Review Article

Pesticides Uses, Impacts on Environment and their Possible Remediation Strategies- A Review

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Abstract | Pesticides are the chemicals substances which are used for prevention of plant diseases, weeds and being used widely for increasing the quantity as well as quality of food products. Naturally, these pesticides interact with environment by altering the properties of host substances by producing the adverse impacts because most of the famers have no idea of using these chemicals substances. Pesticides are absorbed by soil particles which are transported to plants as well as animals through food chain and severely affect the ecosystem by causing acute or chronic disorders in the people of all ages. Similarly these pesticides cause serious threats to the aquatic ecosystem after their release by comprising different toxic substances, heavy metals and contaminants. This review paper has focused on the toxic nature of different pesticides, impacts and their possible refinement strategies from the environment as well as ways to minimize their impacts on plants and animals as adverse impacts of pesticides have also been observed on the human health, plants and other animals which need to control by reducing the use, release and synthesis on large scale.

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Introduction

Pesticides are the chemical substances which are used to kill harmful or which can damage the living organisms (Mathews, 2006). Pesticides have been put in to diferent classes based on their uses and handling e.g. bactericides, algicides, herbicides, fungicides, nematicides, insecticides, and rodenticides, while those having carbon rings are organophosphorus, carbamates, organochlorine, acetamides, Triazines and triazoles, pyrethroids and neonicotinoids (Tarla *et al*., 2020). During the period of green revolution in Pakistan, major focus was also to produce the harmless pesticides in order to control the widespread variety of insects and herbal pests which can deteriorate the quality and quantity of global food stuffs (Hassaan and El-Nemr, 2020; Gunstone *et al*., 2021). Among the pesticides, about 85% production of pesticides is consumed in agriculture sector while rest of pesticides are consumed for the public health activities e.g. for controlling vector-borne diseases, unwanted or extra plants while in industries to control insects, fungi, bacteria, pest's algae in electrical appliances, daily used equipment and food packaging (Gilden *et al*., 2010). It has been estimated that about 5.6 billion pounds of pesticides are being utilized worldwide annually which is also increasing unexpectedly (Alavanja, 2009). The estimated amount of pesticides being used globally is approximately 45% in Europe, 25% in USA and 25% in rest of the world (Bourguet and Guillemaud, 2016) in which China and USA are the top while Pakistan has been ranked at the second position in Soth Asian (Yadav *et al*., 2015; Waheed *et al*., 2017).

A variety of compounds are present in pesticides which are used for different agricultural practices including, herbicides, nematicides, molluscidies, rodenticides, insecticides, fungicides and various plant growth regulators. Pesticides have a wide range of uses, sources and toxic nature depending upon the purpose of use and synthesis (Bashir *et al*., 2018) and due to these reasons; pesticides have high global concerns (Damalas and Eleftherohorinos, 2011) because harvesters and neighborhood of the cultivated areas are exposed directly or indirectly to the pesticides during treatment, cleaning and storage of agriculture products (Hutter *et al*., 2021). Even a good pesticide is not only harmful for the plants and animals in the ecosystem but also causes the damage to the targeted specimen organisms for which being used (Arias-Estevez *et al*., 2008). Unfortunately, many new and powerful pesticides are being formulated to combat the increasing food demand (Mostafalou and Abdollahi, 2013) because without usage of pesticides, vegetables, fruits and cereals are attacked by pests and relevant diseases causing losses of quantity as well as quality of food stuff. However many authors e.g. (Oliveira *et al*., 2021; Riedo *et al*., 2021; Trudi *et al*., 2021) have reported several adverse impacts on plants, animals and ecosystem due to their usage.

Types of pesticides in use

According to Gracia (2012) pesticides are categorized in to diverse groups based on ther chemistry, modes of action, functional groups and toxicity levels. Mostly pesticides are categorized in to fungicides, herbicides, insecticides and rodenticides based on their nature of use (Amaral, 2014; Mnif *et al*., 2011). Group of pesticides based on chemical classes, are categorized into inorganic and organic components. Inorganic pesticides contain copper sulfate, copper, ferrous sulfate, sulfur and lime while organic pesticides are more complex having severe chronic effects (Kim *et al*., 2017). Organic pesticides can be categorized further rendering to their chemical structure, such as chlorohydrocarbon insecticides, carbamate insecticides, organophosphorus insecticides, metabolite, synthetic pyrethroid insecticides, synthetic urea, herbicides, benzimidazole nematocides, triazine herbicides, metal phosphide and rodenticides (Zhang *et al*., 2018).

Overall the use of pesticide is expected to cross about 4 million tons/year (FAOSTAT, 2010) because their supply all over the world is very rough and unchecked (Pimentel, 1996). It has been observed that European countries are utilizing one third of pesticide while a quarter of total pesticide is utilized by North America. Herbicides accounts for approximately half of the total pesticides utilized in North America including fungicides 13%, insecticides 19% and the remaining 22% contains diversity of other materials (Gianessi and Silvers, 1992). Similarly insecticides are also considered as predominant in emerging agricultural activities, i.e. crops and livestock, are the chief consumers of these insecticides worldwide reaching to 74% of the yearly utilization with 1% for forestry (Pimentel *et al*., 1991). Pesticides like Dichloro Diphenyl Trichloroethane (DDT), lindane are being widely used in Scandinavian and Asian countries on large scale for agriculture purposes. (Voldner and Li, 1995). While the maximum use of the DDT is to resist mosquito vectors of tse-tse fly and malaria in South Africa and tropical countries. The use of these pesticides also varies as harvests fluctuate extensively like corn, cotton crops and soybean are the chief herbicides consumers in the world with 75% in United States of America and 25% rest of the world, similarly insecticides are used for plantations while vegetables and vineyards utilize maximum of the fungicides (Pimentel *et al*., 1991).

Pesticides are also classified on the basis of their composition named: Organophosphates, pyrethroids, organochlorines, carbamates and chlorines. Some pesticides are soluble in water while others are soluble in organic solvents. They perform various functions

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on the basis of their composition. They usually touch the nervous system of the pests and destroy them. They are harmless in expressions of their use for non target material (Badii and Landeros, 2007; Ortiz-Hernandez *et al*., 2013).

Behavior of pesticides in the environment

Pesticides after their utilization for target plants, are disposed of in the soil, they normally have capacity to migrate within the soil through water by the process of transport or degradation (Singh, 2012; Liu *et al*., 2015) and finally degradation of pesticide in the environment generates many new substances or chemicals as mntioned in Figure 1 (Marie *et al*., 2017). Pesticides can also move from target sites to other sites having no vegetation by the process of transfer involving leaching, adsorption, spray drift, volatilization and runoff depending upon their behavior (Robinson *et al*., 1999). Pesticides like organochlorine complexes containing DDT which has low acute toxicity but it can produce chronic impacts because this persists in the tissues of plants leading to long lasting destruction of growth and physiological activities, whereas organophosphate pesticides have also slight effects, but these can produce negative impacts if persist for a longer period in mammals (Kim *et al*., 2017; Damalas and Eleftherohorinos, 2011).

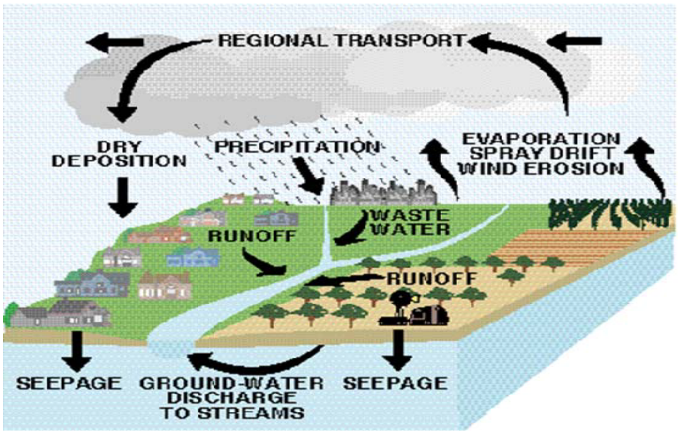

Figure 1: *Pathways of pesticide into aquatic system (Tiryaki and Temur, 2010).*

Initially, pesticides are spread in the environment through air, water, soil, animals and plants but finally these are converted to their derivatives or converted to their more complex structures. The quantity of pesticides also contribute to a larger extent because after degradation, these chemicals migrates towards soil, air and ground water which recirculate with their movement (Kerle *et al*., 2007). Pesticide can persist for a longer period of time in environment depending upon the half life of compounds constituting these pesticides although, a pesticide generally has a half-life of fifteen days. It has been reported by many authors that 50% of the pesticides can exist fifteen days after their applications to the target plants while half of that quantity (25% of the original quantity) can exist for thirty days more. Due to posing this character of extension in the half life, as the life time increases, the mobility of these pesticides also increase in the soil and environment (Tiryaki and Temur, 2010).

There are various factors which effect the persistence of these pesticides which include photo-degradation, microbial degradation and chemical degradation. The degree of degradation of these pesticides in the environment also depends on chemistry of compounds, environmental conditions and circulation pattern (Simeonov *et al*., 2013). Kerle *et al*. (2007) also reported that mobility of pesticides in the environment is exaggerated by the sorption, solubility, vapor pressure, environmental conditions including weather, canopy, topography, ground cover and texture, organic matter, structure of soil. By modeling the occurrence of pesticide, can be a valuable way for evaluating the destiny and also the influence of pesticide in the surroundings, which may be used to find out the amount, frequency of breakdown that provides the evidence for the removal of pesticide from the environment (Sunaryani and Rosmalina, 2021; Tiryaki and Temur, 2010).

Impacts of pesticides on plants, animals, soil ecosystem, aquatic ecosystem and atmosphere

Advantages of pesticides are converted into the disadvantages due to its harmful impacts which are due to interference and inclusion of pesticides in the food chain especially in drinking water sources (Tariq *et al*., 2003) as shown in Table 1. Health impacts are mainly associated with the food which is contaminated with toxic pesticides. This is because pesticides sprayed mostly effect species which are non-targeted in air, water and soil (Miller, 2004). Toxicity of pesticides is resulted from inhalation, ingestion and absorption. If exposure to pesticides continued for a long period, it is resulted in serious diseases including: neurological dysfunctions, hormonal imbalance, immune system dysfunction and blood disorders etc. (Kubrak *et al*., 2012). Pesticides have significant dangerous effects on plant growth, germination, and development, variations in biochemical passageways, yield and some antioxidant enzymes as explained in Table 1 (Parveen *et al.*, 2016). Accumulation of pesticide by plants effects the growth of plants by causing metabolic disorders (Sharples *et al.*, 1997).

Pesticides also have adverse impacts on health of human and animals in several ways as mentioned in Table 2. Pesticides enter into the human body by inhalation from air, dust and vapors containing pesticides, orally by consuming contaminated water and food and by dermal exposure through direct contact with pesticides (Sacramento, 2008). Pesticides are sprayed on food crops from there they secrete in soil and water and pollute them for consuming and spray drift pollute air. Exposure to these contaminated goods takes pace when these are in contact with human body in the environment (Lorenz, 2009). People are put in trouble during management and utilization of pesticides, as these produce toxicity during cleaning, keeping apparatus, pollution of water, clothing and food (Hutter, 2021).

Several impacts of pesticides have also been observed on soil ecosystem as long term storage compartment is provided by soil to pesticides having organic carbon because of its buffer, filtering capacity and high potential of degradation as described in Table 3 (Burauel and Bassmann, 2005). Pesticides present in soil are exposed through direct or indirect ways. Directly these are exposed through application in the field while indirect means are accidental leakage, spillage or run-off through plant surface (Bailey and White, 1970; Rashid *et al.*, 2010). Contamination of soil may occur due to uncontrolled use of pesticides which can kill non-targeted organisms by damaging soil biomass witch effect microorganisms including bacteria, earthworm and fungi (Azam *et al.*, 2003) as shown in Table 4. When pesticides target non-targeted organisms, this damage their metabolism which is required for soil fertility and pesticide degradation (Kale and Raghu, 1989). For control of pests and plant diseases, farmers use pesticides excessively which damage the soil adversely (Oberemok *et al.*, 2015).

Table 1: *Impacts of pesticides on plants.*

S. No	Impact	Reference
1	Affect plant growth, germination, and development, variations in biochemical passageways, yield and some antioxidant enzymes	Parveen *et al.*, 2016
2	Affect the physiology of crop	Giménez–Moolhuyzen *et al.*, 2020
3	Affect the plant growth and cause metabolic disorders	Sharples *et al.*, 1997
4	Block the photosystem II in photosynthesis pathway	DelValle, *et al.*, 1985
5	Affect the photosystem II badly in chloroplast	Devine *et al.*, 1993
6	Reduced chlorophyll a, b and total chlorophyll along with carotenoid contents in the leaves of pepper	Tort and Turkyilmaz, 2003
7	Decrease in the supply of photosynthesis in the roots	Alonge, 2000
8	Decrease in photosystem II and whole chain activities	Mathur and Bohra, 1992
9	Reduced the growth of root and shoot	Mishra *et al.*, 2008
10	Caused nearly complete inhibition of growth in maize plants	Murthy *et al.*, 2005
11	Decrease in pods and seed yield of rice crop	Mugo, 1989
12	Decrease in the growth and yield of barley plants	Boonlertnirun *et al.*, 2005
13	Changes in vegetation growth, death of plant, decrease in reproduction capability, reduced fitness and detrimental, economic and ecological impacts	Altman, 1993
14	Mutations in crop genes and changes in uptake of nutrients, transport of nutrients and metabolism of crops	Marrs *et al.*, 1991

Table 2: *Impacts of pesticides on human and animals.*

Sr. No	Impacts	Reference
1	Cause of chronic diseases which effect nervous system, reproductive system, cardiovascular system, renal system and respiratory system	Mostafalou and Abdollahi, 2012
2	Cause headaches, skin rashes, nausea, body ache, poor concentration, dizziness, cramps, panic attacks, impaired vision, birth defects, production of benign or malignant tumors, toxicity in fetus, mutations, nerve disorders, genetic changes, blood disorders, reproduction effects and endocrine disruption. In animals pesticides cause potential carcinogens, reproductive toxins, neurotoxins and immune toxins. Some studies show the development of neurodegenerative diseases	PAN, 2012

Table 3: *Impacts of pesticides on soil ecosystem.*

Sr. No.	Impact	Reference
1	Damages and reduction of soil biomass	Azam *et al*., 2003
2	Damages in the local metabolism	Kale and Raghu, 1989
3	Contaminate the soil nutrients and cause adverse effects on humans and environment	Oberemok *et al*., 2015
4	Cause acute poisoning for microbial biomass	Yadav and Devi *et al*., 2015
5	Pollute surface and water bodies	Yadav and Devi, 2017
6	Decline in the soil fertility	Jia and Conrad, 2009

Table 4: *Impacts of pesticides on aquatic ecosystem.*

S. No.	Impact	Reference
1	Create pollution in aquatic ecosystem and cause ecological damages which in turn damage the natural habitat of fishes in water bodies	Macneale *et al*., 2010
2	Damages of aquatic life which includes fish and plants by reducing dissolve oxygen levels leading to changes in physiology of aquatic life	Mahmood *et al*., 2016
3	Damage of aquatic plants, animals and marine populations	Helfrich *et al*., 2009

Pesticides also create pollution in aquatic ecosystem as mentioned in Table 4. by contaminating surface and ground water. Ground water contamination cause major changes in water quality. Even after controlled use of pesticides, traces are also found in drinking water which can be a source of human exposure to pesticides (Macneale *et al*., 2010). Water, which is the fundamental need of life, is being polluted severely because of several natural and anthropogenic activities (Hussain and Asi, 2008). Toxicity of pesticides in aquatic ecosystem is depended on some factors including exposure level, immune response, immunologic assay method, stress limits and toxicity of pesticide. Toxicity of pesticides have also been found high when these are present as composite mixture having several components (Banerjee, 1999).

Remediation technologies for pesticides removal

Due to increasing usage of pesticides, it is being a topic of great concern that how to remove pesticides from environment. Many techniques or remedies have been discovered for the removal of pesticides from environment including soil, water, air and food. The instant ways for removal or reduction of pesticide from food are washing, peeling, cooking and blanching (Street, 1969). However these methods are not enough to completely remove pesticides from food due to their stability and persistency. Biological and chemical treatments based technologies are available for pesticide recovery from polluted soil and decommissioning of hazardous wastes (Gavrilescu, 2009). Some suitable techniques have been given in the Table 4 which shows the use of different technologies and plants for removal of pesticides. In this regard, Contaminant-Immobilization Technology (CIT) is an in-situ approach used for very low effective cost for the restoration of soil polluted by pesticides within shorter period of time. In this technique, adsorption takes place which cause toxicity to non-targeted organisms. Minimum treatments are required because carbonate materials are generally are taken up from biological material by using organically active residues (Calugaru *et al*., 2018). Other one which is also most frequently used is the separation technology, in which solvents and synthetic surfactants are used to remove contaminant from sludge medium. In this remediation technique possible methods used are in the form of are; solvents, synthetic surfactants, soil flushing, cyclodextrins and Biosurfactants. The solvent is chosen depending on the pollutant which has to be removed (Mao and Yang, 2013).

Fenton advanced oxidation process is used to remove organochlorode pesticides (OCPs) including DDT. DDT pesticide is highly persistent and has high bioaccumulation which is hazardous to environment. However, this is not enough for complete removal of DDT and other chlorinated organic toxicants. For achieving complete removal of DDT, high utilization of ferrous salts are needed for recovery process and since the acids are used for degradation and removal of DDT, high amounts of acids acidifies the soil and cause erosion with loss of fertility of soil (Villa *et al*., 2008). Supercritical fluid extraction technique is also one of best techniques used for extraction of polycyclic aromatic hydrocarbons from subcritical polluted water. In this technique microorganisms are used for bioremediation and degrading the polycyclic aromatic hydrocarbons from effluents including trinitrotoluene and poly chlorinated biphenyls (Ramos-Contreras *et al*., 2019). In Electro-kinetic remediation technique, zero valance iron nano-particles are used to prevent environment from pollutants such as polychlorinated biphenyls (PCBs) and bio-chlorinated solvents. These are detoxified by using zero valence iron nano-particles but this technique has limitation, as zero valence iron nano-particles have high reactivity (Tummala and Tewari, 2018).

Photocatalysis is also good technique for degradation of pesticides which use semiconductors of metal oxides, sulfides, metal free ions and those materials which serve as substrate for photocatalyst in composite material. This technique may include: titanium oxide based photocatalysis, zinc sulfide based photocatalysis, G-C_3N_4 based photocatalysis and graphite based photocatalysis (Lin and Shen *et al*., 2014). Phytoremediation is a biological technique for the removal of pesticides from environment which is very cheap technique working on solar power. Phytoremediation use efficient plant species which can remove or eliminate pesticide pollutants from environment. This technique can remove pesticide pollutants from 0% to 70% (Main *et al*., 2017). Plants remove pesticide pollutants by using Phytodegradation, Phytoextraction and Rhizodegradation (Truua *et al*., 2015). These techniques are highly ecofriendly, safe, economical or less costly and effective for the removal of pesticide pollutants from environment (Kuppusamy *et al*., 2016). Algae is a potent organism for the removal of pesticide pollutants through microalgae pesticide remediation which is a photosynthetic organism which convert solar energy into chemical energy and has a very simple structure which make transport of nutrients easier and faster (Chacoon-Lee and González-Mariño, 2010). Microalgae remove pesticides from contaminated sites by bioaccumulation and considered a potent organism for this purpose because it uses organic pollutants as their energy source (Chojnacka, 2010). Microalgae are efficient biosorbents which not only accumulate pesticides but also convert them into less toxic substances. The efficiency of this biodegradation is dependent upon environmental condition, nature and concentration of pesticide which is to be degraded (Ortiz-Hernandez *et al*., 2013). Microalgae can survive in any environmental condition and are capable of efficient biodegradation of pesticides from contaminated sites (Subashchandrabose *et al*., 2013).

Degradation of pesticides by using bacteria is another biological method which is very less cost effective, ecofriendly and best technique for removal of pesticides (Gavrilescu, 2005). Bacteria can degrade pesticides at good rate isolated from different ecosystems including bacteria from genus Arthrobacter, Flavobacterium, Burkholderia, Peudomonas and Azobacter. This is an effective technique which does not cause any further damage to environment. In this technique microbes degrade pesticides for nutrients and release CO_2 and H_2O in environment (Huang and Zeng, 2008). Degradation of pesticides is also dependent on the conditions of available environment, exposure and specie of bacteria. Efficiency of bacteria for pesticide removal is faster in the presence of anions (Rani and Dhania, 2014) and bacteria uptake pesticide pollutants converting them into inorganic compounds. Mycoremediation is also a biological technique for pesticide removal which includes fungi for degradation of pesticide as fungi is a eukaryotic, saprophytic, heterotrophic and parasitic organism which produce spore and grow in cool and humid environment (Jobard *et al*., 2010). Fungi transform and detoxify pollutants by taking them up from contaminated environment. By this procedure fungi remove pesticides from soil and water ecosystem (Tortella *et al*., 2005). Fungi also cause changes in chemical structure of pesticide and convert them into non-toxic compounds which are easily degraded by microflora (Hai and Modin, 2012). Fungi use different processes for pesticide degradation including Hydroxylation, Dioxylation, Dechlorination, Dehydrochlorination and Esterification. Fungi use these processes for pesticide degradation because pesticide have various functional groups which minimize the crop damage. Fungi attack on functional groups of pesticides and cause rapid degradation of pesticides (Maqbool *et al*., 2016; Ponnuchamy *et al*., 2021).

Conclusions and Recommendation

Pesticides are chemical fertilizers used mostly in agriculture sector for controlling unwanted organisms which can damage crops. Although pesticides have many benefits but also pose severe impacts on environment. They damage our natural environment by contaminating it and cause several health issues. Recently, removal of pesticide pollutants is a topic of major concern worldwide. Many techniques have been developed for removal of pesticides in this regard and many new techniques are being developed for their safe removal. Pesticides can be removed from soil, water and environment by using plants, animals and different chemicals. Soil and environment can be saved from pesticides toxicity by wise use of pesticide for crops.

Novelty Statement

This review paper will help to get knowledge about the sources, impacts control measures of pesticides which are a serious threat towards health, environmental and soil erosion.

Author's Contribution

Khaliq Dad and Fenliang Zhao: Designed and planned the work.
Rumsha Hassan: Collected the literature.
Tahreem Fatima: Screened the literature.
Humaira Nawaz: Assessed the pesticide material.
Kainat Javed and Muhammad Usman Saleem: Wrote and reviewed the paper.
Muhamad Nawaz: Handled the correction, revision and submission.

Conflict of interest
The authors have declared no conflict of interest.

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