



Mini Review

Pesticide Persistence in Agriculture and its hazardous effects on Environmental Components

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Abstract

Pesticides are applied to protect crops from insects, weeds, and bacterial or fungal diseases during the growth. There would be a 78 percent loss of fruit output, a 54 percent loss of vegetable production, and a 32 percent loss of cereal production if pesticides were not used. When pesticides are applied to a target plant, they have the potential to enter the environment where they can affect non target organisms. Concerns have also been raised about pesticide currently uses and its impact on the environment with the possibility for hazardous or carcinogenic residues. This review paper provides basic information about the general types of pesticide in use and the role of pesticides in agriculture with its impact in environmental components.

Keywords: Agrochemical, Biopesticide, Degradation, Environmental hazards, Human health, Pesticide, Residual effect, Soil

Introduction

Pesticides are chemicals or biological agents that are used to keep pests away. They are applied in agriculture field for attracting, seducing, destroying, or mitigating any pests to protect any crops from its damages (Classification and Impact n.d.). Mainly, pesticides are applied to protect crops from insects, weeds, and bacterial or fungal disease during the growth. Their use is not only restricted to agricultural

fields but also used for protecting stored agricultural products from rat, mice, insects or diverse biological contaminants (MoAFF, 2022). Thus, pesticides include herbicides, insecticides, nematicides, bactericides, molluscicides, avicides, repellants, and fungicides (Bernardes *et al.* 2015). Pesticide's applicators must be aware of the danger and risks of pesticides they apply. The

toxicity of pesticides varies widely. Toxicity is described as the quality of being poisonous or damaging to animals or plants, and it is determined by a substance’s chemical or physical properties (MoAFF, 2022).

Pesticides are vital in agricultural growth because they may minimize agricultural product losses and increase affordable production and food quality (Aktar et al. 2009; Fenik et al., 2011; Strassemeyer et al., 2017). Without a parallel growth in food supply, the world’s population would have surged in the twenty-first century. There would be a 78 percent loss of fruit output, a 54 percent loss of vegetable production, and a 32 percent loss of cereal production if pesticides were not used (Tudi et al., 2021). During World War II, pesticide development accelerated (1939-1945). Furthermore, beginning in the 1940s, the expanded use of synthetic crop protection agents allowed for even more food production (Bernardes et al. 2015). Furthermore, pesticides are used all over the planet from 0.2 million tons in the 1950s to more than 5 million tons in 2000, output climbed at an annual pace of roughly 11% (Carvalho, 2017). Every year, three billion kilos of pesticides are used throughout the world(Hayes and Hansen 2017), although only 1% of all pesticides are successful in controlling insect pests on target plants (Bernardes et al., 2015). The remaining pesticides penetrate or reach non-target plants and environmental media in considerable quantities. Pesticide pollution has subsequently damaged the environment and harmed human health (Bernardes et al., 2015; Hernández et al., 2013).

This literature review provides basic information about the general types of pesticide in use and the role of pesticides in agriculture. The focus then shifts to pesticide behavior in the environment, climate change-related aspects in pesticide usage, and the negative consequences of pesticide use on the ecosystem.

Types of Pesticide Used

Pesticides are classed based on a variety of factors, including chemical classes, functional groups, modes of action, and toxicity (Garcia et al., 2012). To begin, pesticides are divided into categories based on their pest targets, such as fungicides, insecticides, herbicides, and rodenticides. Fungicides, for example, are used to kill fungus, insecticides to kill insects, and herbicides to destroy weeds (Amaral, 2014; Mnif et al., 2011). Pesticides are divided into organic and inorganic compounds in terms of chemical classifications. Copper sulfate, ferrous sulfate, copper, lime, and sulfur are examples of inorganic insecticides. Organic insecticides include more sophisticated components (Kim et al., 2017). Organic pesticides can be classified according to their chemical structure, such as chlorohydrocarbon insecticides, organophosphorus insecticides, carbamate insecticides, synthetic pyrethroid insecticides, metabolite and hormone analog herbicides, synthetic urea herbicides, triazine herbicides, benzimidazole nematocides, metaldehyde molluscicides, metal phosphide rodenticides, and D group vitamin-based rodenticides(Tudi et al. 2021).

Historical Account of Pesticide Use

The green revolution is linked to a huge rise in agricultural yields, which was made possible by the discovery and application of pest control agrochemicals (Dayan et al., 2009). The development and use of pesticides for pest control are attributed with the success of modern agricultural methods(Dayan et al. 2009). Table 1 shows chronological description of pesticides used worldwide.

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Table 1: Important events for pesticides production and uses.

Year	Events
1867	Paris Green (form of copper arsenite) was used to control Colorado potato beetle Outbreak
1885	Introduction of a copper mixture by Professor Mallardite to control mildew
1892	Potassium dinitro-2-cresylate was produced in Germany
1939	DDT discovered by Swiss chemist Paul Muller; organophosphate insecticides and phenoxy acetic herbicides were discovered
1950s	Fungicides captan and glyodin and insecticide malathion was discovered
1961–1971	Agent Orange was introduced
1972	DDT officially banned
2001	Stockholm Convention

Source: Singh (2011)

Role of Fertilizer and Pesticide in Agriculture

Pesticides has been inseparable part of our lives. The yield from crop production relies heavily on the application of pesticides (Isman, 2015). Nearly 67,000 species of organisms affect agricultural crops, and without preventive protection using agrochemicals, 70% of agricultural production could be lost (Kumar & Singh, 2014). The huge burden of diseases that are caused by the vectors has been substantially reduced (Amara,l 2014).

Around the time of World War-II modern era of chemical pest control began as the synthetic organic chemical industry began to develop. First synthetic organic pesticides developed were organochlorines, such as dichlorodiphenyltrichloroethane (DDT) in Switzerland in 1939 (Bajwa and Sandhu 2014). The DDT and other organochlorine insecticides (cyclodiene organochlorines, aldrin and dieldrin, endrin, endosulfan and isobenzan) were widely used as these insecticides control insects by blocking their nervous system, causing malfunction, tremors, and death (Walia *et al.*, 2017).

The increase in food production to sustain growing population today is achieved due to fertilizers(Carvalho 2017). The growth of human population and world production of phosphates has increased significantly and are positively correlated (Roser *et al.*, 2013) . Agricultural productivity also rises by the use of proper pesticides and significantly increases income of farming families (Miller, 1982).

Pesticides Used in Nepal

In the 1950s, pesticides were introduced to Nepal. However, its primary goal was to eradicate malaria. Pesticides are quickly gaining favor among Nepalese farmers. Pesticide usage has become something of an agricultural fad. The enormous health risks posed by pesticides gradually aroused concerns about their usage. In 1991, the Pesticide Act was created to govern pesticide distribution. Thirteen pesticides were first prohibited in Nepal in 2001, in response to rising health concerns and environmental deterioration. Then, between 2007 and 2015, three more pesticides were prohibited. From 2015 forward, eight more pesticides were outlawed. In Nepal, a total of 24 pesticides have been prohibited so far. The Table 2 represents the pesticide name and banned year.

Environmental Contamination by Pesticide

When pesticides are applied to a target plant, they have the potential to enter the environment where they can undergo processes such as transfer and degradation. This pesticide degradation in the environment produces new chemicals(Marie *et al.* 2017). Surveys conducted worldwide have showed the contamination and residues in soil, terrestrial and aquatic ecosystems which also include coastal marine systems (Carvalho 2017). Agrochemical residues spread in the environment causes contamination of

terrestrial ecosystems and also aids in poisoning human foods. This contamination is a unique toxicological concern as pesticides are inherently biologically active substances which are introduced into the environment and they spread unintentionally (Fan and Jackson 1989). This may also result in undesirable residues on various media such as food, drinking water, and air.

Table 2: Banned pesticides names and banned year.

S.N.	Name of pesticide	Banned since
1	Aldrin	2001 AD
2	BHC	2001
3	Chlordane	2001
4	Dieldrin	2001
5	DDT	2001
6	Endrin	2001
7	Heptachlor	2001
8	Lindane	2001
9	Organo mercury compounds	2001
10	Mirex	2001
11	Phosphamidon	2001
12	Toxaphene	2001
13	Methyl parathion	2001
14	Monocrotophos	2007
15	Endosulfan	2012
16	Phorate	2015
Recently banned additional pesticides		
17	Benomyl	Dec,2020
18	Carbofuran	Dec,2020
19	Triazophos	Dec,2020
20	Dichlorvus	Dec,2020
21	Carbaryl	Dec,2020
22	Carbosulfan	Aug 2021
23	Dicofol	Aug 2021
24	Aluminium phosphide (56%)3gm tablet	Aug 2021

Source: Plant Protection Society, Nepal (Anon n.d.)

The organochlorine (OC) pesticides of first generation were environmentally persistent, remaining long time in soils and accumulating in nonhuman organisms with devastating toxic effects at population level (Köhler and Triebkorn, 2013). Pesticide residues are found everywhere in the environment even on marine fauna (Taylor *et al.*, 2002). Development of pathogen and insect populations resistant to synthetic pesticides is another major problem(McCaffery and Nauen 2006).

Pesticide Behavior in The Environment

Pesticides have the potential to enter the environment, when pesticides are applied to a target plant or disposed of. On entering the environment, they undergo processes such as transfer (or movement) and degradation(Marie *et al.* 2017; Scholtz and Bidleman 2007). Pesticide degradation in the environment produces new chemicals(Marie *et al.* 2017). Pesticides relocate from the target site to other environmental media or non-target plants by transfer processes including adsorption, leaching, volatilization,

spray drift, and runoff (Robinson *et al.*, 1999). The different types of chemicals indicate their differences in environmental behavior. For example, organochlorine compounds such as DDT have low acute toxicity but show a significant ability to accumulate in tissues and persist in causing long-term damage. They have been banned from sale in most countries, but their residues remain in the environment for a long time because of their nature. While organophosphate pesticides are of low persistence, they have appreciable acute toxicity in mammals (Damalas and Eleftherohorinos 2011; Kim *et al.* 2017)

Agrochemicals in Soil

In agriculture soil degradation is now considered as one of the greatest environmental challenges (Squire *et al.*, 2015). Agrochemicals applied in the soil for seed treatment, weed control, as well as by spraying on the aerial parts of plants, the falling of treated foliage, and by the movement of contaminated water on the surface and within the soil profile reaches to the soil (Chaplain *et al.*, 2011). Once accumulated in the soil, these chemicals are transported by leaching and surface runoff. They can undergo chemical processes such as hydrolysis, photolysis, and chemical degradation or interact with the living fraction of the soil and be biodegraded (Kookana *et al.*, 1998; Shaheen *et al.*, 2019). Intensive use of agrochemicals increases their persistence in the soil and negatively affects the soil microbes (Campos *et al.* 2019). Pesticides leads to qualitative and quantitative changes in the soil microbiota (Hartmann *et al.*, 2015), causing alterations of soil fertility and, eventually, plant growth (Malik *et al.* 2017).

Adsorption is interaction between soil and pesticides. The extent of adsorption depends on the physical properties of soil and the compound, which include size, shape, configuration, molecular structure, chemical functions, solubility, polarity, polarizability and charge distribution of interacting species, and the acid- base nature of the pesticide molecule (Gevao *et al.*, 2000).

Persistent and bio accumulative chemical compounds, such as DDT, HCH, toxaphene, aldrin, and dieldrin, that were banned by the Stockholm Convention, in 2002, and are now replaced by environmentally friendly chemicals. However, due to massive application of OCs in the past, they are still present in soils, in sediments, and in the biosphere and are toxic (Carvalho, 2006).

Sustainable agriculture should be able to recover soil quality by implementation of strategies as use of biopesticides and biofertilizers, crop diversity, crop rotation (Verma *et al.*, 2015). Botanical pesticides offer a good alternative to traditional chemicals for use in crop protection systems (Bissinger and Roe, 2010).

Agrochemicals in Food

When a pesticide is present in or on food for which the application or use of the substance has not been approved, or when the residue in food is higher than that permitted for human consumption, the pesticide becomes an environmental hazard (Fan and Jackson 1989). Pesticide behavior in the environment, such as volatilization from the treated region to the air, soil, and non-target plants, and residual pesticides conveyed from soil and water to crops, vegetables, and fruits, all contribute to food contamination (Tudi *et al.* 2021). Pesticides of various types are commonly employed in fruit and vegetable growing to boost agricultural output. Which, as a result has lead to multiple incidents of pesticide poisoning that are frequently reported (Bernsten *et al.*, 2009).

Concerns have also been raised about pesticide currently uses and its impact on the environment with the possibility for hazardous or carcinogenic residues to linger in the food chain (Mahindru 2009). Pesticides are unavoidable element of agriculture, yet their widespread usage can result in major health consequences. To reduce pesticide residues below the risk level, several processing techniques are used on fruit and vegetable crops to reduce pesticide residues below the risk level. Furthermore, it was shown that treating vegetables with acidic and alkaline solutions might significantly reduce pesticide residues (Bajwa and Sandhu 2014).

Agrochemicals to Human Health

Unintentional poisonings kill an estimated 355,000 individuals worldwide each year, according to reports, and these poisonings are closely linked to excessive exposure and inappropriate usage of harmful substance (Kumar and Singh, 2014).

The use of various synthetic pesticides on a regular basis can result in a number of issues (Naqqash *et al.*, 2016). This usage has been linked to a variety of human illnesses and problems, including malignancies, respiratory disorders, diabetes, Parkinson's disease, Leukemia, mental disorders, and neurological disorders, to name a few (Kim *et al.* 2017). Unintentional and frequent exposure can cause a variety of illnesses, including asthma, thyroid disease, diabetes mellitus, birth defects and reproductive dysfunction, autism and learning disabilities, neurological disorders such as Parkinson's and Alzheimer's disease, and cancers of the brain, breast, prostate, leukemia, lymphoma, and soft tissue sarcoma, among others (Islam *et al.* 2021).

Agrochemicals on Water Sources

Pesticides drain from treated fields, mixing and washing sites, and waste disposal places, pollutes groundwater (Salem *et al.* 2016). Surface water systems, such as rivers, lakes, streams, reservoirs, and estuaries, are also prone to pesticide and other chemical buildup (Ansara-Ross *et al.* 2012). This is quite concerning since the

extensive presence of chemical residues jeopardizes natural resources such as drinking water, groundwater, and water used in aquaculture (Carvalho 2006).

Pesticides that have lately been introduced and are more degradable, such as chlorpyrifos, parathion, isoproturon, and mecoprop, have been found in river waters (Moreno-González and León 2017). Barceló and Petrovic., 2008 (Gros *et al.*, 2008) found that urban wastewater discharges are a common source of pollution in both urban and coastal locations. Residues of persistent organic pollutants were discovered in deep sea biota, which is still regarded as a pristine habitat (Jamieson *et al.* 2017).

Pesticide Degradation

After pesticides are applied to the target organism, they are degraded by microbes, chemical reactions, or light (Abián, Durand, and Barceló 2002). It may take from hours to days or even years (Tcaciuc *et al.*, 2018), depending on the environmental conditions and the pesticide's chemical characteristics (Wu *et al.*, 2018). Pesticide degradation processes control pesticide persistence in soils and yield different metabolites (Tariq and Nisar 2018). There are three types of pesticide degradation (Luo *et al.* 2018; Su *et al.* 2016). Microbial degradation is the degradation of pesticides by microorganisms such as fungi and bacteria (Han *et al.* 2012). For example, biodegradation is the main path of niclosamide degradation in natural environments, as aerobic and anaerobic naturalized microorganisms have a high capability to degrade niclosamide (Luo *et al.* 2018). Factors including oxygen, temperature, soil moisture, soil pH, and soil porous structure influence pesticide microbial degradation (Qian *et al.*, 2017; Su *et al.*, 2016; Yue *et al.*, 2017). Pesticides can be degraded by chemical reactions in the soil. This process is called chemical degradation (Bansal 2011). Moreover, the chemical reaction of sunlight radiation plays an important role in the degradation of molecules on soil surfaces because it is always active (Geng *et al.* 2017). The rate and type of chemical degradation are influenced by soil temperature, pH levels, moisture, and the binding of insecticides to the soil (Singh, 2011). Photodegradation is the degradation of pesticides by sunlight (Geng *et al.* 2017). All insecticides are capable of photodegradation to some extent, and the rate of degradation depends on the intensity of light, length of exposure, and the properties of the insecticide (Singh, 2011). For example, niclosamide could hydrolyze to generate 5-chlorosalicylic acid and 2-chloro-4 nitroaniline under the effect of light (Luo *et al.* 2018).

Pesticide Migration

Sorption

When pesticides are used, only a small amount of the applied pesticides displays a protective role to fight against plant diseases. In contrast, a large amount of pesticides reaches the soil, resulting in severe soil pollution (Qin *et al.* 2014; Su *et al.*, 2017). The sorption process is a phenomenon that binds pesticides to soil particles due to the attraction between chemical and soil particles (Alvarez *et al.*, 2021; Qin *et al.*, 2014; Su *et al.*, 2016).

Leaching

There are many pesticides that are registered and used worldwide, some of which are likely to leach to the groundwater and cause water pollution (Singh, 2011). Soil permeability and soil solubility is crucial factor influencing pesticide leaching (Fontana *et al.* 2010). Furthermore, the level of leaching also depends on how persistent the insecticide is in the environment. An insecticide low in persistence is less likely to leach as it may remain in the soil for a short time only (Geng *et al.* 2017).

Volatilization

Once pesticides have been volatilized, they can be carried on air currents away from the treated surface (Singh 2011). Vapor pressure, temperature, humidity, air movement (Zhu *et al.*, 2017), and soil conditions such as texture, organic matter content, and moisture (Alamdar *et al.* 2014) determines the volatilization level of pesticides (Connell *et al.* 2005).

Surface Runoff

Runoff is the movement of pesticides in water over a sloping surface (Das *et al.* 2020). Runoff is caused when the speed of water added to a field is so fast that it cannot be absorbed by the soil (Singh, 2011). Pesticide runoff results in pesticide pollution in streams, ponds, lakes, and wells, and pesticide contamination could negatively impact plants, animals, and humans (Aktar *et al.* 2009).

Agrochemicals on Climate Change Related Factors

Since World War II (1939–1945), the use of synthetic pesticides has risen fast to avoid, moderate, or eliminate pests, decrease agricultural output losses, and enhance economical yields and food quality (Damalas and Eleftherohorinos 2011). Many factors impact pesticide application, including socioeconomic considerations, environmental factors such as soil quality, crop development, and the presence of insect pests, weeds, and diseases, and pesticide behavior in the environment. Climate change has a significant impact on these variables (Tudi *et al.* 2021).

Influence on Crop Growth

Climate change causes quick changes in soil characteristics, which leads to changes in pesticide treatments (Bernardes *et al.* 2015). Greater average temperature causes a decrease in soil organic matter, resulting in higher potential for soil erosion due to increased rates of water, organic, and inorganic chemical transport (Bloomfield *et al.*, 2006). Climate change has a direct impact on pesticide application, but it also has an impact on the distribution and growth of crops, insect pests, weeds, and diseases, which in turn has an impact on pesticide usage (Tudi *et al.*, 2021).

Weather variations, such as unpredictable or low rainfall with poor distribution, can have a detrimental influence on agricultural performance and yields (Marvin *et al.*, 2013).

Influence on Pests, Weeds, and Diseases

Climate change may cause phenology and regional distribution changes in a variety of habitats (Scherm, 2004). Climate change has an impact on the distribution and characteristics of pests, hosts, and bio-control agents that have a link with agricultural productivity (Meynard *et al.*, 2017). Climate change is altering pest insects, weeds, and illnesses via increasing temperatures, changing precipitation, and increasing carbon dioxide levels (Alamdar *et al.*, 2014; Fontana *et al.*, 2010; Lesk *et al.*, 2017).

Harmful Effects of Pesticide Use

Farmers throughout the world continue to use chemical pesticides as their first option (Su *et al.* 2016). Pesticide misuse has exposed humanity to a variety of health risks across the world (Islam *et al.*, 2021). Pest and weed resistance have spread fast over the world since the advent of insecticides. Pesticide resistance has been documented in 954 pest species worldwide, including 546 arthropods, 218 weeds, and 190 plant diseases (Tabashnik *et al.* 2014). Pest control costs might rise by approximately \$40 million per year as a result of Laxminarayan and Simpson (2002).

Control of Hazardous Impact of Pesticide Use

To protect the public from additional exposure to these chemicals through widespread environmental pollution, residues from both legacy and present agricultural, industrial, and domestic uses must be closely monitored in the environment and in foods (EFSA. 2017).

For the minimization of risk of different pesticides on health, different processing operations are applied on fruit and vegetable crops that reduce the pesticide residues below the risk level vegetable treatment with acidic and alkaline solutions can be effective (Smith *et al.*, 2021).

Eco-friendly Pesticide: Biopesticide

Botanical pesticides are most suited for use in organic food production in developed nations, but they can play a far larger role in food production and post-harvest protection in impoverished countries (Walia *et al.*, 2017). Biopesticides are thought to be less hazardous, ecologically friendly, and safe for people and other species (Paudel, 2016).

Botanical insecticides, such as nicotine and pyrethrum, once dominated crop protection and domestic pest control before the discovery of the insecticidal properties of DDT and methyl parathion in the late 1930s (Morgan, 2004). However, with the discovery of additional inexpensive and highly efficacious synthetic insecticides (organochlorines, organophosphates, and carbamates) in the 1970s and onward, botanicals were quickly disregarded in pest control (Isman 2006).

With encouraging results, a growing variety of plant essential oils (EOs) have been tested against a diverse spectrum of arthropod pests (Pavela, 2007). Pyrethrum and neem are herbicides made from plant essential oils that are still relatively new on the market. The most frequently used botanical pesticide, pyrethrum, is derived from the blooms of *Tanacetum cinerariifolium* (pyrethrum) (Anon n.d.). The active ingredients in piper are well-known irritants.

Azadirachtin is a molecule with a lot of potential, both in terms of its chemical structure and its biological capabilities as a feeding deterrent and a growth disruptor for most insects (Morgan, 2004). Every year, several research are published demonstrating that EOs have significant potential as active components in the development of botanical pesticides. Despite this, just a few commercial goods based on EOs have been released, and the number of new items is still small. EOs have a significant effect on insects even on sublethal doses (Pavela 2007).

Authors' Contribution

All authors contributed equally at all stages of work. Final form of manuscript was approved by all authors.

Conflict of interest

The authors declare no conflict of interest.

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