**A comprehensive review of pesticide effects on the environment, human health, and sustainable management as bioremediation**

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**Abstract**

Pesticides are uses for paste control that increases agricultural production. Pesticides are chemicals that are used to control, repel, mitigate, or kill pests that are harmful to humans. Pesticides benefit crops, but they also have a significant negative impact on the environment. Pesticides have an impact on both targeted and non-targeted species, including humans. The parent pesticides, as well as their degradation products and metabolites, can be harmful to the environment, ecosystem, and human health. The World Health Organization (WHO) classifies them according to their harmful effects, emphasizing the importance of public health. The usage can be reduced to a minimum by using them sparingly and with a thorough understanding of their classification, which is beneficial to both the environment and human health. Bioremediation strategies, which are both inexpensive and environmentally friendly, are presently being used to combat pesticide pollution. In this review we discussed pesticides in terms of their global scenarios, such as global distribution, environmental impacts, human health issues, and sustainable management as bioremediation.

**Keyword:** Pesticides, Bioremediation, Enviromental hazards, toxicity, health effects, Eco- sustainable technology.

**Introduction**

Agriculture is the mainstay of Indian economy. In India about 65-70% of its population depends on agriculture for live hood (Sachdeva, 2007). A large part of agricultural land is depleting every year due to the rapid growth in human population, establishment of industries and urban encroachments which creates food scarcity. The Indian agriculture scenario has changed drastically after the first in 1960’s green revolution. Major part of population is being engaged with agriculture in India and for gaining self-sufficiency in food grains and in other agricultural commodities, pesticides and other chemicals were introduced on very large scale for high yielding crop varieties (Tudi et al., 2021). Application and consumption of pesticides are increasing due to increasing demand of agro product in regional climate changes (Strassemeyer et al., 2017).

The term pesticide covers a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators and others. Pesticides contamination from a wide variety of compounds may result from manufacturing, improper storage, handling, and disposal of pesticides, as well as from agricultural processes. Pesticides have been used continuously for preventing disease transmitted by pest such as mosquitoes and fleas in animals and humans, increasing food production by destroying insects and other pests present in agricultural areas and protecting the environment by controlling the growth of moulds, algae and weeds from many decades, (Zhang et al., 2018). Pesticides are biologically active substances which used for averting, destroying and controlling pests by interfering with their metabolic activities (Lamichhane, 2017)*.* It issued globally and mostly in agrarian economy countries like India to fulfill growing populations food demand.

**Types of Pesticides and target organism**

There are different types of pesticides classified according to the target organism. A biocide used to kills a wide-ranging of living organisms. More precise substances are named after their target organism. Herbicides are specially planned to destroy plants, insecticides for insects and fungicides for fungi. Specific pesticides include: acaricides, rodenticides and nematicides, (Osman *et al*., 2011).

1. **Herbicides**

Herbicides are known as weed killers, used to kill unwanted plants. Selective herbicides kill specific targets and while leaving the desired crop relatively unharmed. Some of these interfered with the growth of weed and often synthetic “imitations” of plant hormones. Herbicides are used for clear waste ground, railways, railway embankments and industrial sites are not selective and kill all the plant material with which they come into contact. In other hand smaller quantities are used in forestry, pasture systems and management of areas set aside as wildlife habitat, (Aksakal et al., 2013).

1. **Fungicides**

Fungicides are chemical compound or biological organism used for kill or inhibits fungi or fungal spores. Fungus are small plant like organism which get nourished from other living or nonliving things. Fungicides are used in agriculture as well as to fight fungal infections in animals and humans. Chemicals which used to control oomycetes, and are not fungi are referred as fungicides because they use the same mechanisms as fungi to infect plants, (Toda et al., 2021). Fungicides either can be contact, translaminar or systemic. in contact fungicides it can’t take up plant tissue but only protect the plant where the spray has been deposited, Translaminar fungicides usually redistribute fungicide upper sprayed leaf to lower surface which is unsprayed surface and systemic fungicides taken up and redistributes through xylem vessels to upper part of plants and new leaf growth is protected for a short period, (Rathour et al., 2022).

1. **Insecticides**

An insectides is used against the insects. It includes ovicides and larvicides which are used against the eggs and larvae of insects. Mainly insecticides are used in agriculture, industries, medicine and the household. The major factor behind increasing agriculture productivity in the 20th century is because use of insecticides, (Bowman and Zilberman, 2013). Almost all the insecticides have potential to significantly alter ecosystems; many are concentrated in the food chain and toxic to humans, (Landrigan et al., 2020).

1. **Acaricides**

Acaricides kill fellows of the arachnid order Acari group which include mites and ticks. Acaricides used in agriculture and medicine both, although the chosen selective toxicity between the two fields differs, (Guo et al., 2021).

1. **Nematicides**

Nematicides are chemical type of pesticide used to kill plant parasitic nematodes. Nematicides have lean towards broad spectrum poisonous substance keeping high volatility or some other properties encouraging migration through soil, (Gill and Garg, 2014).

1. **Rodenticides**

Rodenticides are the categorized in pest control chemicals intended to destroy rodents. Single feed baits are chemically sufficiently dangerous, first dose is sufficient to kill, (Tosh, *et al.*, 2011). Rodents are very difficult to kill using poisons because of their feeding habits Reflect their place as scavengers. An effective rodenticide must be unsavory and odorless in lethal concentrations and have delayed effects, (Pelfrene, 2010).

On the basis of chemical nature, pesticides are classified into five groups which are synthetic pyrethroids, organochlorine, carbamate, organophosphate, formamidin and avermectin (Mandal, 2019). Organochlorine, Organophosphate and carbamates are of major group in concern because of their toxicity and persistence in the environment. All these pesticides are widely used worldwide for controlling agriculture and household pests. Organophosphate represent largest group of chemical insecticides which used in plant protection throught out the world (Ghorab and Khalil, 2015). Organophosphate represent about half of the total insecticide used with annual application over 75 million pounds in the United States (Carvalho, 2017). 75% accounted by insecticides of the total market.

**Sources of Pesticides in the environment**

The rapidly growing population in world needs increase in the food production, for this one of main strategies to enhance crop productivity is effective pest management because more than 45% of annual food production is lost due to pest infestation (Dubey et al., 2011). So the application of a wide variety of pesticides becomes necessary in agricultural fields to combat pests. But improper, excessive and misuse of pesticides in agriculture may increase the danger of environmental contamination hazard due to the dispersion of pesticides into non- target sites. Intensive use of chemicals in agricultural has contributed to build up of many hazardous compounds in air, water and soil, which cause environmental pollution (Sharma et al., 2019). Uncontrolled use of pesticides in agricultural areas attributes greatly to environmental and health hazards. The consumption of pesticides in India is comparatively very low, there has been a widespread contamination of food commodities with pesticides residues, basically due to non-judicious usage. India is unfortunately included among those countries where production and use of some chlorinated pesticides such as DDT and lindane is still going on (Sharma et al., 2014). The Survey was performed on the basis of pesticides application in the agricultural field by farmers in Punjab and Haryana showed various health problems including cancer, still birth, infertility, kidney failure, etc. (Abhilash and Singh, 2009). In the world it is reported that more than 2500 pesticides are currently in use (Stehle and schulz, 2015). The world-wide deaths and chronic diseases due to pesticide poisoning number about 1 million per year (Boedeker et al., 2020). The US National Academy of Sciences stated that the DDT metabolite DDE causes eggshell thinning and that the bald eagle population in the United States declined primarily because of exposure to DDT and its metabolites (Aktar et al., 2009).

Recently evidence indicated that pesticides may damage the immune system and it can mimic hormones and many disrupt the endocrine system of both humans and animals, causing a variety of disorders. According to United Nation, approximately 1 to 5 million cases of pesticides poisoning occurs every year, resulting in several thousand fatalities among agriculture workers (Patel et al., 2012). The toxicity in pesticides depends on many factors including exposure, concentration and time of exposure. In India, the First report of poisoning due to pesticides was reported in Kerala in the year 1958, where over 100 people died after consuming wheat flour contaminated with parathion (Kumar et al., 2016). Due to those farmers of villages noted serious health problems to their cattle population due to water contamination. In children’s and women’s the signs of serious ailments were seen (Mrema et al., 2017). A study on workers (N=356) in four units manufacturing HCH in India revealed neurological symptoms (21%) which were related to the intensity of exposure (Hashim, 2015). Data on reproductive toxicity were collected from 1,106 couples when the males were associated with the spraying of pesticides (OC, OP and carbamates) in cotton fields (Hashim, 2015). Early health investigations including liver function, immune function, neurologic impairment, and reproductive effects yielded inconclusive results. An excess mortality from cardiovascular and respiratory diseases was uncovered, possibly related to the psychosocial consequences of the accident in addition to the chemical contamination. An excess of diabetes cases was also found. Pesticides can contaminate soil, water, turf, and other vegetation. Insecticides are generally the most acutely toxic class of pesticides; butherbicides can also pose risks to non-target organisms.

Pesticide residues are found in soil and air, and in surface and ground water across the countries, and urban pesticide uses contribute to the problem. Pesticides can reach surface water through runoff from treated plants and soil. Contamination of water by pesticides is widespread. The results of a comprehensive set of studies done by the U.S. Geological Survey (USGS) on major river basins across the country in the early to mid- 90s yielded startling results. More than 90 percent of water and fish samples from all streams contained one, or more often, several pesticides (Aktar et al., 2009). The USGS also found that concentrations of insecticides in urban streams commonly exceeded guidelines for protection of aquatic life (Philips and Bode, 2004). According to USGS, “in general more pesticides were detected in urban streams than in agricultural streams”, (Philips and Bode, 2004). Groundwater pollution due to pesticides is a worldwide problem. According to the USGS, at least 143 different pesticides and 21 transformation products have been found in ground water, including pesticides from every major chemical class. During one survey in India, 58% of drinking water samples drawn from various hand pumps and wells around Bhopal were contaminated with Organo Chlorine pesticides above the EPA standards (Sarkar, 2019). Heavy treatment of soil with pesticides can cause populations of beneficial soil microorganisms to decline. Indiscriminate use of chemicals might work for a few years, but after a while, there aren’t enough beneficial soil organisms to hold onto the nutrients” (Gyawali, 2018). Pesticide sprays can directly hit non-target vegetation, or can drift or volatilize from the treated area and contaminate air, soil, and non-target plants. Some pesticide drift occurs during every application, even from ground equipment (Gyawali, 2018). Nearly every pesticide investigated has been detected in rain, air, fog, or snow across the nation at different times of the year (Philips and Bode, 2004). Many pesticides have been detected in air at more than half the sites sampled nationwide. Many ester formulation herbicides have been shown to volatilise off treated plants with vapors sufficient to cause severe damage to other plants (Nieder et al., 2018).

**Global scenario of pesticides usage**

Currently, approximately 2 million tonnes of pesticides are used globally, with 47.5% being herbicides, 29.5% being insecticides, 17.5% being fungicides, and 5.5% being other pesticides (De et al., 2014). The United States, Brazil, China, Argentina, Russia, Canada, France, Australia, India, and Italy (Fig.1) are the top ten pesticide-consuming nations in the world (Worldatlas, 2018). Furthermore, it is predicted that global pesticide usage will rise to 3.5 million tonnes by 2020 (Zhang, 2018).

Fig.1: Global pesticide consumption

Although use of chemicals to control pest dates back to 2500 BC, but in the mid-1940s the production and use of synthetic organic pesticides increased rapidly and by 1991, approximately 23,400 pesticide products were registered with the U.S Environmental Protection Agency (EPA). In India use of pesticides began in 1948when BHC (Benzene hexachloride) for locust control and DDT (Dichloro-diphenyltrichloroethane) was imported for malaria control. The production of pesticide in India started with manufacturing plant for DDT and BHC near Calcutta in the year 1952 (Yadav et al., 2015). By the year 1958, India produced over 5000 metric tons pesticides including insecticides like BHC and DDT, and by the mid-nineties , approximately 145 registered pesticides were in use and later on production was increased to approximately by 85,5000 metric tons. Presently, India is the second largest manufacturer of pesticides in Asia after china and ranks 12th globally (Bhardwaj and Sharma, 2013).

In India pesticides are mainly used in public health and agriculture sector for controlling pests and diseases that affect man. The worldwide consumption of pesticides is about two million tons per year, in which 45% in Europe, 25% is consumed in the USA alone, and 25% in the rest of the world, in which India’s share is only 3.75% (Kumar et al., 2019). The consumption of pesticide in agriculture sector is approximately 77%, whereas industrial, commercial and government organizations used 12% and remaining 11% used by private households (Grude et al., 2011). Among different classes of pesticides used in India, the percentage share by insecticides is 76% followed by fungicide (13%), herbicides (11%) and others (1%) (Sharma et al., 2019). The use of herbicides and fungicides is comparatively less. The main use of pesticides in India is for the cotton crops (45%) followed by paddy then wheat crops (Mahajan et al., 2013). As per data presented by the Directorate of plant protection, Quarantine and Storage, Govt. of India, during the period of 2005-06 to 2009-10, sulphur, a fungicide is the maximum consumed pesticide in India with total of 16424 metric tons followed by endosulfan, as shown in **Table 1**.

**Table 1:** Example of most consumed pesticides in India (During 2005-06 to 2009-10)

|  |  |  |
| --- | --- | --- |
| **S.NO.** | **Pesticide(Technical Grade)** | **Quantity consumed (metric tons)** |
| 1 | Sulphur (fungicide) | 16424 |
| 2 | Endosulfan ( insecticide) | 15537 |
| 3 | Mancozed ( fungicide) | 11067 |
| 4 | Phorate ( insecticide) | 10763 |
| 5 | Methyl parathion ( insecticide) | 08408 |
| 6 | Monocrotophos ( insecticide) | 08209 |
| 7 | Cypermethrin ( insecticide) | **07309** |
| 8 | Isoproturon ( herbicide) | 07163 |
| 9 | Chlorpyrifos ( insecticide) | 07163 |
| 10 | Malathion ( insecticide) | 07103 |
| 11 | Carbendazin ( fungicide) | 06767 |
| 12 | Butachlor ( herbicide) | 06750 |
| 13 | Quinalphos ( insecticide) | 06329 |
| 14 | Copper oxychloride | 06055 |
| 15 | Dichlorvos ( insecticide) | 05833 |

**Source-** Directorate of Plant Protection, Quarantine and Storage, Govt of India.

**Production and Usage of Pesticide in India:**

In India the production of pesticides started in 1952 with the establishment of the plant for the production of benzene hexachloride( BHC) at Rishra near Calcutta followed by the two units for manufacturing DDT { 1,1,1-trichloro-2,2-bis (4-chlorophenyl) ethane by Hindustan Insecticides Ltd (Geetha and Fulekar, 2008) Indian pesticide industry is the fourth largest industry among the world. India at present is the leading producer of pesticides among Asian countries. The Indian pesticide industry with 82000 MT of production in the year 2005-06 and ranked second in Asia (Behind china) and twelfth in the world for using pesticides with an annual production of 90,000MT (Boricha and Fulekar, 2009). It has been seen the steady growth of technical grade production of pesticides in India from 5,000MT in 1958 to 102,240MT in 1998. The demand for pesticides in means of value estimated around Rs.22 billion (USD 0.5 billion) in 1996-97 which is around about 2% of the total world market. Pesticides usage pattern in India is different from the world. As can see in Figure.1 in India around 76% of pesticide used is insecticide, as against 44% in globally (Geetha and Fulekar, 2008). The herbicides and fungicides usage is less comparatively. Mostly in India 45% use of pesticide is for cotton crops followed by paddy and wheat crops.

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**Figure.** 2: Consumption pattern of pesticide

**Use of Pesticides in crop protection**

Pesticides are mixture or substances used for preventing, repelling, destroying or mitigating plants and animal’s pests in agriculture as well as domestic field According to census of India 2001, in Gujarat approximately 97% of workers in rural areas are engaged in agricultural activities. The main cash crops of the state are cotton, groundnut, tobacco, cumin, rice and other vegetables. The total estimated consumption of technical grade pesticides is approx. 3642 metric tons in the year 2001-2002 as per data available from department of agriculture, government of Gujarat.

It’s reported that 45% of annual food production is depleted by pest infestations (Abhilash and singh, 2009). Million tons of pesticides are released annually into environment to protect crop plants from damage caused by these pests. Approximately 3% of total pesticides used in the world used by India and its increasing at the rate of 2-5% per annum. Out of the total pesticides consumption in India, Approximately 67%is consumed in agriculture and horticulture field and insecticides accounts 75% of the total. Mainly insecticides include organochlorines (40%), organophosphates (30%), carbamates (15%), synthetic pyrethroids (10%) and others (5%). Remaining 25% of total pesticides used are fungicides (10%), herbicides (7%) and others (8%). According to the Directorate of plant protection, Quarantine and storage, Government of India (2010); Uttar Pradesh is the highest pesticides consuming state during 2005 to 2010, followed by Punjab, Haryana, Maharashtra, Rajasthan, Gujarat and Tamil Nadu as shown in Table .2.

**Table.2: Pesticide-consuming states in India during 2005-2010 (**Source: <http://www.indiaforsafefood.in/farminginindia.html>**).**

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| --- | --- | --- |
| **S. No.** | **State** | **Total pesticides consumed** |
| 1 | Uttar Pradesh | 39948 |
| 2 | Punjab | 29235 |
| 3 | Haryana | 21908 |
| 4 | Maharashtra | 16480 |
| 5 | Rajasthan | 15239 |
| 6 | Gujarat | 13430 |
| 7 | Tamil Nadu | 12851 |
| Total | All India | 210,600 |

During this period of 2005-06 to 2009-10, Uttar Pradesh consumed maximum pesticides followed by Punjab, and in which Gujarat stands on 6th position (**Table. 2**). Besides this, comparing the consumption of pesticide across agricultural crops in India, 45% accounted in cotton followed by rice (22%), vegetables (9%), plantation crops (7%), pulses (4%), wheat (4%) and others (9%) (Subramanyam *et al.,* 2012). In Gujarat, major cash-crops are cotton, groundnut, tobacco, sugar cane, cumin, rice and vegetable including green chillies, where pesticides are commonly used to protect them from pests. According to census of India 2001, approximately 97% of rural area workers are engaged in agriculture related activities. They are using application of pesticides for protecting crops from pests for higher production. As per data available from Department of Agriculture, Government of Gujarat, the estimated consumption of technical grade pesticides was approximately 3643 metric tons during 2001-2002.

**Effect of Pesticide on Environment**

Pesticides primarily enter the environment during planning and application. Application can happen through various procedures, contingent upon variables, for example, the controlled pest, the formulation type, and, the application timing. Pesticides can be applied to crops or to the soil in agriculture. Boom sprayers, tunnel sprayers, and aerial application are all common ways to apply liquid sprays to crops. Systemic pesticides are another option. Pesticides can be applied to soils as granules, sprayed onto the soil surface where they may be incorporated into the soil top layer or injected as a fumigant. Before planting, pesticides are sometimes applied to seeds (Long and Krupke, 2016).

Pesticides can be taken up by target creatures, debased, or moved to the groundwater after application; they can likewise also enter the water bodies surface, volatilize to the air, or reach non-target organic entities by ingestion, for instance. Pesticide behavior and fate are influenced by pesticide physical and chemical properties, soil, site conditions, and management practices. (Perez- Lucas et al., 2019).

Adsorption is affected by the chemical as well as the soil type. Pesticide volatility indicates their proclivity to turn into a gas; the higher the volatility (elevated vapour pressure), the greater the loss to the atmosphere. Humidity and temperature affect volatility, which can occur from soil, plants, or surface water and can last for many days or weeks after application of pesticide. Chemicals can travel long distances through the atmosphere. Pollution of surface water can result from subsequent atmospheric deposition. Eventually, pesticide degradation affects the behavior and fate of these all compounds in the environment. Microorganisms, photodecomposition, and a variety of physical and chemical reactions can all degrade (break them down into some other chemical forms (Gangola et al., 2022).

The following site conditions that can influence pesticide behavior in the environment: depth to topographical circumstances, geology, groundwater, and environment. Because of shallow groundwater filters a lesser volume of water with chemicals and adsorbs and deteriorates fewer pesticides, contamination is a due to geological conditions are significant concern. As to land conditions, the presence of sinkholes, wells, and exceptionally porous materials, for example, stores, rock works with groundwater pollution. The presence of waste trenches, streams, lakes, and ponds expands the likelihood that precipitation or water system spillover will taint surface water. Flat landscapes, areas with closed drainage systems at which water passes toward the centre of a basin, and particularly subsurface areas are more vulnerable to groundwater contamination due to topography. In regard to the climate, heavy rainfall or irrigation may result in large quantities of water percolating through the soil and reaching groundwater. Rainfall can also transport pesticides to contaminating rivers, surface waters, lakes, and seas and transporting these chemicals to remote locations. In terms of pesticide container handling, proper storage and disposal have an influence on environmental contamination (ANR, 2014).

Pesticides that reach non-target organisms might indeed undergo biotransformation via reaction which catalyzed by liver enzymes such as hydrolysis, oxidation, reduction, or conjugation. The organism's attempt to purify and remove xenobiotics is known as biotransformation; however, this method can also generate metabolites which are more harmful than their parent compound, a concept called as bioactivation. The biotransformation of DDT, that is not extremely toxic to birds, into DDE, which causes eggshell shrinking since it disturbs calcium metabolism (Schweitzer and Noblet, 2018) is an example of bioactivation. A study conducted by Semalulu et al., 2005 on agricultural chemicals and metal contaminants in the Ugandan catchment of Lake Victoria discovered the presence of a total count of banned organo chlorinated pesticides (e.g. DDT, endosulfan, lindane and dieldrin) in the air, indicating that they might still be used in the lake Victoria basin. The UK's plan for pesticide sustainability is to make sure that pesticides are utilized in a sustainable manner by lowering the risks and impacts of pesticide use on human health and the environment, as well as encouraging the development and implementation of pest management alternate solution methods and strategies (Ngowi et al., 2007).

**Effect of pesticides on Human health**

Many employees and residents, particularly in the rural sector, come into direct contact with pesticides on a regular basis, putting them at high risk of toxicity. Suicide by pesticides is popular in so many Latin American countries and Asian, as per World Health Organization (WHO) data (WHO, 2014). Pesticides are frequently largely uncontrollable and freely accessible, especially in low and middle-income nations (Sarchiapone et al., 2011). The first epidemiological observations of pesticide-related suicides emerged in the early 1990s. Many organisations and governments are currently concerned about pesticide-related homicides and suicides because suicide and depression clearly relate with high pesticide exposure. This issue has inspired and continues to encourage several more studies into when or where and why pesticide exposure occurs; researchers have also discovered ways to resolve this severe social problem (Freire and koifman, 2013).

Pesticides enter the human body either directly or indirectly. Humans come into contact with pesticides when they are used on crops, and they harm the eyes, mouth, respiratory tract, and skin causing severe reactions including such vomiting, headache, sneezing, skin rashes and irritation. The toxicity of these pesticides to humans is determined by interaction time and concentration. Pesticides are usually eliminated from the body through excretion (urinary, biliary, and secretory gland). Long-term consuming of pesticide-contaminated vegetables and fruits increases the amount of toxins within the body organs and did cause chronic diseases such as neurotoxicity, necrosis, cancer, reproductive disorder, asthma, diabetes, cardiac disease, and many more (Kalyabina et al., 2021). Although quaternary nitrogen compounds like paraquat have been linked to neurodegenerative diseases like Parkinson's, their molecular mechanisms are still unknown (Baltazar et al., 2014). Similarly, the carbamate pesticide group inhibits acetylcholinesterase (AChE) action and is utilized as a biomarker of neurotoxicity (Gupta et al., 2016). The various pesticides are to blame for the cancer issue, but breast cancer is among the most common of all cancer types and is linked to organophosphorus (malathion and parathion) which affects cellular growth and proliferation (Calaf, 2021). Likewise, organophosphorus is implicated in the case of asthma by autoinhibitory M2 muscarinic receptors on parasympathetic neurons that innervate airway smooth muscle (Calaf, 2021). It also decreases fertility and causes genital tract anomalies in both males and females by interfering with endocrine hormone action, scheduling of release, and trying to imitate these hormones. Several studies have found that organophosphorus lessens paraoxonase activity while raising the risk of coronary artery disease (Kabir et al., 2015). Hunger and malnutrition are among the most serious problems across several African countries.

When fertilisers and pesticides are used in farmlands, they are either directly or indirectly transferred into the corns and vegetables, affecting human health (Kumari and Sharma, 2008). Pesticides have been linked to endocrine disruption, chronic neurotoxicity, immune system disruption, carcinogenesis, genotoxicity, and mutagenicity, (Oluwole and Checke, 2019). Pesticide exposure has been linked to diabetes, asthma, Parkinson's disease, cancer, and leukaemia (SIDA, 2016). Kumari and Sharma (2008) and Damalas (2009) conducted research on farmers' perceptions of the effects on the environment of pesticide use as well as strategies used in the Himalaya western mountains.

**Bioremediation as Sustainable management**

Bioremediation is defined as the use of microorganisms for destroying or immobilize waste materials (Abatenh et al., 2017) without further disruption to the local environment. Bioremediation generally occurs due to microorganisms used the pollutants as a sole carbon and nitrogen source. So the degradation of pollutants is accompanied by microbial activities. The activity occurred by microbes in soil are affected by physico-chemical and environmental conditions such as pH value, temperature, moisture content, oxygen and so on. The degradation of pollutant also depends on the presence of other required nutrients like nitrogen, phosphorus and carbon. Bioremediation process is based on the activities of aerobic or anaerobic heterotrophic microorganisms. Very well-known problem throughout the world, mainly in industrialized areas are soil Contaminated with various persistent pollutants. The control and optimization of bioremediation processes is a complex system involving many factors (Kensa, 2011). These factors include the survival of a microbial population capable of degrading pollutants; the bioavailability of contaminants to microbial attack; the environmental factors contributing to microbial growth. Bioremediation process promotes the microbial metabolism of contaminants by adjusting the water; air and nutrient supply in the soil (Bhatt et al., 2021). If the bioremediation performed properly then it can be very cost effective technique. It acquires relatively very low cost which generally have a high public acceptance and can carried out on site. In this technique it involves utilization of naturally occurring microorganisms to detoxify or degrade persistent pollutants which are hazardous to environment as well as human health. In the bioremediation may use indigenous microorganisms to the polluted area or may isolate from elsewhere and brought to contaminated sites. These pollutants are transformed by living microorganisms through various reactions such as bioremediation, bioaccumulation, biomineralizaion, biodegradation, biotransformation and co-metabolism (Zhang et al., 2020; Chugh et al., 2022), By actions of various microorganisms, biodegradation of pesticides take place. In remediation of pesticide waste physico chemical methods are not sufficient and effective. many conventional methods for treating synthetic pyrethroids contaminated sites includes chemical treatment, recycling, incineration , pyrolysis and landfills are not effective ,efficient and costly which can lead to formation of toxic intermediates (Riser-Robert, 2020; Raheem et al., 2018). Thus bioremediation seems to be a reliable technique that utilizes microorganism for the removal of pesticides from contaminated area. Bioremediation is very cost effective and easy to use technique compare to other approaches. It does not pose any threaten of secondary pollution to the environment (Sharma, 2020; Medfu et al., 2020)

Bioremediation process is relatively slow process and requires weeks to months for effective clean up but on other hand it seems good alternative to conventional technologies (Medfu et al., 2020). It can be effective only when environmental conditions are favorable for microbial growth and microbial activities. It often involves manipulation of environmental parameters to allow microbial growth and degradation rate proceeds faster. Some essential factors which affect bioremediation process are pH, temperature, moisture content, organic matter, oxygen, microbe and Level of nutrients and co-substrates.

**Conclusion**

Pesticide use has increased dramatically in recent years, causing ecological harm, particularly water and soil contamination. Pesticides are available in a variety of forms, but the most commonly used pesticides are organophosphates, carbamate, organochlorine, and pyrethroids, which pose human and environmental concerns. Some pesticides, particularly organochlorides, are so persistent in the environment that they do not degrade. As a result, they have long-term environmental effects that are hazardous to both non-targeted organisms and humans. Pesticide misuse and management, as well as pesticide behavior in the environment, contribute to environmental pollution, which includes water pollution, soil pollution, air pollution, and food contamination. The scientific community has been working hard developing innovative methods to pesticide pollution reduction. Numerous bioremediation approaches and servers are used in environmentally sustainable management strategies to fix pesticide issues or identify new green solutions. Bioremediation approaches are also inexpensive and environmentally friendly. The use of pesticide deteriorating microorganisms constructively to manage pesticide pollutants in an environmentally friendly manner. As a result, more research into the screening of effective enzymes and microbial strains is required to decrease pesticide risks to both the environment and human health.

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