited, acetylcholine accumulates in the nervous system, causing overstimulation of nerve cells and a range of neurological symptoms.

Acute poisoning can produce headaches, dizziness, nausea, excessive salivation, respiratory distress, muscle weakness, seizures, and, in severe cases, death (WHO, 2019; PAN International, 2024).

Beyond acute toxicity, chronic exposure to lower concentrations of chlorpyrifos has been associated with neurological impairment, developmental toxicity, endocrine disruption and immune system effects. Epidemiological studies indicate that exposure during pregnancy may interfere with fetal brain development and has been associated with reduced birth weight and impaired cognitive development in children (Rauh et al., 2012).

Occupational Exposure Among Pesticide Sprayers

Agricultural pesticide applicators represent one of the most highly exposed groups. In Pakistan, pesticides are commonly applied using manual backpack sprayers or tractor-mounted sprayers, often without adequate protective equipment.

During pesticide mixing, loading, and spraying, workers may be exposed through inhalation of spray aerosols, dermal contact with concentrated formulations, and contamination of clothing and equipment.

Studies examining pesticide exposure in Pakistan report frequent health symptoms among agricultural workers, including headaches, dizziness, respiratory irritation, and neurological disturbances associated with organophosphate exposure (Tariq et al., 2007; Khan et al., 2019).

Beyond acute toxicity, chronic exposure to lower concentrations of chlorpyrifos has been associated with neurological impairment, developmental toxicity, endocrine disruption and immune system effects.

Exposure Among Women Agricultural Workers

Women represent a substantial but often overlooked component of the agricultural labour force in Pakistan. In many cropping systems—including cotton, rice, vegetables and fruit orchards—women carry out labour-intensive activities such as transplanting rice seedlings, picking pesticide-treated cotton, harvesting wheat, collecting vegetables and harvesting fruits. These tasks frequently take place shortly after pesticide spraying, increasing the likelihood of dermal exposure to pesticide residues on plant surfaces and soil (Tariq et al., 2007; FAO, 2018).

Research conducted among female cotton pickers in Pakistan has demonstrated measurable exposure to organophosphate pesticides. Studies analysing blood cholinesterase levels among cotton field workers in cotton-growing areas of southern Punjab reported significant reductions in cholinesterase activity among exposed workers, indicating exposure to anticholinesterase pesticides such as organophosphates (Khan et al., 2000; Tahir et al., 2012). In one exposure-assessment study comparing female cotton pickers with non-pickers, cholinesterase activity in exposed workers declined markedly during the harvesting season, confirming biochemical evidence of pesticide exposure.

Additional biomonitoring studies of pesticide-exposed farmers in Pakistan have reported altered biochemical indicators—including reduced butyrylcholinesterase activity and elevated liver enzyme levels—consistent with chronic exposure to organophosphate insecticides (Shahzad et al., 2015). Surveys of agricultural workers have also documented common health symptoms associated with pesticide exposure, including skin and eye irritation, headaches, dizziness, and fatigue, particularly among workers involved in cotton harvesting and pesticide-treated fields (Tariq et al., 2007).

Women may also be exposed through domestic and farm-management activities. In many rural households, women participate in mixing pesticide solutions, washing pesticide-contaminated clothing, cleaning spraying equipment, and storing pesticide containers, creating additional exposure pathways through inhalation, dermal absorption, and accidental ingestion.

Reproductive Health Risks for Women

Chlorpyrifos exposure may have important implications for women's reproductive health. Organophosphate pesticides can disrupt hormonal regulation and interfere with reproductive processes.

Epidemiological studies have linked pesticide exposure with menstrual irregularities, reduced fertility, and adverse pregnancy outcomes (Bretveld et al., 2006).

These risks are particularly relevant in agricultural communities where women of reproductive age are frequently exposed to pesticides through both field labour and household pesticide handling. Because many women continue agricultural work during pregnancy, exposure during critical periods of fetal development may occur. Exposure during pregnancy may also affect fetal development and increase the risk of developmental disorders in children (Rauh et al., 2012).

Chlorpyrifos exposure may have important implications for women's reproductive health.

Health Hazards of Chlorpyrifos Exposure in Women

Type of Exposure	Health Effects in Women	Biological Mechanism	Key References
Acute exposure	Headache, dizziness, nausea, vomiting	Inhibition of acetylcholinesterase , leading to accumulation of acetylcholine and overstimulation of the nervous system	Eaton et al., 2008
	Muscle weakness, tremors, excessive sweating and salivation	Cholinergic overstimulation affecting neuromuscular function	WHO, 2019
	Respiratory distress and breathing difficulty	Disruption of nerve signals controlling respiratory muscles	EPA, 2020
	Skin and eye irritation during spraying or field work	Dermal absorption and mucosal exposure to pesticide formulations	Tariq et al., 2007
Chronic exposure	Menstrual irregularities and hormonal disruption	Endocrine-disrupting effects of organophosphate pesticides	PAN International, 2024
	Reduced fertility and reproductive disorders	Interference with reproductive hormones and ovarian function	Eaton et al., 2008
	Adverse pregnancy outcomes (miscarriage, low birth weight)	Developmental toxicity and placental transfer of pesticide metabolites	Rauh et al., 2011
	Increased risk of fetal developmental disorders	Prenatal neurotoxicity affecting fetal brain development	Bouchard et al., 2011
	Long-term neurological symptoms (memory problems, fatigue)	Chronic inhibition of acetylcholinesterase and neurotoxicity	WHO, 2019

Exposure Risks for Children in Farming Communities

Children living in agricultural households may face significant exposure risks. Pesticides are often stored inside homes or in nearby storage spaces, increasing the potential for accidental exposure. Children may also accompany parents to agricultural fields or play in areas where pesticides have recently been applied.

However, pesticide exposure is not limited to rural farming communities. Urban children may also be exposed through the food supply chain, as pesticide residues present in fruits, vegetables, grains, milk, and other food products produced in agricultural areas are transported and sold in urban markets. Studies have shown that pesticide residues can persist in food commodities through harvesting, storage, and distribution processes, creating dietary exposure pathways for children living in cities. In addition, chlorpyrifos and other insecticides have historically been used for household pest control and termite treatment in residential buildings, potentially exposing urban children through contaminated indoor air, dust, and surfaces.

Children are particularly vulnerable to pesticide exposure because their nervous systems are still developing and their metabolic capacity to detoxify chemicals is limited. They also consume more food and water relative to their body weight and frequently engage in hand-to-mouth behaviour, which can increase ingestion of contaminated dust or soil. Research indicates that early-life exposure to chlorpyrifos may lead to developmental delays, impaired motor function, and cognitive deficits (Rauh et al., 2012; Shelton et al., 2014). Because of these risks, the Pesticide Action Network International

has classified chlorpyrifos as a Highly Hazardous Pesticide due to its developmental neurotoxicity and risks to children (PAN International, 2024).

Health Hazards of Chlorpyrifos Exposure in Children

Type of Exposure	Health Effects in Children	Biological Mechanism	Key References
Acute exposure	Nausea, vomiting, headache, dizziness	Inhibition of acetylcholinesterase , causing accumulation of acetylcholine in the nervous system	Eaton et al., 2008
	Muscle twitching, tremors, excessive salivation, sweating	Overstimulation of cholinergic nerve receptors	WHO, 2019
	Respiratory distress and difficulty breathing	Paralysis of respiratory muscles due to nervous system disruption	EPA, 2020
	Seizures, loss of consciousness in severe cases	Severe cholinergic toxicity affecting brain function	WHO, 2019
Chronic exposure	Reduced IQ and impaired cognitive development	Developmental neurotoxicity affecting brain development during pregnancy and early childhood	Rauh et al., 2011
	Attention deficit and behavioural disorders	Disruption of neurotransmitter systems in developing brain	Bouchard et al., 2011
	Developmental delays and impaired motor skills	Neurotoxic effects on central nervous system development	Eaton et al., 2008
	Increased risk of autism spectrum disorders and learning difficulties	Prenatal exposure affecting fetal brain development	Shelton et al., 2014
	Endocrine disruption and growth effects	Interference with hormone regulation during development	PAN International, 2024

Global Response to the Hazards of Chlorpyrifos

More than forty countries have now banned or severely restricted chlorpyrifos due to its documented neurodevelopmental toxicity and environmental persistence. Regulatory authorities in these countries have concluded, based on accumulating toxicological and epidemiological evidence, that exposure to chlorpyrifos can adversely affect the developing nervous system, particularly in foetuses, infants and young children. Concerns have also been raised about its broader ecological impacts, including contamination of soil and water resources and toxicity to pollinators, aquatic organisms and other beneficial species that support ecosystem functioning. These regulatory decisions reflect a growing international consensus that the continued use of chlorpyrifos poses unacceptable risks to human health, biodiversity and environmental sustainability, and that safer and more sustainable pest-management approaches are both necessary and achievable.

Global Regulatory Status of Chlorpyrifos

1. Complete Ban (All agricultural uses prohibited)

Country / Region	Year	Notes
European Union (27 countries)	2020	Approval not renewed; banned across all member states
Austria	2020	EU ban
Belgium	2020	EU ban
Bulgaria	2020	EU ban
Croatia	2020	EU ban
Cyprus	2020	EU ban
Czech Republic	2020	EU ban
Denmark	2020	Earlier national restrictions
Estonia	2020	EU ban
Finland	2020	EU ban
France	2020	EU ban
Germany	2020	EU ban
Greece	2020	EU ban
Hungary	2020	EU ban
Ireland	2020	EU ban
Italy	2020	EU ban
Latvia	2020	EU ban
Lithuania	2020	EU ban
Luxembourg	2020	EU ban
Malta	2020	EU ban
Netherlands	2020	EU ban
Poland	2020	EU ban
Portugal	2020	EU ban
Romania	2020	EU ban
Slovakia	2020	EU ban
Slovenia	2020	EU ban
Spain	2020	EU ban
Sweden	2020	Never approved earlier
United Kingdom	2016	National ban before EU exit
Switzerland	2020	Ban aligned with EU risk assessment
Norway	2020	Ban following EU evaluation
Thailand	2020	National prohibition on production, import and use
Sri Lanka	2022	National ban on agricultural use
Vietnam	2021	Agricultural ban
Chile	2021	Ban on agricultural use

Colombia	2022	National ban
Peru	2021	Ban on use
Argentina	Partial national bans (some provinces)	Increasing restrictions
Nicaragua	National prohibition	
Nepal	2024	Ban on highly hazardous pesticides including chlorpyrifos

2. Agricultural Ban but Some Non-Agricultural Uses Allowed

Country	Status	Notes
Malaysia	Agricultural ban (2023)	Public health uses allowed
United States (state-level bans)	Agricultural bans in some states	California, Hawaii, Maryland, New York, Oregon
Singapore	Termite control banned since 2009	
South Africa	Residential use banned since 2010	
Canada	Most residential uses banned; strong restrictions	
Australia	Household uses banned; agricultural use restricted	

3. Crop-Specific Restrictions

Country	Restriction
Pakistan	Ban on chlorpyrifos in rice cultivation (2025)
United States (federal)	Agricultural use still allowed on limited crops after court rulings
Japan	Strict limits and reduced agricultural uses

Policy Implications: The Case for a Comprehensive Ban on Chlorpyrifos

The scientific evidence reviewed in this paper indicates that chlorpyrifos contamination occurs across multiple environmental compartments in Pakistan, including agricultural soils, irrigation water, groundwater, and food crops. Residues have been documented in rice, vegetables, fruits, soil, and water systems, while occupational exposure among agricultural workers and environmental exposure among rural communities have also been reported. These findings demonstrate that the impacts of chlorpyrifos are not confined to a single crop or production system but instead extend across agricultural landscapes and food systems. Consequently, regulatory measures that restrict chlorpyrifos use only in rice cultivation are unlikely to adequately protect human health and the environment.

A crop-specific ban addresses only a narrow portion of the exposure pathways associated with this pesticide. Chlorpyrifos is widely used in Pakistan in multiple cropping systems, including cotton, vegetables, fruit orchards, and other field crops. Agricultural workers who mix and apply

pesticides are exposed regardless of which crop is being treated, and women agricultural workers may encounter residues while picking cotton, transplanting rice, harvesting wheat, or harvesting fruits and vegetables. Because pesticide exposure occurs through contact with sprayed crops, contaminated soil, spray drift, and pesticide handling, restricting chlorpyrifos in a single crop does not eliminate the occupational exposure risks faced by farm workers.

Similarly, environmental contamination resulting from chlorpyrifos use is not limited to the fields where it is applied. Chlorpyrifos residues can persist in soils and move into irrigation water and groundwater through runoff and leaching, affecting aquatic ecosystems, wildlife, and drinking water sources. In addition, chlorpyrifos can be transported through the atmosphere over long distances, contaminating environments far from where it was originally applied. The Arctic Monitoring and Assessment Programme (AMAP) has reported chlorpyrifos residues in surface waters of the Bering and Chukchi Seas, as well as in Arctic air, snow, ice, fog, fish, and lakes in Alaska and northern Canada, demonstrating its capacity for long-range environmental transport (AMAP, 2016; Hung et al., 2016). These findings have contributed to international concern over the global dispersal of chlorpyrifos and support proposals to consider the pesticide under the Stockholm Convention on Persistent Organic Pollutants (AMAP, 2016). Therefore, continued use of chlorpyrifos in other crops may still contribute to contamination of water bodies, agricultural landscapes, and distant ecosystems, undermining the effectiveness of crop-specific regulatory measures.

Chlorpyrifos can also travel long distances to remote areas far from its source. The Arctic Monitoring and Assessment Program reported the presence of chlorpyrifos in a number of locations:

Surface water, ice, & fog from the Bering & Chukchi Sea. Alaskan snow and fish from Alaskan parks

Arctic & subarctic Canadian lakes This contamination from transport has driven proposals to consider chlorpyrifos for global elimination under the Stockholm Convention on Persistent Organic Pollutants. From PAN North America

A crop-specific restriction also fails to address non-agricultural uses of chlorpyrifos. Household use introduces additional exposure risks for families, particularly children, through indoor contamination of air, dust, and surfaces. When pesticides are used inside homes or stored within household environments, exposure may become continuous and difficult to control. Protecting public health, therefore, requires addressing all potential exposure pathways rather than limiting regulatory action to agricultural uses in a single crop.

The global regulatory trend further supports the need for a comprehensive approach. Many countries have moved toward complete bans on chlorpyrifos following extensive scientific evidence of its neurotoxicity and developmental risks. These decisions reflect a precautionary approach in which pesticides that pose significant risks to human health—particularly to children and pregnant women—are removed from the market rather than restricted to specific uses. In 2025, the Conference of the Parties (COP) to the Stockholm Convention on Persistent Organic Pollutants adopted Decision SC-12/9 to list chlorpyrifos in Annex A of the Convention, with time-limited specific exemptions. Annex A requires Parties to eliminate the production and use of listed chemicals, except where specific exemptions have been registered in accordance with Article 4 of the Convention. The decision therefore

Protecting public health, therefore, requires addressing all potential exposure pathways rather than limiting regulatory action to agricultural uses in a single crop.

represents a legally binding global commitment to phase out and ultimately eliminate chlorpyrifos while allowing limited, temporary exemptions where suitable alternatives are not yet available (Stockholm Convention, 2025).

In Pakistan, the recent decision to ban chlorpyrifos use in rice cultivation represents an important step toward reducing pesticide residues in exported crops and protecting food safety (Government of Pakistan, Ministry of National Food Security & Research, Department of Plant Protection, 2025). However, given the documented environmental contamination and the multiple exposure pathways affecting agricultural workers, women, and children, limiting the ban to rice cultivation is unlikely to address the broader public health and environmental risks associated with this pesticide. A comprehensive regulatory framework that prohibits chlorpyrifos in all agricultural, household, and other uses would provide a more effective means of protecting ecosystems, food systems, and vulnerable populations.

Such an approach would also align Pakistan's pesticide regulation with emerging international standards and encourage the adoption of safer pest management practices. Ultimately, transitioning away from chlorpyrifos across all sectors would contribute to healthier agricultural environments, improved worker safety, and greater protection of rural communities.

Agroecology as a Sustainable Alternative to Chlorpyrifos-Based Pest Control

An extensive body of scientific evidence documenting the environmental contamination, ecological disruption and human health risks associated with chlorpyrifos underscores the urgent need to transition toward safer and more sustainable pest management strategies. Agroecology provides a scientifically grounded and practical framework for achieving this transition. Rather than relying on synthetic insecticides to suppress pests through toxic chemical inputs, agroecology seeks to regulate pest populations through ecological processes, biodiversity, healthy soils and the redesign of farming systems. Reflecting the international scientific consensus, the High-Level Panel of Experts on Food Security and Nutrition (HLPE) concluded that agroecology is among the most promising approaches for transforming food systems to improve environmental sustainability, conserve biodiversity, enhance resilience, reduce dependence on external agricultural inputs, and strengthen food security and nutrition (High Level Panel of Experts on Food Security and Nutrition [HLPE], 2019). The following sections examine the key agroecological principles and practices that provide effective, science based alternatives to chlorpyrifos-dependent pest management.

Soil health and plant resilience

Agroecological management emphasizes the restoration and maintenance of healthy soils, which play a critical role in plant health and pest resistance. Healthy soils rich in organic matter and microbial diversity enhance nutrient cycling and support stronger plant growth (Altieri & Nicholls, 2003; Lal, 2004). Plants grown in biologically active soils often exhibit improved resistance

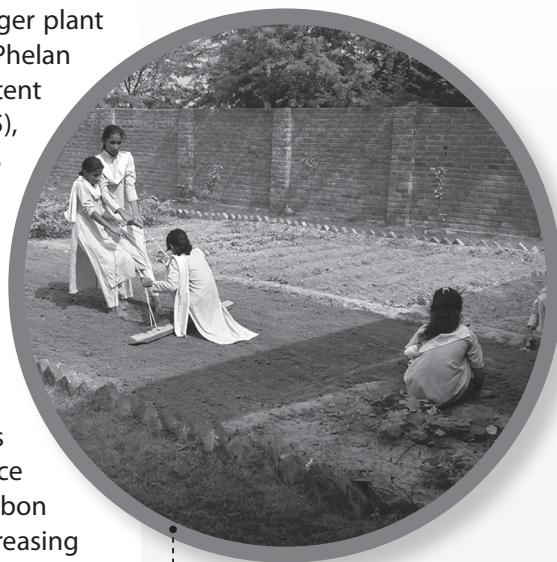


School children preparing Neem pesticide.

Photograph © Nasira Habib

to pests and diseases due to enhanced nutrient availability, stronger plant immune responses, and improved plant–microbe interactions (Phelan et al., 1996; van Bruggen et al., 2019). These principles are consistent with the Soil Food Web Approach developed by Ingham (2005), which emphasizes restoring diverse and functional communities of bacteria, fungi, protozoa, nematodes and other soil organisms to improve nutrient cycling, plant health, and resilience, thereby reducing and, ultimately, eliminating dependence on synthetic fertilizers and pesticides.

Practices such as compost application, green manures, crop rotations and reduced tillage help build soil organic matter and microbial biodiversity (Gliessman, 2015; Lal, 2004). These practices not only improve soil fertility but also contribute to climate resilience and long-term agricultural sustainability by enhancing soil carbon storage and water retention (Lal, 2004; Pretty et al., 2018). Increasing evidence also suggests that healthy, biologically active soils produce crops with greater resilience to insect pests and diseases by supporting balanced plant nutrition and beneficial plant–microbe interactions (Montgomery & Biklé, 2021; van Bruggen et al., 2019). In contrast, heavy reliance on chemical pesticides can disrupt soil microbial communities and reduce the abundance of beneficial organisms that contribute to nutrient cycling and plant health (Aktar, Sengupta, & Chowdhury, 2009; Imfeld & Vuilleumier, 2012).



Levelling a vegetable bed to grow winter vegetables. (Colour on back cover.)

Photograph © Nasira Habib

Ecological pest regulation through biodiversity

One of the core principles of agroecology is the enhancement of biological diversity within farming systems so that ecological processes regulate pests. Rather than relying on synthetic insecticides for pest suppression, agroecological farming systems are designed to strengthen natural biological control mechanisms. Diverse agroecosystems support populations of natural enemies—including parasitoids, predatory insects, spiders, and insectivorous birds—that naturally suppress pest populations and help maintain ecological balance within crop systems (Landis et al., 2000; Letourneau et al., 2011).

Research across a wide range of cropping systems has demonstrated that diversified farming practices such as intercropping, crop rotations, polycultures and the maintenance of semi-natural habitats can significantly enhance biological pest control. Habitat diversification increases the abundance and effectiveness of predators and parasitoids, thereby reducing pest outbreaks and limiting the need for chemical interventions (Gurr et al., 2017).

Agroecological pest management, therefore, emphasizes the redesign of farming systems to support these ecological interactions. The introduction of flowering plants, hedgerows, cover crops, and mixed cropping systems can provide nectar, pollen, and refuge for beneficial organisms that regulate pest populations. Such ecological infrastructure strengthens natural pest regulation processes and improves the resilience of agroecosystems.

Evidence from cotton systems—historically among the most pesticide-intensive cropping systems—demonstrates the potential of ecological pest management. Studies conducted in Pakistan and other cotton-producing regions have documented diverse communities of predators and parasitoids, including lacewings (*Chrysoperla carnea*), ladybird beetles (*Coccinellidae*), predatory bugs (*Geocoris* spp.), and parasitoid wasps (*Trichogramma* spp.), which can substantially suppress key pests such as aphids, whiteflies, and

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bollworms when ecological conditions allow their populations to flourish (Arif et al., 2012; Arshad et al., 2015).

These findings highlight an important shift in pest management philosophy. Agroecological approaches aim not merely to reduce pesticide use but to redesign farming systems so that pest regulation is achieved through ecological processes. By strengthening biodiversity-based pest regulation, such systems can progressively replace pesticide-dependent production models and enable the long-term phase-out of hazardous synthetic pesticides that threaten biodiversity, ecosystem health, and human well-being.

Integrated ecological pest management

Agroecology promotes pest management strategies that integrate ecological knowledge, farmer observation and adaptive decision-making rather than routine pesticide application. Regular crop monitoring enables farmers to assess pest populations, the presence of natural enemies, crop health and environmental conditions before deciding whether intervention is necessary. This approach recognizes that the presence of some insects is a normal feature of healthy agroecosystems and that many pest populations are naturally regulated before they cause significant crop damage (Altieri & Nicholls, 2004; FAO, 2018).

A key principle of agroecological pest management is that interventions should be based on economic thresholds rather than the mere presence of pests. Action is taken only when pest populations are likely to reach levels at which the expected economic losses exceed the cost of intervention. This approach avoids unnecessary pesticide applications, conserves beneficial organisms, reduces production costs, and delays the development of pesticide resistance (Stern et al., 1959; Pedigo & Rice, 2014).

When intervention is required, agroecology gives priority to ecological and biological measures, including cultural practices, mechanical control, habitat management, biological control agents, microbial biopesticides and botanical pesticides. These approaches are designed to suppress pest populations while conserving beneficial organisms, maintaining ecosystem functions and protecting human health. Rather than substituting one pesticide for another, agroecological pest management seeks to restore the ecological processes that naturally regulate pests, thereby progressively eliminating dependence on hazardous synthetic pesticides such as chlorpyrifos (Altieri & Nicholls, 2004; Gurr et al., 2017; FAO, 2018; Pretty et al., 2018).

By emphasizing prevention, continuous observation and ecological regulation, agroecological pest management provides an effective, economically viable and environmentally sustainable alternative to pesticide-dependent farming systems. Instead of treating pesticides as the primary means of pest control, it redesigns farming systems so that biodiversity, healthy soils and ecological interactions become the foundation of long-term pest regulation.

Benefits for farmers, workers and rural communities

Transitioning from chlorpyrifos-based pest control to agroecological systems would generate significant benefits for farmers and rural communities. Reducing dependence on hazardous pesticides lowers occupational

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exposure risks for pesticide applicators, farm workers, and their families (FAO & WHO, 2019; Tariq et al., 2007). Women agricultural workers—who are frequently involved in harvesting, transplanting, and other labour-intensive tasks—are particularly vulnerable to pesticide exposure and therefore stand to benefit substantially from reduced pesticide use (London et al., 2002).

Agroecological farming systems can also reduce input costs by decreasing reliance on synthetic pesticides and fertilizers. By strengthening ecological processes within farms, farmers can achieve more stable yields while improving soil health, biodiversity and resilience to climate variability (Pretty et al., 2018; Gliessman, 2015).

Policy support for agroecological transitions

Achieving a meaningful transition away from hazardous pesticides such as chlorpyrifos requires supportive public policies. Governments can play an important role by promoting research, extension services and farmer training programmes that support agroecological pest management (De Schutter, 2010). Investments in ecological farming practices, farmer-to-farmer knowledge exchange and participatory research can accelerate the adoption of agroecology across agricultural landscapes.

Policy frameworks that phase out highly hazardous pesticides while simultaneously supporting agroecological practices can help ensure that farmers have access to safe, effective and economically viable alternatives. Such policies not only protect environmental and human health but also strengthen long-term food security and agricultural sustainability (Pretty et al., 2018; FAO, 2018).

Conclusion

The scientific evidence reviewed in this paper demonstrates that chlorpyrifos contamination occurs across multiple environmental compartments in Pakistan, including agricultural soils, irrigation water, food crops and rural environments. Residues have been documented in rice, vegetables and fruits, while occupational exposure among pesticide applicators and agricultural workers has also been reported. These findings indicate that chlorpyrifos exposure is not confined to a single crop or production system but extends across agricultural landscapes and food systems. Consequently, regulatory measures that restrict the pesticide only to rice cultivation cannot adequately protect public health or environmental integrity.

The risks posed by chlorpyrifos are particularly serious for children. As a neurotoxic organophosphate insecticide, chlorpyrifos inhibits acetylcholinesterase and can interfere with the development of the nervous system during critical stages of foetal and childhood growth. Scientific studies have linked prenatal and early-life exposure to chlorpyrifos with developmental delays, cognitive impairment and behavioural disorders. Children in rural farming communities face elevated exposure risks because pesticides are often stored in homes, applied near living areas and present in contaminated soil, dust and water. Urban children may also be exposed through the consumption of contaminated food products transported from agricultural regions. Eliminating chlorpyrifos from agricultural and household

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use would therefore represent an important step toward protecting the neurological development and long-term health of future generations.

Women agricultural workers are also disproportionately affected by pesticide exposure. In many farming systems in Pakistan, women participate extensively in crop production activities such as cotton picking, rice transplanting, harvesting and fruit collection, often in fields recently treated with pesticides. Exposure to organophosphate pesticides such as chlorpyrifos has been associated in toxicological and epidemiological studies with reproductive health effects, including hormonal disruption, menstrual irregularities, adverse pregnancy outcomes and developmental effects in offspring. Protecting women from pesticide exposure is therefore essential not only for safeguarding their own health and reproductive well-being but also for protecting maternal and child health within rural communities.

Restricting chlorpyrifos use in a single crop does not address the broader exposure pathways associated with this pesticide. Chlorpyrifos continues to be used in cotton, vegetables, fruit orchards and other crops, and it is also marketed for household pest control and termite treatment. These multiple uses create cumulative exposure risks for agricultural workers, women labourers, rural families and consumers. A comprehensive regulatory approach that eliminates chlorpyrifos from all agricultural and household uses would therefore provide a far more effective means of protecting human health and ecosystems.

At the same time, a growing body of research demonstrates that the transition to agroecological pest management is both scientifically feasible and socially beneficial. Agroecological farming systems enhance biodiversity-based pest regulation, restore soil health and strengthen the resilience of agroecosystems. By conserving natural enemies, improving soil biological activity and promoting diversified cropping systems, these systems enable ecological processes to regulate pest populations, thereby eliminating dependence on hazardous synthetic pesticides while maintaining agricultural productivity. Such a transition would also protect farmers and farm workers from occupational exposure to hazardous synthetic pesticides, improve the health of rural communities, conserve biodiversity and ecosystem services, and contribute to safer, healthier and more sustainable food systems. A comprehensive ban on chlorpyrifos should therefore be accompanied by policies that support an agroecological transition in Pakistan's agricultural sector. Government investment in farmer training, participatory research, extension services and ecological pest-management strategies can enable farmers to adopt diversified and biologically based farming practices. Strengthening research and policy support for agroecology would help ensure that farmers have access to safe, effective and economically viable alternatives to hazardous pesticides.

Protecting the health of Pakistan's children, safeguarding women's reproductive health and ensuring the long-term sustainability of agriculture require moving beyond crop-specific restrictions toward a comprehensive prohibition of chlorpyrifos. By coupling such a ban with strong support for agroecological farming systems, Pakistan can protect people and the environment from hazardous pesticide exposure, strengthen food safety, and build resilient agricultural landscapes capable of sustaining both human and ecological health.

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