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Source and Effects of Glyphosate Pollution on Public Health: A Review

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Abstract

Glyphosate is the most popular herbicide because it can be used to control various weeds as well as enhancing the yield of commercial crops. Nonetheless, the use of glyphosate has increased to agricultural and non-agricultural uses, which resulted in the increase in geo- and biospheric contamination and human exposure issues. This review analyzes the persistence of glyphosate in the environment, including soil and water ecosystems, as well as in the food chain, and evaluates its exposure by multiple pathways. Active glyphosate and its primary degradation product, aminomethylphosphonic acid, are among the most frequently detected herbicide metabolites in human and environmental exposure matrices, corroborating the evidence for human and environmental exposure. Glyphosate exerts varied and potentially overlapping toxic effects, including oxidative and other metabolic disruptions, geno- and biotrophic dysregulation, and degradation of the microbiome. Glyphosate-induced disruptions ecologically include reductions in soil and water microbial communities, invertebrate and vertebrate organisms, and overall biodiversity. Modern ecological theories are challenged by the disruption's glyphosate is known to cause. Numerous toxicological and ecological hypotheses contend for dominance explaining glyphosate-induced disruptions of natural ecosystems. However, the cumulative, low-dose effects of glyphosate, as well as the effects of its co-formulants in glyphosate-containing herbicide preparations, are some of the gaps in the literature. Evidence-based global glyphosate regulation, coordinated monitoring, harmonized control measures, and collaborative cross-national research are urgently needed to address these issues. This review strives to reinforce the need for coordinated international monitoring and the enforcement of glyphosate use regulations for the protection of human health and biodiversity.

Keywords: Glyphosate; Environmental contamination; Human health; Persistence; Toxicity; Public health risk.

1. Introduction

Glyphosate is among the most commonly used herbicides with herbicides because it is effective toward most herbaceous weeds and helps increases agricultural productivity. Since the 1970s and the commercialization of genetically modified herbicide-resistant crops, glyphosate has been a key input in modern agriculture (Buffin & Jewell, 2001). Almost all countries have adopted glyphosate because most modern agricultural systems are economically dependent on glyphosate for effective weed control and high yields. The benefits associated with glyphosate have made the concerns related to it an afterthought. However, the concerns are of a magnitude that should not be dismissed, as glyphosate have been found in soil, water, and food, and has been bioaccumulated in the human body (Rivas-García et al., 2022).

Although glyphosate is recognized as an economically important compound, its safety remains an issue of considerable controversy in the scientific and regulatory communities. The International Agency for Research on Cancer (IARC) classified glyphosate as “probably carcinogenic to humans,” based on its genotoxic and carcinogenic characteristics (Van Bruggen et al., 2018). In contradistinction, the European Food Safety Authority (EFSA) and the United States Environmental Protection Agency (EPA) found that glyphosate is unlikely to pose a carcinogenic threat to humans when used within the prescribed parameters (García-Villanueva et al., 2024). These conflicting evaluations have generated worldwide controversy and uncertainty about the risks of glyphosate exposure between consumers, regulators, and farmers.

In attempting to fill the gap between the environmental fate of glyphosate and health consequences resulting from human exposures to glyphosate, the different ways glyphosate is contained within and passes through soil, water and air needs to be understood to assess the contribution of occupational, dietary, and environmental exposures to human glyphosate health exposures (Galli et al., 2024). Glyphosate environmental persistence and bioavailability ability is multidimensional in the sense that the bioavailability and environmental persistence alters this glyphosate has a stabilizing effect and equilibrium of human health. The influence of glyphosate and other emerging toxicants should be examined to obtain a clear image of the complexity of the correlation between industrial pollutants and the human health (Kanangire et al., 2016).

This review will attempt to fulfill this goal by integrating the knowledge about the environmental persistence and bioaccumulation of glyphosate, the biosystems and environmental exposure risks, and the toxicological effects, including effects of co-formulants, which might be associated to the heightened toxicity (Gandhi et al., 2021). This will be done by identifying the research gaps and investigating current scientific knowledge on the value of glyphosate as an agricultural input and environmental and public health impacts.

2. Sources of glyphosate pollution

2.1 Agricultural applications

Glyphosate has a history of use in agriculture because it was initially introduced in the form of a broad-spectrum herbicide to be sprayed on crops and kill a large variety of weeds. This growth in the use of glyphosate was aided by the introduction of genetically modified crops that were glyphosate resistant (Roundup Ready varieties). The technology assists farmers to spray entire fields with glyphosate so as to manage the weeds and facilitates the process of managing the weeds and improving crop productivity (Parven et al., 2025). Crops desaturated with glyphosate before harvesting has also become common and usually the root cause of the increasing amounts of glyphosate in the food and the environment (Niemann et al., 2025). Aside and beyond the food and environmental issues, extreme utilization of glyphosate in farming has been observed to contribute to the adverse ecological and health effects of glyphosate, including the buildup of glyphosate and its residues in the soil and water and the imbalance of the soil microbial community that forms the foundation of sustainable farm practices (Mohd Ghazi et al., 2023).

Furthermore, overuse of glyphosate on agricultural lands can result in some of the weed species becoming glyphosate resistant in these lands, or double the use of glyphosate with other herbicides, which will increase environmental contamination of glyphosate by leaching and runoff (Pérez-Vázquez et al., 2023). Therefore, the dependence of agriculture on glyphosate is a double-edged sword, giving short-term economic benefits, but poses long-term risks to health and the environment (Mason, 2013).

2.2 Non-agricultural sources

Besides agriculture, the uses of glyphosate in other areas of society are sources of its contamination. Glyphosate is used in urban settings for the maintenance of weed-free zones, such as on sidewalks, in recreational areas, and along the fringes of gardening and landscaping (Pesticide Action Network UK, 2019). In the Forestry sector, Glyphosate is used for the same purpose in the management of commercially grown trees, as well as for controlling roadside vegetation which is of use to Fire and Road Safety (Parven et al., 2025). The same uses of glyphosate for the control of invasive vegetation in water bodies and for the maintenance of clear water also lead to contamination and runoff to the surrounding ecosystems (Pérez-Vázquez et al., 2023). The extent of these uses, that are well beyond agricultural land, is significant in contributing to the contamination of the environment. Glyphosate leaches to the water and affects non-target organisms, contributing to altered aquatic ecosystems and loss of biodiversity (Mohd Ghazi et al., 2023).

2.3 Industrial and accidental releases

Besides deliberate uses, glyphosate pollution arises from Poor- Waste Management, Poor-Manufacturing Practices, Accidental- Spills, and Poor- Industrial Disposals. (Mohd Ghazi et al. 2023) explains how glyphosate and its co-formulants enter the aquatic environment when leaks, inadequate storage, and residues are disposed of. Likely due to (Moore's 2023) emphasis on glyphosate and its co-formulant's potential to runoff, glyphosate will also infiltrate ground water due to its high solubility. Accidental releases ofin-transit and storage can also contaminate regions, which (Mason 2013) strongly argues is the "culprit" of poor regulation and "negligent" infrastructure esp. in developing economies, where high standard WDS, safe WDS, and chemical management are implemented.

2.4 Global Patterns and Usage Trends

Worldwide, glyphosate continues to dominate as the most used herbicide, and its usage has been on the rise since it was first commercially introduced in the 1970s. Following the rise of genetically modified crops in the 1990s, the use of glyphosate skyrocketed, especially within North and South America (Parven et al., 2025). Brazil and Argentina, large soybean, maize, and cotton producers, report some of the highest glyphosate usage in Latin America (Pérez-Vázquez et al., 2023). The same pattern is observable in Southeast Asia, where glyphosate is used liberally with little regulation on rice and oil palm plantations (Mason, 2013). In Europe, the public may be increasingly resistant and regulations become more stringent, but glyphosate is still used in weed management within both conventional and conservation agriculture (Niemann et al., 2025).

In recent years, there has been increased concern about the occurrence of glyphosate and its by-products in an expanding range of matrices, including soil and water, and its tendency to bioaccumulate within the impacted ecosystems, which has galvanized the public on its legacy ecological impacts (Mohd Ghazi et al., 2023). Globally, glyphosate dependence has been documented (Pesticide Action Network UK, 2019), and it is within this context that the need to implement more stringent regulations, better monitoring of glyphosate residues, and the development of more economically and ecologically balanced alternatives to curb glyphosate dependence and thus protect ecosystems and the public becomes critical

3. Environmental fate and transport

3.1 Physicochemical Properties

Glyphosate is characterized by high water solubility; adsorption to minerals and organics is strong and context-dependent with desorption occurring later; it is non-volatile with variable and condition-dependent environmental half-lives; and it has variable environmental persistence (Torretta et al., 2018; Ansari et al., 2019). In addition, some settings environmental persistence is likely longer than assumed (Myers et al., 2016). In aquatic systems, the water solubility facilitates mobility, but lower water solubility and sorption to sediments bioavailability and residence time are regulated (Thanom sit et al., 2020).

3.2 Degradation Pathways

Microbial, photolytic, and chemical processes contribute to degradation, and the rates depend on temperature, light, pH, and microbial communities (Ansari et al., 2019; Torretta et al., 2018). The principal metabolite, aminomethylphosphonic acid, may persist longer than the parent compound and contribute to the prolonged signature, or longer, environmental persistence (Ansari et al., 2019; Myers et al., 2016).

3.3 Transport Mechanisms

Runoff, leaching, and spray drift each facilitate the transfer of glyphosate and its metabolite to groundwater and surface water, as well as to leachate and airborne reservoirs, respectively. Further, sorption of glyphosate and its metabolite binds the compounds to suspended particles, sediments, and, eventually, sediment layers (Torretta et al., 2018; Thanomsit et al., 2020). Health impacts observed at downstream locations and associated with agricultural activities conducted at upstream positions affirm the transport of glyphosate and its metabolite across connected watersheds hydrologically (Dias et al., 2019). Discriminatory behaviors are matrix-specific: in soils, strong sorption, as a result, immobilization; in surface waters, the co-occurrence of dissolved and particulate phases; in groundwater, leaching and subsequent detection during moist periods; in air, episodic drift in proximity to source; in sediments, binding and prolonged persistence (Myers et al., 2016; Thanomsit et al., 2020; Torretta et al., 2018).

4. Behavior and persistence in environmental media

4.1 Soil environment

Soil environments exhibit persistence of glyphosate alongside highly adsorbed glyphosate due to strong association with clay minerals and organic matter. Adsorbed glyphosate may slowly release given favourable conditions including pH and moisture changes (Van Bruggen et al., 2018). The retention of glyphosate in the soils is very much related to pH, temperature and microbial activity. Heat conditions inside of the soils and active microbial communities elevate degradation of soil glyphosate whereas cold conditions, low biology, and acidity elevate persistence artificially since the soils have low degradation potential (Rivas-Garcia et al., 2022). Repeated use of glyphosates is reported to result in the accumulation of residue on agricultural soils, especially in cases of low tillage of soils and runoffs (Buffin and Jewell, 2001). Moreover, glyphosate co-formulates and their synthetic analogs could also alter the chemical properties of soils and contribute to their persistence or mobility in soils (Gandhi et al., 2021).

4.2 Aquatic systems

In water, glyphosate exists both in a soluble and non-soluble form, which is bound by sediments. The source of glyphosate contamination in surface water is mainly agricultural runoff and soil erosion, and groundwater contamination is caused by glyphosate leaching through sufficiently permeable soils (Van Bruggen et al., 2018). Water bodies are exposed to glyphosate, which exhibits limited bioaccumulation in aquatic organisms. However, glyphosate-laden sediments have bioaccumulated glyphosate and, thus, extended environmental residence times, persisting and potentially re-releasing glyphosate under different conditions (García-Villanueva et al., 2024). Glyphosate, especially in nutrient enriched conditions, may indirectly contribute to eutrophication as certain microorganisms may use glyphosate as a phosphorus source (Rivas-García et al., 2022). There are increasing concerns on the ecological and health impacts of glyphosate in areas like the Lake Victoria Basin when water bodies in the area support local communities (Kanangire et al., 2016). The accumulation of glyphosate in aquatic systems to support local livelihoods has sparked interest, especially in the Lake Victoria Basin (Kanangire et al., 2016).

4.3 Atmospheric pathways

The transport of glyphosate into the environment results more from the movement of treated areas rather than volatilization due to glyphosate's very low vapor pressure (Van Bruggen et al., 2018). The rate of air dispersal of the spray from field applications and off target dispersal can be influenced by wind speed, droplet size, and spray height. Communities adjacent to treated field sites, whether in urban or agri- areas, may be indirectly exposed to contaminated drift (Rivas-García et al., 2022). From the archives, spray drift of glyphosate was identified as a critical factor causing unintentional dispersal of glyphosate, subsequently raising the need for improved landscape Ct and dispersal air spray rate control (Buffin & Jewell, 2001).

4.4 Food Chain Transfer

The presence of glyphosate residues has been documented at multiple points in the food chain, starting with the cultivations that are directly sprayed. These residues have been documented in grains, fruits, vegetables, and in the processed foods that are made from these crops (Van Bruggen et al., 2018). Furthermore, there are residues in honey and other animal products, suggesting that pollinators and livestock are glyphosate residue transferal intermediaries within ecosystems

(Rivas-García et al., 2022). Contamination of food and food products makes food consumption the major pathway of exposure for the entire population (Galli et al., 2024). The presence of glyphosate in foods makes the case for the need for constant and more stringent monitoring and regulation. The persistence of glyphosate residues in the environment, with the potential for major public health consequences, advocates for the need for more sustainable agricultural methods to control the buildup of residues in practice (García-Villanueva et al., 2024).

5. Human exposure pathways

5.1 Occupational Exposure

Agricultural workers and personnel engaged in pesticide application and equipment maintenance can encounter direct dermal and inhalational contact during the mixing, loading, and spraying processes, and cleaning equipment. There also remains the possibility of take-home exposure via residues on clothing and gear (Mason, 2013; Pesticide Action Network UK, 2019). Reviews cite workplace exposure as the critical driver of body burdens, particularly where use is intensive or where there is insufficient protective measures (Pérez-Vázquez et al., 2025). Moreover, exposure potential is shaped by application duration, formulated product, climatic circumstances, and compliance with safety protocols. Workers in developing countries encounter greater risks and even pesticide-related health effects because of absence of regulations, low-quality protective gear, and insufficient training on pesticide safe handling procedures, which also promote the chronic retention of glyphosate in the tissues.

5.2 Non-Occupational Exposure

Dietary exposure through food and drinking water is one of the most significant non-occupational exposures, and most risk assessments cite ingestion as the primary risk for the general population (Niemann et al., 2015). For those living close to treated fields or along rights-of-way, spray drift and contaminated household dust, as well as community and consumer use in gardens and shared areas, contribute to residential exposure (Pesticide Action Network UK, 2019; Mason, 2013; Mohd Ghazi et al., 2023). Additional exposure risk is presented to children and pregnant women, who consume more of certain foods relative to their body weight and are more sensitive to the toxic effects of certain contaminants. Chronic exposure is continuous and occurs in populations that are not actively farming, as evidenced by glyphosate being detected in rain and contaminated surface water, which indicates cycles of persistent environmental contamination.

5.3 Evidence of Biomonitoring

Studies used in the literature review have acknowledged the detections of glyphosate and its primary metabolite, aminomethylphosphonic acid, in human urine and, to a limited extent, in blood and breast milk. This indicates both occupational and non-occupational recent and ongoing exposure (Mesnage et al., 2015; Pérez-Vázquez et al., 2023; Mohd Ghazi et al., 2023). The concentrations and detections are reported to have variabilities which may be based on a specific region, population, and closeness of the population to glyphosate and registration. These variations indicate the variance in the application practices, laws, and diet (Mason, 2013). In addition, longitudinal studies have documented instances of increased agricultural use and corresponding increases in biomarker levels, which indicates widespread exposure to glyphosate and suggests that current exposure assessments are likely to underestimate the extent of exposure. The metabolite detections in the biological sample have provided critical means for evaluating the risk of exposure and environmental contamination, estimating the internal dose, and public health informing the risk assessment and policy decisions.

6. Toxicological and health effects

6.1 Mechanisms of Toxicity

Glyphosate's action involves 5-enolpyruvylshikimate-3-phosphate synthase enzyme inhibition, oxidative stress, and potential endocrine disruption and genotoxicity (Ansari et al, 2019). In addition to its primary herbicidal action, the herbicide is associated with impaired mitochondrial activity and the consequent production of reactive oxygen species which sorption and peroxidation injury cell membranes. glyphosate is also reported to disrupt endocrine and developmental processes likely through the alteration of hormonal activity, inhibition of some enzymes, DNA methylation, and per the control of several disrupt biochemical pathways. These exposures and disruptions cumulatively explain the glyphosate tissue and organ system multifactorial and disorders.

6.2 Acute and Chronic Effects

Gastrointestinal irritation and systemic toxicity are part of the acute effects reported. In human and animal observational studies, the chronic exposures largely focused on the renal and hepatic system with reported neurologic impacts as well (Myers et al, 2016). Developmental and reproductive toxicity signs, including poor birth outcomes were reported in epidemiological studies and reviews attributing such outcomes to proximity to glyphosate-using agriculture (Dias et al, 2019). Chronic exposures were also associated with hormonal disorders, metabolic syndrome, and oxidative stress with associated DNA damage. Animal studies showing organ inflammation and degeneration chronic glyphosate exposures likely are contributing to immune dysfunction and physiological stress as glyphosate is known to chronic cumulative irritation of the tissues.

6.3 Assessment of Carcinogenic Potential

According to the reviews, the International Agency for Research on Cancer categorized glyphosate as "probably carcinogenic to humans." This assessment differs from those made by the United States Environmental Protection Agency and the European Food Safety Authority, although epidemiological studies as noted by Ansari et al. (2019) have documented associations between glyphosate exposure and non-Hodgkin lymphoma as well as other malignancies. Glyphosate formulations have also been shown in some experimental research to induce oxidative damage to DNA and other alterations such as chromosomal and epigenetic changes which can lead to tumorigenesis. These discrepancies in the regulatory conclusions may arise from differences in the design of the studies, exposure assessment methodologies, and the inclusion of co-formulants, which might be assessed and found to augment carcinogenic effects. These differences in conclusions documented in the presented works highlight the need for dual approach research.

6.4 Effects on Microbiota and Metabolism

Exposure to glyphosate and glyphosate-based products negatively impacts gut microbiome function as well as microbiome-associated metabolic pathways, which in turn may undermine health due to changes in metabolism and gut microbiome composition (Myers et al., 2016; Torretta et al., 2018). The dysregulation of gut microbiota caused by glyphosate may also adversely affect immune and gut function because it encourages pathogenic bacteria and permits the selective elimination of beneficial bacteria. Absorption of nutrients, hormones, and neurotransmitters may become dysregulated due to the gut microbiota imbalances, resulting in, and sustaining, systemic metabolic dysregulation. Chronic health impacts associated with long-term glyphosate exposure may be attributable, in part, to the unrelenting health impacts of disrupted gut microbiome.

7. Ecological and indirect public health effects

Glyphosate and its formulations affect biodiversity through changes to plant communities which impact a sequence of organisms, such as soil fauna, pollinators, and organisms that occupy higher trophic levels. Documented impacts of glyphosate and its formulations on biodiversity include changes to the structure and function of soil microbes, interference with processes within the rhizosphere that provide soil-benefit, loss of pollinator floral resources, and toxicity to water organisms due to waterborne glyphosate and soluble formulation mixtures (Hernández-Vázquez, & Schwentesius-Rindermann, 2022). Historical assessments flagged increased reliance on glyphosate coupled with genetically modified herbicide-tolerant crops as a likely intensifier of impacts on farmland biodiversity (Buffin & Jewell, 2001).

These biodiversity and ecological changes provide shifts in the potential of ecosystem services and food safety. The potential loss of ecosystem services such as pollination, nutrient cycling, and biological pest control directly influences public health through food and its quality, availability, and associated contaminants, and indirectly through the potential of the food to become a biological vector of harmful pathogens. The cross the food supply and provide residue raises to concerns dietary exposure (García-Villanueva et al., 2024).

Repeated inputs and movement through environmental compartments and food webs may result in cumulative exposure. Residues and metabolites in water, sediments, crops, feed, and animal tissues suggest potential trophic transfer, and additive and overlapping burdens likely exist in systems with high application intensities (Van Bruggen et al., 2018).

8. Mitigation strategies and policy framework

8.1 Regulatory perspectives

Regulatory approaches vary from partial or precautionary bans and use restrictions to continued approvals with stated maximum residue limits, and advocacy documents stress precaution if cumulative exposures and susceptible populations are involved (Mason, 2013; Pesticide Action Network UK, 2019). Reviews highlight the heterogeneity regarding countries for re-registration decisions, buffer zones, and application conditions (Pérez-Vázquez et al., 2015). In response to the need for policy adjustments, some governments have conducted national reviews to assess agricultural benefits against ecological and public health risks, which have subsequently resulted in stronger policy revisions and enforcement adjustments to mitigate misuse and safeguard vulnerable groups.

8.2 Analytical detection methods

High-performance liquid chromatography, gas chromatography–mass spectrometry, and liquid chromatography–tandem mass spectrometry are standard techniques used in the analysis of environmental and food samples. There is also recent literature describing emerging biosensor approaches which prioritize speed and applications in the field (Pérez-Vázquez et al., 2023;

Mesnage et al., 2015). These techniques facilitate the monitoring of water, soil and biological samples for the presence of glyphosate and its metabolite, aminomethylphosphonic acid, and trace residue levels. Research is also geared towards monitoring the environment in low-resource settings through the use of portable and low-cost analytical techniques.

8.3 Bioremediation and Removal Technologies

Mitigation options depend on the matrix and the co-formulants, and include phytoremediation with tolerant plant species, microbial degradation by specialized bacteria and fungi, and advanced oxidation processes for the transformation of water and soil residues (Pérez-Vázquez et al., 2023; Mason, 2013). Combining these approaches with ecological restoration initiatives will improve the prospective sustainability. Studies support the use of site-specific microbial consortia, and the management of other ecological factors for enhanced degradation, reduced secondary pollution, and effective detoxification of agricultural and aquatic ecosystems.

8.4 public health interventions

Suggested actions comprise open risk communication with the community surrounding treated areas; monitoring human exposure through biomonitors and integrated pest management that lowers glyphosate use while protecting crops (Pesticide Action Network UK, 2019; Mason, 2013; Mesnage et al., 2015). Increasing community education and enforcement of these actions will help with pesticide safety, protective action, and chemical herbicides alternatives. Evidence-based proposals on long-term exposure reduction will come from intersectoral partnerships between environmental coordination and health decision makers.

9. Knowledge gaps and future directions

Research on glyphosate continues to expand globally, yet considerable knowledge gaps remain, especially on the chronic and low-dose exposures over long periods and the subsequent effects on humans and the environment. Most of the current studies concentrate on the short-term effects or the acute toxicity of glyphosate. As a result, the ramifications of extended, low-grade exposure that may occur through one's diet, occupational exposure, and the environment's inertia remain unresolved. In the absence of longitudinal epidemiological and ecotoxicological research, the exposure of humans and gaps of endocrine-disrupting, carcinogenic, neurotoxic, and reproductive toxic effects will prevent the correlation and causation of study findings.

The world's research and monitoring systems remain uncoordinated, which is yet another constraint. The absence of congruent monitoring systems and unharmonized research methodologies, detection limits, and result reporting systems within and among countries complicate the performance of cross-country research and meta-analyses. The international research community should prioritize the design and implementation of harmonized monitoring systems and the control of glyphosate and its primary metabolite, aminomethylphosphonic, acid flow in human and ecosystem biometrics. Coordination of glyphosate research and monitoring through international coalitions, contoured databases, shared research facilities, and cooperative diplomacy would globally enhance the resolution of glyphosate's long-term effects and correlations.

There should be investigations to combine glyphosate with its associated acids to find out how the compounds may behave differently together than with glyphosate alone. Also, there are still few studies on some co-formulants of commercial herbicide mixes, even though there is evidence that some of these co-formulants can increase toxicity and change how herbicides are absorbed by the body. The chronic toxicity of co-formulants is essential to study, especially if the toxicity is synergistic or cumulative. Strong collaborations and data integration in multisector environmental health research can helps in safer farming practices and regulations to minimize the use of herbicides. To develop evidence-based practices that will be beneficial to public health and the environment, the world must promote research on glyphosate and form strong global research collaborations that include cohort studies and data integration.

10. **Conclusion**

Glyphosate's Environmental Persistence Glyphosate's Environmental Persistence through the Food Chain The cumulative persistence of glyphosate through soil, water, and the food chain recalls its risks to human and ecosystem health. It circulates within these interconnected pathways and bio-accumulation through food systems, indicating cycles of exposures which then permeate to human dietary and occupational exposures. Environmental glyphosate risks to biodiversity, soil microbial community structures, community composition of biological (aquatic) and terrestrial wildlife, and thus, ecosystem services, imply global security risks to human and community health. Spaces and places of human and community health inevitably harvest the detrimental spores of glyphosate accompanied by the rife other spatial and ecological contaminations of glyphosate. The more human and ecosystem health concurrently harvest and tolerate exposures, the more challenges and health risks to systems of global health, community and ecologic balance.

The enforcement of health abuse liability shifts and coordinated international health and ecological abuse shifts of glyphosate depend on effective policy enforcement and coordinated international regulation to mitigate ecological and long-term health abuse dependence on glyphosate. Global glyphosate abuse dependence will decrease by adopting biological weed control, integrated pest management, and precision agriculture. These sustainable practices will offer pathways to mitigate the risks of glyphosate persistence through soil, water, and food chain.

It is equally important to create global surveillance systems to monitor glyphosate and its metabolites in and biological and environmental matrices. Countries would benefit from unified monitoring and collaborative databases to improve monitoring and decision-making during risk assessments. In closing, protecting public health and the environment requires a neutral position based on the integration of science, active public policy, and new methods of farming. Only with comprehensive global cooperation will the ongoing challenges of glyphosate be addressed and a more sustainable future be achieved.

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