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ENVIRONMENTAL AND HUMAN IMPACTS OF THE TOXIC PESTICIDES USE IN AGRICULTURE: A REVIEW

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To ensure food safety and security for the global population, a wide range of pesticides are applied in agriculture, which generally proved to be harmful to the environment and human health. Often, even if the effects of pesticides on ecosystems and humans were known, they still received approval for use. Therefore, many organizations, whose mission is to protect the environment and people from the toxic action of pesticides, assessed their effects and started campaigns demanding the competent authorities to ban their use and production. In this regard, the main objective of this review is to highlight the hazards to human health and the environment of the 13 highly toxic pesticides for which Pesticide Action Network Europe (PAN Europe) was demanding the European Union to withdraw their authorizations. Most of them are highly toxic to the aquatic environment and are considered endocrine disruptors for humans. For example, cypermethrin has been shown to kill honey bees, but it received approval until 2029. Therefore, to achieve the EU target of 50% reduction in the use and risk of hazardous pesticides, the competent authorities are advised to revise the authorizations of the 13 pesticides as soon as possible.

Keywords: environmental hazard, health hazards, highly toxic pesticides.

INTRODUCTION

Pesticides are defined by the Food and Agriculture Organization of the United Nations (FAO) as "*the substance or mixture of substances intended for the prevention, destruction or control of any pest, including vectors of human or animal diseases, undesirable species of plants or animals which cause damage during the production, processing, storage, transport or marketing of food, agricultural products, wood and wood products or animal feed or any substance which may be administered to animals to control insects, arachnids or other pests on or in their bodies*". Also, are considered pesticides "*the substances intended for use as a plant growth regulator, defoliant, desiccant or agent for thinning or preventing premature fruit drop, and substances applied to crops before or after harvest to protect commodities from damage during storage and transport*"[1]. This definition reveals, in fact, the complexity of scientific research on pesticide synthesis, properties, uses and effects on the environment and humans in the short, medium and long term and highlights the timeliness of previous and present studies in this field[2,3].

Although the negative effects of pesticides on human health and animals are known, different types of pesticides are regularly used by farmers for pest and disease control to maintain a positive balance between market supplies and demand for food plants[4–6].

The risks to human health and ecosystems induced by the use of pesticides in various fields of activity rely both on the intrinsic properties of their components (*e.g.*, active substances, co-formulants, adjuvants) and on the way they are used – for example the frequency, volume and method of application, as well as the type of crop and soil[7].

For a proper management of pesticides to protect human health and the environment, different organizations and authorities such as Pesticide

Action Network, U.S. Department of Agriculture (USDA), European Food Safety Authority (EFSA) and others, elaborated and implemented several monitoring and control programs. Through the information provided by these programs the regulatory authorities can approve an active substance and set the legal limits for pesticide residues in food and feed[8].

Pesticide Action Network (PAN), whose primary mission is to protect human health and the environment by removing highly hazardous pesticides from the market and replacing them with environmentally friendly alternatives, is now alerting the world about 34 highly hazardous pesticides[9]. This organization further reports that at the European level in 2023, for 24 banned pesticides, European Commission has given no less than 236 derogations. Therefore, EU member countries can still use some pesticides such as diquat, 1,3-dichloropropene, chlorpyrifos, chlorothalonil, linuron, mancozeb, thiacloprid etc.[10]. In view of its mission, PAN Europe has started a campaign demanding the European authorities to ban several highly toxic pesticides, such as chlorotoluron, propyzamide, pendimethalin, flufenacet, cypermethrin, esfenvalerate, lambda-cyhalothrin, pirimicarb, 8-hydroxyquinoline, dimoxystrobin, ipconazole, tebuconazole and ziram[11].

In the light of the aforementioned, it is extremely important to pay special attention to the use of chemicals in the control of different pests. A review of the hazards to human health and the environment of pesticides proposed by PAN Europe to be banned is therefore examined in this paper.

IMPACT OF PESTICIDES ON THE ENVIRONMENT AND HUMAN HEALTH

Pesticides are the only group of chemicals intentionally applied in the environment to suppress plant and animal pests and protect agricultural and industrial products. The majority of pesticides, however, do not specifically target the pest and their application also affects non-target plants and animals. Many pesticides are not easily degradable, persist in soil, leach into ground and surface water and further contaminate the environment (Figure 1). Some of pesticides or their metabolites can be absorbed by living organisms, bioaccumulate along the food chain and ultimately affect the human health. Overall, the intensive application of pesticides results in several negative environmental impacts that cannot be ignored[6,12,13].

Pimentel D.14 states that "*only 0.1% of applied pesticides reach the target pests, leaving the bulk of pesticides (99.9%) to adversely affect public health and beneficial biota, and contaminate soil, water, and the atmosphere of the ecosystem*". Environmental hazards related to the application of pesticides in the control of pests are:

– biodiversity loss and extinction of key species (*e.g.*, bees);

– groundwater and surface water pollution;

– soil contamination;

– increased resistance of pest to the pesticide, leading to the need to increase the application rate or to apply alternative pesticides.

The presence of pesticides in the aquatic environment often induces algae blooms[15], but can also cause egg shell thinning, suppression of the immune system, reproductive failure and the death of aquatic organisms[16]. The application of pesticides affects beneficial soil biota and causes significant reductions in populations of bees, predators, birds and small animals[17]. Pesticide air pollution contributes to global warming and climate change, but may also causes respiratory disorders in humans and animals[18].

Pesticides can enter into the human body via three common pathways: through the skin (dermal contact), mouth (ingestion) and lungs (inhalation). Pesticides in liquid or gaseous form can penetrate the body via all three pathways, while solids enter in the lungs only if the particle sizes are small enough[19]. The workers of pesticide factories, agriculture and public health are among the most exposed groups to pesticides. Exposure during pesticide production, handling, dilution, mixing and application procedures can induce acute pesticide poisoning to workers which can lead to death and serious illness[20]. They are exposed to pesticides mainly through dermal contact, the liquid pesticides being those that are most easily absorbed by skin. Furthermore, the most rapidly absorbed are the liquid pesticides containing solvents and oil-based pesticides[19]. The majority of population is exposed mainly through consumption of pesticide-treated food crops and contaminated drinking water[20]. Their long-term consumption is related to a variety of chronic health effects such as asthma, diabetes, Parkinson's disease, depression and different types of cancer[6].

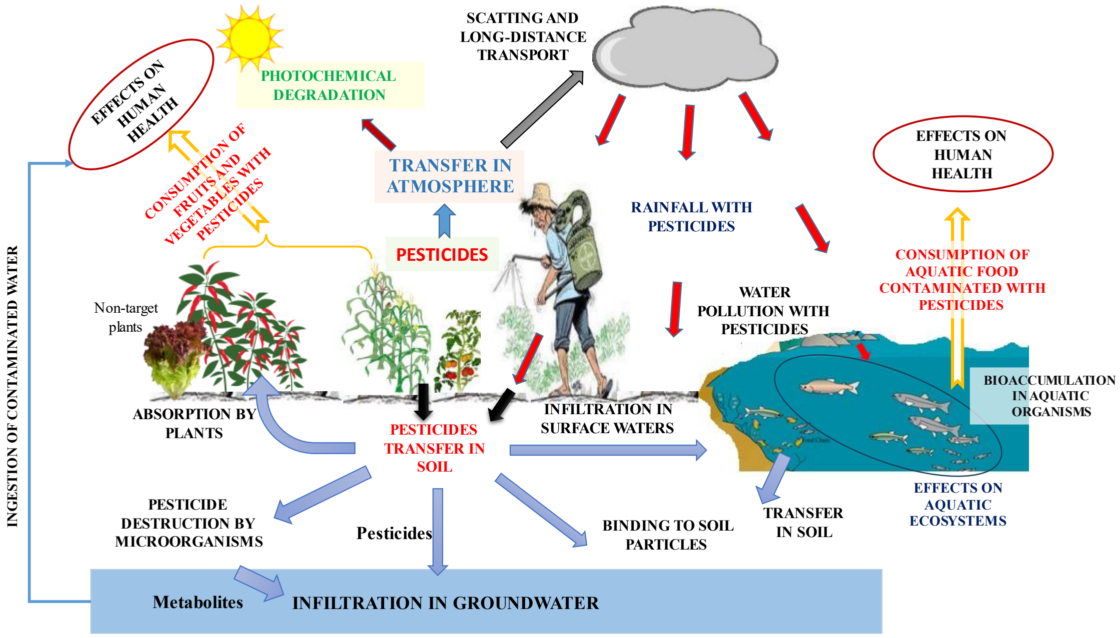

Figure 1. Pesticide cycle in environment.

Studies focused on assessing the impact of pesticides have shown that not only the active substances have negative effects on the environment and human health, but also the metabolites resulting from their degradation, which are sometimes more harmful than the parent substance[20,21]. As pesticides in the environment can be degraded by various (photo)chemical and biological processes, knowledge of the toxicity of pesticide metabolites is currently incomplete[20]. Therefore, the limited research on the toxicity of pesticides and their metabolites has led to the banning of some pesticides after a given period of application in the control of various pests. Many pesticides have been shown to cause severe damage to ecosystems and human health. According to Tubbs C.W.[22], DDT (dichlorodiphenyltrichloroethane) and its metabolites used in the 1940's–1970's nearly caused the extinction of California condors. Pesticides such as thiamethoxam, dimethoate, methomyl, cypermethrin, tetraconazole, cyfluthrin and esfenvalerate have been shown to be highly toxic to honey bees and responsible for reducing their population[23].

The use of pesticides, particularly in agriculture, caused the contamination of groundwater resources, with a further risk to human health. Chlorantraniliprole, dimethomorph, fluopicolide, metalaxyl-M, penconazole, tetraconazole and S-metolachlor were the main pesticides detected in groundwater of Tidone Valley, Province of Piacenza, North-West of Italy. In 30% of the samples, the pesticides levels were above the Environmental Quality Standard limits for groundwater[24]. Voutchkova D.D. *et al*.[20] stated that drinking water pollution with pesticides is a major concern in the Netherlands, since in 1/3 of all drinking-water sources, the water-quality standard was exceeded.

Therefore, due to the variety of toxic effects on all ecosystems and human health, many non-governmental organizations are campaigning to ban the production and use of pesticides that have proven to be highly toxic.

THE HAZARDS OF TOXIC PESTICIDES USED IN EUROPE ON THE ENVIRONMENT AND HUMAN HEALTH

European Environment Agency reports that although in some EU Member States there has been a significant reduction in pesticide use, pollution by these chemicals still poses significant risks to human health and the environment. In order to reverse this situation, the European Commission claims that a greater effort must be made to reach the EU's zero pollution targets. Thus, the EU intends "*to reduce by 50% the use and risk of chemical and more hazardous pesticides by 2030*"[25].

PAN Europe considers that pesticide substitution with a non-chemical alternative could help the EU to achieve its objective. Unfortunately, PAN Europe found that the EU still grants derogations for the use of banned pesticides and European citizens are significantly exposed to the most dangerous pesticides in the EU, either through food or in the environment. Following the assessment of the European pesticide situation, PAN Europe has compiled a database of the 50 highly toxic pesticides that are still approved for use in the EU. For the 13 of these, PAN Europe have started a campaign demanding the European authorities to immediately ban their production and use. This list includes pesticides such as chlorotoluron, propyzamide, pendimethalin, flufenacet, cypermethrin, esfenvalerate, lambda-cyhalothrin, pirimicarb, 8-hydroxyquinoline, dimoxystrobin, ipconazole, tebuconazole and ziram11. Fortunately, from 2024, dimoxystrobin and ipconazole will be banned (Table 1).

Pesticides proposed for ban are herbicides, fungicides or insecticides used on a wide range of crops and are linked to various hazards to human health and the environment (Table 2). Most of them are highly toxic to the aquatic environment and endocrine disruptors for humans[11].

According to Marín-Benito J.M. *et al.*[26], chlorotoluron was frequently detected in surface and groundwater, sometimes above the EU permitted limits for pesticides in drinking water (0.1 µg L^{-1}). Lerebours A. *et al.*[27] detected the presence of chlortoluron in bivalve tissues and in particular in mussels of the Charente estuary. In oysters, in 2020, the average concentration was 17 ng/g w.w. and in mussels 16 ng/g w.w. Cypermethrin, an insecticide used for cereal crops, has proven to be highly toxic to honey bees with an oral LD50 of 64 ng/bee. This pesticide was detected in pollen (up to 49 ng/g), in honey or nectar (20–30 ng/g), in exposed honey bees (36.3–49 ng/g) and in wax (131 ng/g)[28]. Lee G. *et al.*[29] showed that ipconazole has the potential to alter neurodevelopment by deregulating mitochondrial homeostasis in zebrafish embryos.

Table 1

The acceptable daily intake (ADI), maximum residue levels (MRL) in food and approval period of toxic pesticides in EU30

Pesticides	**ADI (mg/kg bw/day)**	**MRL (mg/kg)**	**Date of approval**	**Expiration of approval**
Chlorotoluron	0.04	0.01 – 0.05	01/03/2006	15/08/2026
Propyzamide	0.05	0.01 – 0.06	01/04/2004	30/06/2025
Pendimethalin	0.125	0.05 – 2.00	01/01/2004	30/11/2024
Flufenacet	0.005	0.10 – 0.15	01/01/2004	15/06/2025
Cypermethrin	0.005	0.05 – 0.7	01/03/2006	31/01/2029
Esfenvalerate	0.0175	0,02 – 0.2	01/08/2001	31/12/2023
Lambda-Cyhalothrin	0.0025	0.01 – 0.7	01/01/2002	31/03/2024
Pirimicarb	0.035	0.01 – 4	01/02/2007	15/03/2025
8-Hydroxyquinoline	0.05	0.01 – 0.05	01/01/2012	31/12/2023
Dimoxystrobin	0.004	0.01 – 0.08	01/10/2006	31/07/2023
Ipconazole	0.015	0.01 – 0.05	01/09/2014	31/05/2023
Tebuconazole	0.03	0.02 – 15	01/09/2009	15/08/2026
Ziram	0.006	0.1 – 0.2	01/08/2004	15/03/2025

Table 2

Environmental and human health hazards of toxic pesticides[11]

Pesticide class	**Pesticide name**	**Use**	**Health hazards**	**Environmental hazard**
HERBICIDE	Chlorotoluron	Cereal crops	Probably toxic to reproduction and carcinogenic; kidney adenomas and adenocarcinomas, and evidence for fetotoxicity.	Very toxic to aquatic life with acute and long-lasting effects. Persistent pollutant
	Propyzamide	Wide range of crops	Cancer, thyroid tumors, adenomas and carcinomas. Effects on hormonal levels and endocrine glands being an endocrine disruptor.	Very toxic to aquatic life. High risks for soil organisms and aquatic organisms living in surface waters.
	Pendimethalin	Broadleaved weeds and grasses, wheat and other small grain cereals, vegetables including beans and peas	Endocrine disruptor, toxic to reproduction, thyroid effects. Cause chromosome aberrations and developmental effects.	A high risk for aquatic organisms (particularly algae), with acute and long-lasting effects. Possibly a persistent, bioaccumulative and toxic substance.

	Flufenacet	Wheat, barley and potatoes	Endocrine disrupting activity, neurotoxic effects and skin sensitizer.	Persistent in soil and water, very toxic to aquatic life. Risk of groundwater contamination
INSECTICIDE	Cypermethrin	Cereal crops, oilseeds and potatoes	Hormone-related adverse effects (for example: reduced male fertility, altered hormone levels and gene expression), possible relation to Parkinson's disease.	Bee-killer and highly toxic for aquatic and soil organisms.
	Esfenvalerate	Potatoes, peas, beans, grassland, cereals. Used for non-agricultural settings such as schools' grounds, industrial sites, and public buildings.	Health risks connected to testicular tumors and developmental effects, endocrine and neurotoxic effects.	Very toxic to aquatic life with acute and long-lasting effects.
	Lambda-Cyhalothrin	A wide spectrum of agricultural crops and other pests such as: mosquitoes, flies and ticks	Acutely toxic in short term exposure. Very neurotoxic: bystanders are advised to keep a 10-meter distance from spraying.	Highly toxic to mammals and fish, aquatic invertebrates and honey bees. Moderately toxic to earthworms. Very toxic to aquatic life.
	Pirimicarb	Wheat, vegetables, fruits and ornamental plants	Suspected carcinogenic.	High risk for aquatic organisms, long term risk to birds is observed. This pesticide has a medium to high persistence in soil. Its metabolites have medium persistence.
FUNGICIDE	8-Hydroxyquinoline	Used as preventative and curative treatment for grapevines, tomatoes, and hops	Toxic to the reproductive system: clear evidence that exposure to this can cause increased abortions and impaired fetal development as well as hormone disruption.	Very toxic to aquatic life, with acute and long-lasting effects.
	Dimoxystrobin	Foliar application in cereals, oilseeds and grass against brown rust, ear blight, stem rot	Probable reproductive toxin and carcinogen.	Very toxic to aquatic life with acute and long-lasting effects. High chronic risks to aquatic invertebrates, algae and to fish and earthworms. High risks to birds and mammals. Risk for groundwater pollution by persistent metabolites.
	Ipconazole	A wide range of crops, including root and leafy vegetables (e.g., beet, carrot, radish, celery, fennel, lettuce, spinach, broccoli, cabbage and kale).	Toxic to the reproductive system: clear evidence connected to malformations in offspring. Adverse effects on the liver, and the thymus gland, impacting the immune system.	High risk to non-target terrestrial vertebrates and other non-target terrestrial organisms. Poses long-term risks to small granivorous birds. Classified as very toxic to aquatic life with acute and long-lasting effects. Ipconazole exhibited high to very high persistence in soil and lasting metabolites.
	Tebuconazole	Cereals (e.g., wheat, barley, oat, rye), oilseed rape and grapes.	Toxic to reproduction, with many negative findings on fetal development. Connected to liver tumors. Endocrine disruptor, altered steroid hormone levels and had effects on receptor binding.	Long-term risk to insectivorous birds, granivorous birds, herbivorous mammals and granivorous mammals. Very toxic to aquatic life, with acute and long-lasting effects.
	Ziram	Almonds, apples, pears, peaches, grape and tomato.	Toxic to reproduction, endocrine disruptor, fatal if inhaled, severe skin burns and eye damage. Endocrine disruptor.	High risk for aquatic organisms and non-target arthropods.

Marín-Benito J.M. *et al.*[26] stated in their study that the flufenacet, a herbicide moderately soluble in water, has two major degradation products (flufenacet ESA (2-[(4-fluorophenyl)-isopropyl-amino]-2-oxo-ethanesulfonic acid) and flufenacet OA (2-[(4-fluorophenyl)-isopropyl-amino]-2-oxoacetic acid), with a soil half-life of 230 days and 11 days, respectively. Khattabi L. *et al.*[31], through their study, showed that pirimicarb had critical deleterious impacts on male rats' health by affecting the neuroimmune-endocrine axis.

Therefore, these pesticides should be immediately banned to protect both the environment and human health.

CONCLUSIONS

Pesticides are chemicals intentionally applied in the environment to suppress plant and animal pests and protect agricultural and industrial products, but which unfortunately have often proven to cause adverse effects on the environment and human health. Many pesticides that are highly toxic to both humans and aquatic and terrestrial ecosystems are still approved for pest control. For example, chlorotoluron, propyzamide, pendimethalin, flufenacet, cypermethrin, esfenvalerate, lambda-cyhalothrin, pirimicarb, 8-hydroxyquinoline, dimoxystrobin, ipconazole, tebuconazole and ziram which were found to be highly toxic to humans and environment are currently approved for use. Most of them are highly toxic to the aquatic environment and endocrine disruptors for humans. Cypermethrin, which is honey bee-killer, has been authorized for use until 2029.

Thus, both within European Union's target to reduce pesticide pollution by 50% by 2030 and the campaign initiated by PAN Europe, it is absolutely necessary to ban these pesticides in the EU as soon as possible.

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