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ECO-TOXIC EFFECTS DUE TO EXTENSIVE USE OF PESTICIDES AND PHYTOREMEDIATION IN ACTION

Environmental Science

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ABSTRACT

Frequent use of Insecticides including Carbamates, Organophosphate and Pyrethroids in agriculture increased the environmental toxicity. The use of such chemicals is very common now a days. The proper management, storage and use can help in such toxicity prevention up to some extent. This review article put forwards a detailed discussion on phytoremediation, where it emphasised the importance of phytoremediation of pesticide contaminated soil. The scope of this article covers the basics of carbamate pesticides (Carbofuran), Sources of contamination, ecosystems that are being affected and the rhizosphere as the active site of remediation (importance of plantation to help get rid of toxicity). The recent advantages in the similar field are taken into consideration by reviewing some important research works done in past.

KEYWORDS

Phytoremediation, Environmental Toxicity, Insecticides, Pesticide remediation, Biodegradation.

1. INTRODUCTION

Pesticides now a days are frequently and widely used in agriculture and various other sectors as well. Due to its easy availability and useful applications the extensive use of such chemicals can be encountered very easily. According to the application motive or in easier term according to the targeted organism pesticide is divided into various categories including Insecticides, Herbicides, Rodenticides, Bactericides, Fungicides etc. In various vegetable cultivation pesticides plays a great role in safeguarding the crop because of the high chances of getting exposed and affected by pests (Fontem, Gumedzoe, & Nono-Womdim, 1998). But apart from all these useful applications, studies suggested various adverse effect to human and animal health. Environmental contamination has also been dramatically increased (Abhilash & Singh, 2010; Adeyemi, Ukpo, Anyakora, & Unyimadu, 2008; Aktar, Sengupta, & Chowdhury, 2009). China, Argentina, Thailand, USA, Brazil are the top five countries to use pesticides extensively ("The developing world is awash in pesticides. Does it have to be?," n.d.). Various report also suggests the use of obsolete pesticides in various countries. Obsolete pesticides are those pesticides which are either outdated or banned in a particular country (Chen, Duan, & Luo, 2008). Such pesticides need to be processed further in order to reduce the toxicity. Now as technology and science advanced, we have got exposure to various bioremediation techniques and it basically considered as the mentioned 3 categories, viz Phytoremediation, Microbial remediation and Bioaugmentation (Bisht et al., 2015; Cunningham et al., 1997). In case of phytoremediation, plants will be helping the process of degradation as their roots contains useful bacteria and fungi which encourage the metabolism of toxic elements (Rohrbacher & St-Arnaud, 2016).

2. Classification of Pesticides

Pesticides are divided on the support of different principles. Frequently used principles for classification of pesticides are its mode of entry, mode of action, chemical composition, based on toxicity and source of origin (Akashe, Pawade, & Nikam, 2018).

2.1. Classification On the basis of mode of entry:

The routes through which pesticides comes in contact with the target are known as mode of entry.

2.1.1.Systemic pesticides- Pesticides which are absorbed by plants or animals and shift to untreated tissue. Example- 2,4-D glyphosate.

2.1.2.Contact pesticides: It acts on target pests when they come in contact. Example such as Paraquat, diquat.

2.1.3.Stomach poisons: It enters into the pest's body through their mouthy and digestive system. Example- Malathion.

2.1.4.Fumigants: Pesticides which acts or may kill the target pests by producing vapour and enter pest's body through tracheal system. Example- Phosphine.

2.1.5.Repellents: Repellents do not kill the pest's but make pesticides target tasteless enough to keep pests away from treated area. Example- Methiocarb.

2.2. Classification based on mode of action:

2.2.1.Physical poison: Pesticides starts killing of pests by applying a physical effect. E.g., Activated clay.

2.2.2.Protoplasmic poisons: These pesticides are subjected for precipitation of protein. E.g., Arsenicals.

2.2.3.Respiratory poisons: These pesticides inactivate the respiratory enzymes. E.g., Hydrogen cyanide.

2.2.4.Nerve poison: These poisons obstruct impulse conduction. E.g., Malathion.

2.2.5.Chitin inhibition: These poisons obstruct the chitin synthesis in pests. E.g., Diflubenzuron.

2.3. Classification based on chemical composition:

This is the common process of classifying pesticides i.e., based on chemical composition. Pesticides like insecticides, fungicides, herbicides and rodenticides are also divide on the basis of chemical composition.

2.3.1. Insecticides: On the basis of chemical composition insecticides are classified as carbamates, organochlorine, organophosphorus, pyrethroids and miscellaneous pesticides such as spinosyns, benzoylureas etc.

2.3.2. Fungicides: These are the chemicals which are used to prevent and cure to eliminate the fungi completely. Some examples are aliphatic nitrogen fungicides, amide fungicides, aromatic fungicides, dinitrophenol fungicides, dicarboximide fungicides etc.

2.3.3. Herbicide: These are the toxic substances that are used to kill plants or obstruct the growth of plants. Herbicides are classified as anilid herbicides, phenoxy acetic herbicides, quaternary ammonium herbicides, sulfonylurea herbicides etc. some examples are alachlor, butachlor, cyhalofop, sulfosulfuron, paraquat, atrazine, glyphosate etc.

2.3.4.Rodenticides: These are the substances that are used to kill rats and some other animals. Some of these poison's examples are strychnine, bromadolone, warfarin, zinc phosphide, lindane, aluminium phosphide.

2.4. Classification based on toxicity:

Toxicity of pesticides chiefly depend on two factors namely dose and time. Thus, how much of the substance is involved i.e., dose and how usually the exposure of the substance occurs i.e., time give two different types of toxicity: acute toxicity and chronic toxicity.

2.4.1. Acute toxicity: Acute toxicity indicate how poisonous a pesticide for human, animal or plants after a single short-term exposure. A pesticide is considered to be as deadly even when a very small amount is absorbed.

2.4.2. Chronic toxicity: Chronic toxicity is postponed poisonous effects from exposure to the pesticide after a regular dose long-term exposure.

2.5. Classification based on source of origin:

Pesticides are natural or biological agents that are used to kill undesirable plants and animal pests. Based on source of origin, pesticide may be classified into bio-pesticides and chemical pesticides.

2.5.1. Bio-pesticides: These pesticides act on the target pests and those organisms which are strongly linked to the pests. Bio-pesticides include microbial pesticides and chemicals that are from animals, bacteria, fungi and plants. Bio-pesticides are less toxic, decomposed easily and required in small quantities. Bio-pesticides are classified into three major classes.

- Microbial pesticides
- Plant incorporated protectants
- Biochemical pesticides

2.5.2. Microbial pesticides: These pesticides are made up of microorganisms. The active component of these microbial pesticides are microorganisms such as fungi or bacteria. Examples- Bacterial toxins produced by *Bacillus sphaerius* and *Bacillus thuringiensas* acts on mosquito larvae, black fly larvae.

2.5.3. Plant incorporated protectants: Those pesticides which are produced by plants naturally and genetic material introduced together is termed as plant incorporated protectants.

2.5.4. Bio-chemical pesticides: Those pesticides which combine natural material that have non-toxic mechanism to controls pests. Example- Insect sex pheromones.

2.5.5. Chemical pesticides: Chemical pesticides are actually toxic and not constantly biodegradable. These pesticides affect large group of non-target organisms. These pesticides are divided into organochlorine, organophosphate, carbamates and pyrethroids.

3. Source of Toxicity

When the pesticides directly applied in agricultural fields and industries or indirectly by drifting and volatilization from the treated fields can be the chief source of pesticides toxicity to environment it can contaminate the air, soil and water ecosystem, non-target plants, animals as well. The correct amount of any pesticide that is use in the application to any agricultural fields never fully reaches to the target organisms and its maximum amount is dissolved into the environment. The unused pesticides can cause air contamination, soil contamination, water ecosystem (Suryapratap & Shikha, 2021). Mostly the labours working in the pesticide manufacturing organizations, in fields, executing of household pests and green house are primarily affected by pesticide exposure. The chances of exposure are higher in the working area of the pesticides at the time of manufacturing and management since in this process risk is very high. During manufacturing the chance of exposure is high during this process they deal with several hazardous chemicals including pesticides, crude materials and some dangerous solvents (Rani et al., 2020).

4. Effects of pesticides on aquatic species

The pollution of pesticides in water is a source of greatest risk to the water bodies, primarily by lowering levels of dissolved oxygen in water. they can affect the aquatic species at various trophic levels, from algae to fishes. The distinct research involves the turf regarding pesticides have been discovered in surface water and water sources like streams, lakes and ponds. Heavy usage of pesticides could result in the reduction of number of fishes and other aquatic species. Aquatic species receive exposure of pesticides by three modes i.e, direct absorption by skin (dermally), uptake of pesticides by means of gills (breathing) and intake by drinking contaminated water (orally). The oxygen level decline rapidly due to killing of aquatic plants by usage of herbicides that certainly starts suffocation in fishes and reduce fish production. The reproductive capacity of aquatic species also affected by usage of herbicides. Atrazine showed adverse effects on few fish species and affects the immunity of some amphibians and glyphosate can increase the mortality of tadpoles and young frogs (Rani et al., 2020).

5. Effect of pesticides on soil health

Pesticides are broadly used in the agriculture sector. Only 0.1% of used pesticides are taken by the target and the extra volume can contaminate the soil environment. Pesticides can harm the indigenous microorganisms; disturb soil flora and fauna and they can penetrate into the food chain and can show negative effects on human health.

5.1. Soil enzymes

Pesticides have negative actions on the enzymes of soil which are necessary biocatalysts to regulate the soil quality, to maintain nutrient cycle and involved in fertilization. Pesticides can disturb the activity of enzymes relevant to carbon, nitrogen, sulphur and phosphorus cycles like acid phosphatase, dehydrogenase, fluorescein doacetate hydrolase, beta-glycosidase, urease, aryl sulfatase and alkaline phosphatase. Enzyme activities chiefly depend on soil parameters consisting moisture, organic matter level and temperature. Harmful effects of pesticides on the soil biocatalysts such as oxidoreductase, hydrolases and dehydrogenase were largely noted.

6. Effects of pesticides on the ecosystem

Pesticides have utmost effect on the non-target organisms and also influence the animal as well as plant biodiversity. Majewski and Capel (1996) gave an explanation that around 80-90% of the used pesticides be capable to stimulate in shorted time periods of utilization. As pesticides, being volatilized in nature they can quickly fuse with the air and cause harm to the non-target individuals (Sweet, 1996). The importance of uncontrollable administered of pesticides is decrease in various aquatic and terrestrial plants as well as animal species. Natural ecosystem can be polluted by pesticides in two distinct ways established on their solubility. The pesticides which are dissolved in water can enter into the rivers, lakes, ground water and can generate harm to the non-target organisms. On the other hand, fat soluble pesticides can enter into the bodies of animals through bio-amplification derive the longer survival in the food chain.

7. Effects of pesticides on human health

Various types of health problems including cancer, diabetes mellitus, respiratory disorders, neurological disorders, reproductive syndromes and oxidative stress are caused due to the direct exposure and handling of pesticides etc. The direct exposure to the pesticides is the chief reason of cancer all over the world. Some clues contribute from agricultural health study in relation of raising the risk for cancer of prostate, breast, bladder, lungs, colon due to continuous exposure of pesticides. The importance of distinct explanations proved the interrelationship between the exposure of pesticides and diabetes. Due to regular contact with the pesticides intensify the danger of diabetes. Positive correlation between the organochlorine compounds and diabetes was examined and similar interrelationship with organophosphate was also observed with the risk of type 2-diabetes. Lung diseases including asthma, bronchitis, organic dust lethal condition, over-sensitivity pneumonitis and neuromuscular respiratory failure amongst farm labours can result from the exposure to organic dust, chemicals and toxic gases. Exposure to pesticides shows contributory role in the growth of neurological syndromes. Most familiar diseases linked to the neurotoxic impact of the pesticides are Parkinson's and Alzeheimer's disease. Fertility disorders can also be observed in males as well as females through pesticide exposure (Sweet, 1996).

8. Instrumental Analysis of Pesticides

To determine the quality, concentration of pesticide in soil or water etc. we can implicate various instruments to analyse multiple components. Basically, we can perform quantitative and qualitative analysis for various reasons. When we talk about the use of advance analytical instruments, we are basically using an instrument according to the sample's physical and chemical nature and the bioavailability of active component. So, GC, HPLC, ECD, LC, TLC, Spectrometry, Polarography are the frequently used methods for analysis. Along with these instruments we can attach various detectors, not only in case of pesticide but also for various other elemental analysis. Such detectors including MS, which can be coupled with the GC and LC to give the more accurate quantitative and qualitative results (Hippelein & McLachlan, 1998; Maini & Boni, 1986). Apart from MS we can attach FID, NPD, ECD to GC as well (Sapahin, Makahleh, & Saad, 2019). Similarly, for LC, the MS is most suitable and commonly used detector for pesticide analysis.

Before analysing a sample using any such instrumentation, the sample preparation must be done along with sample clean-up process. In case of pesticide the active compound needed to be separated from plant or soil matter in most of the cases. Liquid phase extraction process is the most frequently used sample preparation technique (Pham, Phan, & Nguyen, 2014; Djurovic, Djordjevic, Radivojevic, Santric, & Gajic-Umiljendic, 2012). Ultra-sonication can also be done to enhance the extraction and mixing process. Sonication or Ultra-sonication basically applies ultrasonic frequencies which is greater than 20kHz to agitate particles in a mixture. Solid phase extraction can be done when the matter is soil or plant. In some case we can also encounter the pesticide present in lipid rich regions. In such case it is more complicated to quantify the amount or concentration of active component that is distributed. Here we can use the higher end extraction methods which includes the Solid phase Micro Extraction (SPME), Microwave assisted Extraction, Supercritical fluid Extraction etc (Fenoll, Hellín, Marín, Martínez, & Flores, 2005). Apart from all this the most common and effective technique that is being practiced now a days is the QuEChERS technique. QuEChERS stands for QUICK, EASY, CHEAP, EFFECTIVE, RUGGED, SAFE.

9. Phytoremediation

Phytoremediation technology basically implicates the plants and their associate microbes in a proper soil amendment and agronomic method to degrade the soil contaminants. This technique is cost effective and an eco-friendly approach for remediation of pesticides in soil. Plants usually encourage the growth of certain microbes including bacteria and fungi, which ultimately helps plant to grow and during this symbiotic phenomenon the toxic elements are transforms into other metabolites either by plant intake or by microbial metabolism. The octanol/water partition coefficient (Kd), (which is defined as the ration of pesticide in organic phase and aqueous phase) plays significant role in phytoremediation as it influences greatly the solubility in water and the uptake of water into the plant and the distribution as well (Hogendoorn, Huls, Dijkman, & Hoogerbrugge, 2001; Aslund, Zeeb, Aslund, Zeeb, & Kulakow, 2009). A healthy soil must consist of the associate microbes in a particular environment friendly concentration apart from all other soil elemental constituents. However, it has already been noted in various studies that phytoremediation effectively increases the soil microbial diversity and the soil health which ultimately leads to the soil quality improvement (Anderson-Teixeira, Davis, Masters, & Delucia, 2009; L. Davis et al., 2014). Figure-1 illustrate the whole process of phytoremediation.

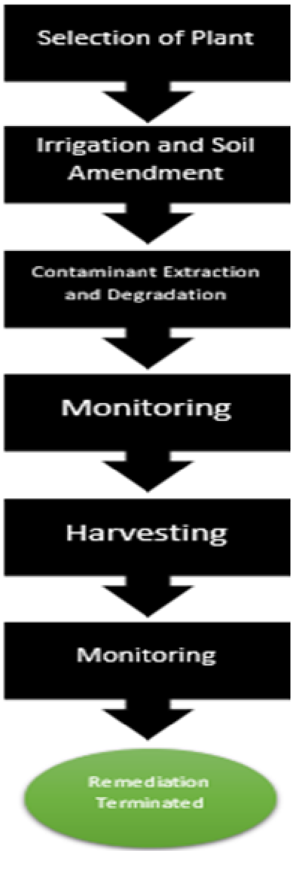

Figure 1

The main process that the plant follows which results in degradation may involve-

a) Addition of a reactive group to the active component such as -OH
b) Conjugation of other element to the active element by the help of additional reactive group and
c) Integration of newly formed compound to any other part of the plant where the toxicity level cannot hamper the plant growth or development (Eevers, White, Vongronsveld, & Weyens, 2017; Truu, Truu, Espenberg, Nolvak, & Juhanson, 2015).

In some case, we can introduce endophytes that can help boosting the phytoremediation process. These can be bacteria or fungus etc (Dhankher, Pilon-Smits, Meagher, & Doty, 2012).

10. Selection of Plants

For the process of phytoremediation, the selection of appropriate plant is important. So, following are some important points to keep in mind while choosing a plant species for such remediation phenomena.

a) The plant's easy availability
b) Plant must survive in the weather condition and environmental fluctuation in the selected region
c) The selected plant must be cost effective
d) Selected plant must be proven to provide the desired result (Hussain, Siddique, Arshad, & Saleem, 2009)
e) There should be no legal objection to grow such plants in local areas
f) The toxicity of soil must not affect adversely to the plant growth (L. C. Davis, Castro-Diaz, Zhang, & Erickson, 2002)

11. Soil Amendments

Various soil amendments can be implicated in order to increase the biodegradation rate in the contaminated zone. Manuring and providing nutrients via composts can be beneficial. In addition to this we can add microbes with degrading enzymes which can boost up the process remarkably (Cycoń, Mrozik, & Piotrowska-Seget, 2017). Arbuscular mycorrhizal fungi have been found effective in phytoremediation as it is having the required beneficial enzymes which are effective against the soil contaminants. pH can be an important parameter to be considered to provide a proper environment for the phytoremediation. Those area which are not exposed to rain fall adequately, needs to be taken care of. Such contaminated zone must be provided with adequate water in order to carry out the process as water is essential for various organism's growth (Brussaard, 1997). To increase water holding capacity organic carbon, biochar can be implicated further.

12. Monitoring

The plant growth and survival rate must be taken into consideration to monitor the fate of vegetation. Further the length of plant and the mass can be recorded. Next thing to be considered is the soil's chemical properties such as Nitrogen concentration, Phosphorus and organic carbon concentration, microbial concentration etc. to be taken into account. The ultimate aim is to record and analyse the progress, wherein we can also get information regarding the plant growth in the amended soil condition. Further enhancement can be performed according to the recorded data (Doran & Zeiss, 2000). Morning glory, cat tail, soybean, groundnut, sunflower, egg plant, Chinese- kale and cabbage these plants can be used to examine phytoremediation capacity. These plants are helpful due to their short life cycle. This short life cycle makes them convenient for planting after harvesting of any crop.

13. Drawbacks of Phytoremediation

Unlike other chemical methods of remediation, the process of phytoremediation is slow as compared to those techniques. Usually, biological processes are slow. But we can expect a result with minimal adverse effect in such case. Apart from this there is no such major drawbacks which can act against the desired results or can put forward major hinderance during the process (Huang & Cunningham, 1996).

14. Conclusion

Use of pesticide is beneficial in several aspects of agriculture sector. Although it is very commonly and widely practised all over the world, we must be aware about the toxic after effect to the environment. The toxicity as discussed above can affect not targeted organisms. So, considering all the adverse impacts there are various methods developed for the degradation of such toxic elements. Phytoremediation as discussed above is one of the cost effective and eco-friendly approach. Also, microbial remediation is having similar impact for degrading pesticides. Bioremediation of carbofuran is reviewed in a recent article named as "Review on Bioremediation of Carbofuran & Different Factors Influencing the Process" (Suryapratap & Shikha, 2021) and the scope of article includes the remediation of carbofuran using various microbes, necessity of degradation and how GMOs can be useful in such remedial activity.

REFERENCES

1. Fontem DA, Gumedzoe MYD, Nono-Womdim R. Biological constraints in tomato production in the western highlands of Cameroon. Tropicultura. 1998;16:89–92.
2. Abhilash PC, Singh N. E ect of growing Sesamum indicum L. on enhanced dissipation of lindane (1,2,3,4,5,6-Hexachlorhexane) from soil. Int J Phytorem. 2010;12:440–453.

3. Adeyemi D, Ukpo G, Anyakora C, Unyimadu J. Organochlorine pesticide residues in fish samples from Lagos lagoon, Nigeria. Am J Environ Sci. 2008;4(6):649–53.
4. Aktar MW, Sengupta D, Chowdhury A. Impact of pesticides use in agriculture: their benefits and hazards. Interdiscip Toxicol. 2009;2(1):1–12.
5. The developing world is awash in pesticides. Does it have to be? [Internet]. Ensia.com. [cited 2020 Dec 31]. Available from: https://ensia.com/features/developing-world-pesticides/
6. Chen Y, Duan J, Luo Y-H. Investigation of agricultural residues pyrolysis behavior under inert and oxidative conditions. J Anal Appl Pyrolysis. 2008;83(2):165–74.
7. Pesticides FAOO, Problems P, DisposalFagervold SK, Chai Y, Davis JW, Wilken M, et al. Bioaccumulation of polychlorinated dibenzo-p-dioxins/dibenzofurans in Eisenia fetida from floodplain soils and the e ect of activated carbon amendment. Environ Sci Technol. 2010;44:5546–5552.
8. Bisht S, Pandey P, Bhargava B, Sharma S, Kumar V, Sharma KD. Bioremediation of polyaromatic hydrocarbons (PAHs) using rhizosphere technology. Braz J Microbiol. 2015;46(1):7–21.
9. Cunningham SD, Shann JR, Crowley DE, Anderson TA, Kruger EL, Anderson TA, et al. Phytoremediation of ContaminatedWater and Soil. In Washington, DC, USA; 1997. p. 12–17.
10. Rohrbacher F, St-Arnaud M. Root exudation: The ecological driver of hydrocarbon rhizoremediation. Agronomy (Basel). 2016;6(1):19.
11. Hippelein M, McLachlan MS. Soil/Air Partitioning of Semivolatile Organic Compounds. 1. Method Development and Influence of Physica Chemical Properties. Environ Sci Technol. 1998;32:310–316.
12. Maini P, Boni R. Gas chromatographic determination of dithiocarbamate fungicides in workroom air. Bull Environ Contam Toxicol. 1986;37(6):931–7.
13. Sapahin HA, Makahleh A, Saad B. Determination of organophosphorus pesticide residues in vegetables using solid phase micro-extraction coupled with gas chromatography–flame photometric detector. Arab J Chem. 2019;12(8):1934–44.
14. Pham TL, Phan TH, Nguyen TD. Analysis of pesticides in soil using dispersive solid phase extraction coupled to GC-MS. Soil Sediment Contam. 2014;23(3):339–52.
15. Djurovic R, Djordjevic T, Radivojevic L, Santric L, Gajic-Umiljendic J. Multiresidue analysis of pesticides in soil by liquid-solid extraction procedure. Pestic Fitomed. 2012;27(3):239–44.
16. Fenoll J, Hellín P, Marín C, Martínez CM, Flores P. Multiresidue Analysis of Pesticides in Soil by Gas Chromatography with Nitroge Phosphorus Detection and Gas Chromatography Mass Spectrometry. J Agric Food Chem. 2005;53:7661–7666.
17. Hogendoorn EA, Huls R, Dijkman E, Hoogerbrugge R. Microwave assisted solvent extraction and coupled-column reversed-phase liquid chromatography with UV detection use of an analytical restricted-access-medium column for the eicent multi-residue analysis of acidic pesticides in soils. J Chromatogr A. 2001;938:23–33.
18. Aslund MW, Zeeb BA, Aslund MW, Zeeb BA, Kulakow P. A Review of Recent Research Developments into the Potential for Phytoextraction of Persistent Organic Pollutants (Pops) fromWeathered, Contaminated Soil. Application of Phytotechnologies for Cleanup of Industrial, Agricultural, and Wastewater Contamination. 2009;V., Eds:35–59.
19. Kiflom WG, Wandiga SO, Ng'ang'a PK, Kamau GN. Variation of plant p,p′-DDT uptake with age and soil type and dependence of dissipation on temperature. Environ Int. 1999;25(4):479–87.
20. Anderson-Teixeira KJ, Davis SC, Masters MD, Delucia EH. Changes in soil organic carbon under biofuel crops. Glob Change Biol Bioenergy. 2009;1(1):75–96.
21. Davis L, Erickson L, Hattiarachchi G, Mengarelli J, Pidlisnyuk V, Roozeboom K, et al. Phytoremediation with Miscanthus Produced for Bioenergy. In Herklion, Greece; 2014.
22. Truu J, Truu M, Espenberg M, Nolvak H, Juhanson J. Phytoremediation and plant assisted bioremediation in soil and treatment wetlands: A review. Open Biotechnol J. 2015;9:85–92.
23. Eevers N, White JC, Vongronsveld J, Weyens N. Chapter 7. Bio and phytoremediation of pesticide-contaminated environments: A review. Adv Bot Res. 2017;83:277–318.
24. Dhankher OP, Pilon-Smits EAH, Meagher RB, Doty S. Biotechnological approaches for phytoremediation. In: Plant Biotechnology and Agriculture. Elsevier; 2012. p. 309–28.
25. Hussain S, Siddique T, Arshad M, Saleem M. Bioremediation and phytoremediation of pesticides: Recent advances. Crit Rev Environ Sci Technol. 2009;39(10):843–907.
26. Davis LC, Castro-Diaz S, Zhang Q, Erickson LE. Benefits of vegetation for soils with organic contaminants. CRC Crit Rev Plant Sci. 2002;21(5):457–91.
27. Akashe MM, Pawade UV, Nikam AV. Classification of pesticides. International journal of Research IN. 2018;
28. Huang JW, Cunningham SD. Lead phytoextraction: species variation in lead uptake and translocation. New Phytol. 1996;134(1):75–84.
29. Suryapratap R, Shikha C. Review on Bioremediation of Carbofuran & Different Factors Influencing the Process. 2021.
30. Rani L, Thapa K, Kanojia N, Sharma N, Singh S, Grewal AS, et al. An extensive review on the consequences of chemical pesticides on human health and environment. J Clean Prod. 2020;(124657):124657.
31. Sweet CW. Pesticides in the atmosphere: Distribution, trends, and governing factors: Michael S. majewski and Paul D. capel, Ann Arbor press, 121 south main st., Chelsea, MI 48118. 1995. 214 p. 1SBN 1─ 57504─ 004─ 2. J Environ Qual. 1996;25(5):1163–4.
32. Cycoń M, Mrozik A, Piotrowska-Seget Z. Bioaugmentation as a strategy for the remediation of pesticide-polluted soil: A review. Chemosphere. 2017;172:52–71.
33. Brussaard L. Biodiversity and ecosystem functioning in soil. AMBIO. 1997;26:563–569.
34. Doran JW, Zeiss MR. Soil health and sustainability: managing the biotic component of soil quality. Appl Soil Ecol. 2000;15(1):3–11.