Agricultural Sciences Journal
Available online at http://asj.mnsuam.edu.pk/index.php
ISSN 2707-9716 Print
ISSN 2707-9724 Online

Research Article

PESTICIDE CONCERNS IN PAKISTAN AND STRATEGIES TO MITIGATE PESTICIDE RESIDUAL EFFECTS

Noel Shamaun[1], Muhammad Aqib Farooq[1], Muhammad Khuram Shahzad[1], Muhammad Usman[1], Muhammad Ahsan[2], Muhammad Sajid[1]

[1]*Department of Biotechnology, University of Okara, Okara, Pakistan*

[2]*Institute of Environmental and Agricultural Sciences, University of Okara, Okara, Pakistan*

Abstract

Unrestrained pesticide usage negatively impacts the ecosystem and harms the health of other organisms, threatening biodiversity. The organophosphates and organochlorine cause convulsions, irritability and tumours which compel us to remove them from the ecosystem for the sustainability of life. The process of cleaning up pesticide-polluted regions is difficult and requires innovative eco-friendly strategies i.e. bioremediation, bio-stimulation and natural attenuation. Bioremediation is the method that biologically degrades organic wastes into their less toxic forms. The current study intends to investigate effective and environmentally acceptable ways of removing pesticide contamination and residues from our ecosystem, with a particular emphasis on bioremediation processes including bacteria, fungus, and other forms of life.

Keywords: Pesticides, Bioremediation, Bacteria, Residual effects, Pakistan

(Received: 25, June 2022 Accepted: 19, August 2022) Cite as: Shamaun. N., Farooq. M. A., Shahzad. M. K., Usman. M., Ahsan. M., Sajid. M., 2022 pesticide concerns in pakistan and strategies to mitigate pesticide residual effects. Agric. Sci. J. 4(2): 90-104.

1. Brief Overview of Pesticides

The word "cide" means to kill and the chemical substances meant to kill or suppress the pests population at tolerable levels are known as pesticides (Jabbar and Mallick 1994). These chemicals are consisting of various products having numerous functions and play quite an important and efficient role in pest management (Asghar et al. 2018). Pest management has historically relied on chemical methods. Pesticides are considered as varied and a large group of different substances designed specifically to kill different organisms such as insects and weeds (Hassaan and El Nemr 2020). Due to the pressing need to expand food production and discover possible chemical warfare weapons in World War II (1939–1945), the research on pesticides accelerated (Bernardes et al. 2015; Gupta 2018). As a result of this, remarkable growth in pesticide production and use was witnessed after WWII and the application of chemicals was considered advantageous in agriculture till 1962 without concerning the possible hazards to the environment and life. In 1962, the first time Rachel Carrison raised her voice against the uncontrolled use of chemicals and their possible effects on life was in her book "Silent Spring" (Gupta 2018; Hamilton and Crossley 2004; Contreras 2020).

After that, a lot of researchers focused on finding the hazardous impacts of chemical use on pest management (Ratcliffe 1967; Butler 1978) and different approaches were developed to control agricultural pests (Walker et al. 2005; Huang and Iskandar 1999). The regular use of different pesticides may also lead to the accumulation of harmful chemicals in various agricultural products (Gupta 2018; Hamilton and Crossley 2004; Joko et al. 2017; Kumar et al. 2019). Numerous pesticides including, herbicides, fungicides, nematicides, insecticides, fumigants, rodenticides, wood preservatives, antioxidants and disinfectants, have adverse effects on the environment (Kumar et al. 2019; Narenderan et al. 2020; Negrete-Bolagay et al. 2021). Almost one-third of the production of agricultural products is damaged because of pesticides every year (Pimentel et al. 1992). Pesticides, on the other hand, are employed over two million tonnes each year. The utilized pesticide products cause the loss of 600 million annually of which 10% are because to birds and rodents, 33% are due to weeds, 20% through insects, 26% are to diseases and 11% from other factors (Jayaraj et al. 2016; Bradman et al. 2007). Pesticides are also used in marine habitats, as well as in domestic and industrial areas (Carvalho and Hance 1993), which harms the environment and harms the health of many creatures, harming biodiversity (Aktar et al. 2009).

The pervasive use of pesticides degrades the quality of soil results to damage the aquatic environment (Joko et al. 2017). Therefore, it is concluded that pesticides activities are forcing us to implement novel approaches to eliminate the harmful chemicals from our environment. Old approaches were utilized to reduce the hazardous chemicals in the environment through pyrolysis, recycling and landfills (Aktar et al. 2009; Abdel-Shafy and Mansour 2018; Eze et al. 2021; Kemona and Piotrowska 2020). However, these approaches have serious effects on society and the environment. The mentioned techniques are expensive and hard to execute specifically for pesticides. Numerous potential approaches used the ability of microorganisms to reduce environmental pollution and to make the economical and eco-friendly (Kharat et al. 2017; Khan and Bano 2016; Kumari et al. 2020).

Biodegradation is the process of degrading pesticides through algae, fungi, bacteria, and other organisms and is considered an economical, efficient and eco-friendly method of detoxification (Kaur and Roy 2021). The genetically modified microorganism is another approach including recombinant strain for degradation of soil bioremediation processes, animal, plant and environmental health (Joutey et al. 2013; El Ghachtouli et al. 2013; Ortiz-Hernández et al. 2013).

2. Contamination of soil

Soil is contaminated with different polluted substances including garbage, pesticides and heavy metals from a variety of sources (Wuana and Okieimen 2011). Municipal garbage often comprises wasted items from households and industrial wastes such as plastic, paper, and organic material. Heavy metals in the soil arise from irrigation, sewage, atmospheric deposition and the use of pesticides and fertilizers (Negrete-Bolagay et al. 2021). The effect of contamination damages the biodiversity and functioning of the soil. Additionally, heavy metals prevent microbial activity (Xie et al. 2016).

3. Contamination of water

The pesticide pollution in the water damages the ecosystems and also the loss of freshwater content. Numerous Asian countries lack access to fresh water and have an acute scarcity of safe drinking water (Brandon 2012). Excessive use of pesticides, herbicides and fertilizers causes adverse damage to aquatic animals (Daniel et al. 1998; Liu and Qiu 2007). Among the pesticides, almost 98% were considered acutely noxious for crustaceans and fishes (De la Cruz et al. 2014). Fig 1 illustrated the effect of pesticides on water, food, soil, and food poisoning in different areas of Pakistan (Tariq et al. 2007).

4. Pesticide poisoning

There have been some documented incidences of pesticide poisoning in Pakistan involving humans, wildlife, and aquatic life (Damalas and Eleftherohorinos 2011). Originally, cramping in the limbs, feeling dizzy, pressure in the chest, changes in faeces, and eye tears were listed as symptoms of methyl parathion poisoning in rural populations (Khan et al. 2020). In the late 1970s, during a malaria control operation, they also found that 40% of spray workers suffered from acute malathion poisoning. According to their findings, malathion caused the deaths of five men and substantial depression in cell and red blood cholinesterase activity in 2800 affected individuals (Badr 2020).

5. Pesticides in food

Pesticide effects have been noted in milk, food, cottonseed, various fruits, vegetables, and fish meal at various times across the nation (Choudhary et al. 2018). Fruits and vegetables have been found to have a considerable variance in pesticide residues, which may be caused by changes in the climate (hot, humid, and cold), as well as variation across various plant species (Bisbis et al. 2018). Because Pakistan's pure food rules are around 40 years old and do not mention pesticide residue limitations in food items, higher values of pesticide residue in food items may also be the result of outdated food regulations (Syed et al. 2014).

Fig. 1. Map of zone studied affected with pesticides. Zone studied the map of pesticides in Pakistan.

6. Pesticide classification and their usage scenario in Pakistan

Pesticides are usually classified based on structure. The structural classification includes nitrogen-based pesticides, carbamates, organophosphorus and organochlorine (Cantrell et al. 2012; Gupta

2011). Pakistan being an agricultural country imported more than 250 metric tons of pesticides for the first time in 1954 after a locust attack. This was the start of the pesticide business in the country, after that the productivity of crops enhanced to 20,648 m tons in 1986-87 (Jabbar and Mallick 1994). After that pesticide business owned by the Private sector was boosted with an annual increase of 25%. More than 105 insecticides, 30 fungicides, 6 rodenticides, and 5 acaricides were among the prevalent pesticides used in Pakistan (Syed et al. 2014; Ejaz et al. 2004; Tariq et al. 2007; Khan et al. 2020). Pyrethroids (45%) comprise the majority of these pesticides, followed by 39% organophosphates, 9% organochlorines and

Table 1. Pesticide residue detection in various ecosystem media and prevalence of pesticide poisoning in Pakistan

Pesticide Characteristics				**Pesticide Poisoning**		
Pesticides	**Pesticide Group**	**Hazardous Class**	**Detected Media**	**Affectees**	**Exposure**	**Effects**
Cypermethrin, Deltamethrin, Diazinon, Monocrotophos and Polytrin-C	Pyrethroids, Organophosphates and combination	II, II, II, Ib	Soil (Jan et al. 2003; Amin et al. 2021)	Vegetable and Fruit workers, Sindh	Occupational	Significant rise in the GOT, ALP and GPT enzyme levels, dyspnea and hepatitis and a burning feeling in the urine (Azmi et al. 2006)
Methamatophos, Baythroids, Cypermethrin, Endone and Aldrin	Organophosphate, Pyrethroid and Organochlorine	I, II, O	Soil (Jan et al. 2003; Amin et al. 2021), Water (Ismail et al. 2021; Eqani et al. 2011)	Female cotton pickers, Punjab (Ahmad et al. 2004) and Sindh (Rizwan et al. 2005)	Occupational as well as Non-Occupational	Significantly increased in reproductive hormones (Ahmad et al. 2004; Rizwan et al. 2005) along with the dangerously increased level of AChE (Ahmad et al. 2004)
Endosulfan, Imidacloprid, Thiodicarb, Carbofuran Methamidophos	Organochlorine, Organophosphate, Carbamate, Carbamate, Organophosphate	II, II, II, Ib, I	Air (Bajwa et al. 2016), Soil (Anwar et al. 2012; Jiandani 2015), Water (Baig et al. 2012)	Factory areas Punjab and Sindh (Khan et al. 2010)	Occupational	Significantly higher concentration of Serum AST, ALT, Antioxidant (total) and Malondialdehyde
Chlorfenapyr	Pyrroles	NA	NA	Chak 105, Punjab (Mohiuddin et al. 2016)	Non Occupational	30 people were killed, while many more were rushed to hospitals for emergency care.
Endosulfan, Aldrin, Dieldrin	Organochlorine	II, II, O	Air (Bajwa et al. 2016) Water (Ahad et al. 2010; Tariq et al. 2004), Soil (Nafees and Jan 2009)	Vehari (Punjab) Farmworkers	Occupational	Farm workers contain the hazardous level of pesticides in their bloodstream (Saeed et al. 2017)

only 4% carbamates widely used against the cotton crop (69%) (Faheem et al. 2015; Sajjad et al. 2015; Tariq et al. 2007). Contrary to the global trend of more herbicides being used than insecticides, Tariq et al. (2004) stated that 74% of Pakistan's overall pesticide application is comprised of insecticides, followed by herbicides (12%). Pesticides cause a lot of health hazards to all types of life due to contamination of soil, water and air. Table 1 illustrates the occurrence of pesticides in soil water and air along with their possible health effects. The present review aims to gather information related to the residual effects of pesticides along with remediation techniques to overcome the effects of pesticides.

7. Pesticide concerns

Pesticides are extremely hazardous to humans and pose a major danger to the quality of water, air, and soil (Damalas and Eleftherohorinos 2011). The pesticide contamination of groundwater and surface is also considered a serious threat to the whole ecosystem and its surroundings (Ahad et al. 2010; An and Zhao 2012; Baig et al. 2012). The pesticide bioremediation technique lowers the toxicity level caused by pesticides. Intrinsic bioremediation occurs due to the microbes present in polluted ecosystems, though subsequently, intrinsic bioremediation is not adequate (Mani and Kumar 2014; Kumar et al. 2011).

8. Pesticide remediation strategies

Pesticide contamination is an adverse environmental issue that must be addressed (Hassaan and El Nemr 2020). Several remediation methods, including chlorination, adsorption, bioremediation, and phytoremediation, have been investigated (Ajiboye et al. 2020; Cycoń et al. 2017). Bioremediation is the method that biologically degrades the organic wastes under controlled conditions to the levels of less concentration of organic materials. Interestingly, this process utilizes the naturally occurring plants, algae, fungi and bacteria for the degradation of harmful substances (Patel et al. 2022; Nie et al. 2020; McLellan et al. 2019; Sarker et al. 2021). Moreover, numerous naturally occurring mitigation processes are also involved in this process including bio-augmentation, bio-stimulation and natural attenuation (Chatterjee 2017). The harmful substances produced as the byproduct of various chemical reactions are being processed by utilizing numerous biological and physiochemical approaches through specific industries to fulfil the basic standards (Chatterjee 2017). The biodegradation process of a substance depends on the activities of numerous microorganisms. Bio-augmentation is the process in which the microorganisms are being used to improve the degradation process (Tyagi et al. 2011; Nzila 2017). The substances with contamination are transformed through various microorganisms leading to the degradation dependent on their metabolic processes to clean the polluted land areas and contaminated water. Bio-pesticides that are commonly used as pathogenic for the pest of interest are bio-insecticides (*Bacillus thuringiensis*), bioherbicides (*Phytophthora*) and bio fungicides (*Trichoderma*) (Gupta and Dikshit 2010; Kachhawa 2017; Ruiu 2015). Following paragraph will illustrate about the different microbe used in bioremediation.

8.1 Role of Bacteria

The bacterial degradation of pesticides belongs to different bacterial species of genera *Pseudomonas*, *Arthrobacter*, *Flavobacterium*, *Azotobacter* and *Burkholderia* (Gurikar et al. 2016; Solyanikova and Golovleva 2004). The oxidation of the parent molecule, which produces carbon dioxide and water along with energy consumed by microbes, is necessary for the pesticide to completely degrade. The pesticides are mandatory to degrade the pests where the innate microbial population is unable to manage the pesticides. Pesticide breakdown by bacteria is influenced by the enzyme system and a variety of environmental factors, such as pH, temperature, and certain other nutrients (Solyanikova and Golovleva 2004). Some pesticides break down rapidly, whereas others are resistant due to the presence of organic anions in the chemical. In addition to organophosphorus chemicals, neonicotinoids are metabolized by pseudomonas species (Parte 2017).

8.2 Role of fungi

Fungi played a crucial part in the breakdown of organic compounds and the modest structural alterations that converted pesticides into innocuous metabolites that could be released into the soil for additional degradation. Figure 2 illustrates a different fungal mechanism for bioremediating hazardous compounds. *Trichoderma Versicolor*, *Phanerochaete chrysosporium* and *P. ostreatus* exhibit good results against dieldrin, simazine and trifluralin residue in soil (Fragoeiro 2005).

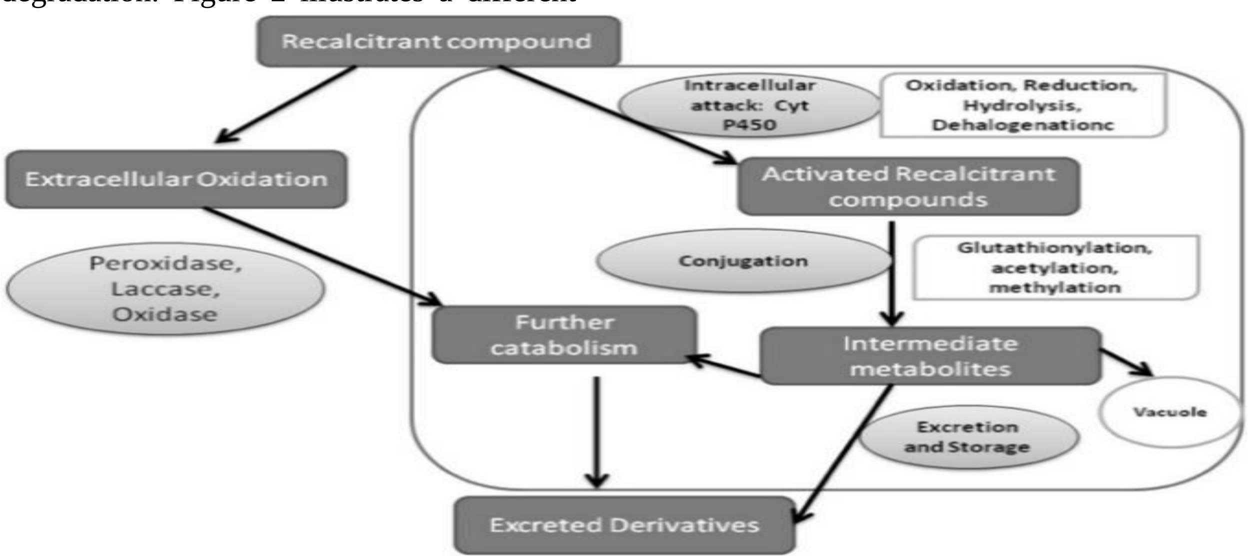

Figure 2: Fungal mechanism for bioremediation hazardous chemicals (Deshmukh 2016).

8.3 Function of enzymes

Enzymes are essential for the biodegradation of all xenobiotics and can significantly speed up the restoration of contaminants (Sarker et al. 2021). The enzymes have the prospective to restore the polluted environment. The enzymes have developed metabolic tolerance and inherent detoxification mechanisms that aid in the breakdown of pesticides (Songa and Okonkwo 2016; Tahir et al. 2020). The theoretical oxygen demand (TOD) enzyme of *P. putida* represents an enzyme family used as biocatalysts in ecologically significant processes (Nikel and de Lorenzo 2018). The fungal enzymes including peroxidase, laccase and oxidoreductases have potent applications for the elimination of polyaromatic hydrocarbons (PAHs) contaminants (Ahsan et al. 2021; Imam et al. 2022).

9. Methods of Removal of Pesticides Residues from Food

Some pesticide residues remain in the environment for long periods before being entirely decomposed by natural forces (Anwar et al. 2012). These persistent substances circulate through plants, animals, air, water, and soil systems to go far. The extensive production and use of such pesticides on one hand and the economic and health problems of obstinate remains on the other, raise the pertinent question: If persisting residues are inevitable, what are the prospects for their removal from foods and other critical sectors? That question is examined in the following paragraphs by employing a brief survey of present information on paths to pesticide removals from foods, soils and water (Chawla et al. 2018; Hamilton and Crossley 2004).

The chemical and physical properties of the parent molecule and its byproducts along with the formulation of the pesticide, and the adsorbents or solvents used affect how long a pesticide residue will last. The qualities of the host may also have a significant role in the persistence i.e., waxy surfaces tend to localise and retain numerous pesticides, making them more difficult to remove than actual surface residues (Baig et al. 2012). Furthermore, milk fats retain traces in the manufacturing of numerous dairy products. Such localization, however, may often be an advantage. For example, fruits and vegetables with easily peeled skins are more amenable to pesticide removal than green leafy vegetables (Chung 2018). Flushing surface residues with water is probably the mildest method that may be effective, while vapour removal by co-distillation with water or some other solvent is extremely effective but generally too severe for many situations (Kaushik et al. 2009). It should be pointed out that these two processes, as well as most other methods, remove pesticides only by physical transfer, thus eventually contributing to the pesticide burdens in air, water and soil.

In discussing foods, it is convenient to categorize the removal of pesticides as either adventitious or intentional. Adventitious is used here to designate any loss of residue occurring as a by-product of normal processing procedures (Street 1969). These paradoxical techniques are effective against the nature of new chemistry insecticides especially systemic insecticides and translaminar insecticides. Such adventitious removals are therefore not only anticipated but relied upon, to provide a substantial margin of safety for the food consumed over and beyond the established safe tolerance. Intentional removal of pesticide residues necessitates processing techniques deliberately designed to remove pesticides and their degradation products.

9.1 Washing and Blanching

Various washing techniques often employed in home or commercial preparation can fairly help eliminate loosely retained residues of many pesticides on a variety of fruits and vegetables (Kaushik et al. 2009). This was the characteristic fate of residues of DDT applied as wet table powder to tomatoes where cold water washing by commercial techniques removed approximately 90% and home-type washing some 78% of the total DDT residues. The use of detergents improved the removal of parathion from spinach, carbaryl from tomatoes, DDT from potatoes, and carbaryl and DDT from apricots (Street 1969). However, in some cases, detergent washing was decidedly less effective than plain water washing. Blanching effectively removes certain residues, although it may not remove more than washing (GC and and Palikhe 2021). National Canners Association (NCA) reveals in a study that blanching of green beans removed substantial portions of DDT, carbaryl and Malathion; water blanching was generally superior to steam (Kaushik et al. 2009). Since the introduction of synthetic organic pesticides into agriculture, researchers have been worried about the destiny of the residues during regular food processing. It was rapidly understood that washing, peeling, and cooking was crucial but not always effective methods of lowering residue levels in fruits and vegetables.

9.2 Peeling

Peeling (and trimming) reduces residues. Washing does not entirely remove substances that penetrate the epidermis, but peeling could be able to get rid of all of the residues. The recent NCA studies showed peeling to be very efficient in the removal of Malathion, DDT, and carbaryl from tomatoes, and DDT from potatoes. Similar observations have been made with other vegetables and fruits (Farrow et al. 1968).

9.3 Cooking

The effects of cooking on pesticide residues are extremely varied but may contribute greatly to residue removal. Shakoori et al. (2018) reported that by cooking through boiling and steam, pesticide residues may decrease up to 20.7-100% in Iranian rice. The NCA studies reported a substantial loss of Malathion during the canning of tomatoes and green beans, but such cooking loss was not apparent for carbaryl in green beans or parathion in spinach and broccoli (Kaushik et al. 2009; Bajwa and Sandhu 2014). Metal ions, especially iron, are involved in the conversion, which does not occur when the canning is done in glass. Major reductions in residues of other compounds have been reported to be affected by cooking.

9.4 Vegetable Oils

Commercial processing of oils may adventitiously reduce chlorinated pesticide residue levels to below detection limits (Chaudry 1980). The key process is in deodorization of the oil by steam stripping under high temperatures. Low-pressure conditions; amount to forced volatilization of the pesticide contaminants. Virtually all the commonly used organochlorine pesticides have been removed from vegetable oils in this manner. The extent to which this type of processing is employed is not known, but monitoring data show that "refined" vegetable oils have substantially lower average residue levels than crude oils.

Various biological fields including biotechnology, bioinformatics, microbiology, biochemistry and molecular biology are trying to solve serious biological issues of health including the removal of organic wastes from the environment (Sehgal et al. 2018a; Tahir and Sehgal 2018; Tahir et al. 2019). Bioinformatics plays a significant role to solve biological problems (Sehgal et al. 2018b).

10. Conclusion

The uncontrolled usage of pesticides threatens the biodiversity of the ecosystem due to their persistency and residual effects. For remediation of these contaminants, bioremediation through microbes serves as an efficient and eco-friendly strategy which is helping to clean the environment for sustainability of life. Further studies are needed about the suitability, efficacy and any potentially harmful environmental implications to use microorganisms on a broad scale for remediation of pesticides and other chemical contaminants.

11. Acknowledgements

The authors acknowledge the Department of Biotechnology, University of Okara for providing the platform for this project.

12. Conflict of interest

The authors declare no conflict of interest.

13. References

Abdel-Shafy, H.I. and M.S. Mansour. 2018. Solid waste issue: Sources, composition, disposal, recycling, and valorization. Egyptian journal of petroleum. 27 (4):1275-1290

Ahad, K., A. Mohammad, H. Khan, I. Ahmad and Y. Hayat. 2010. Monitoring results for organochlorine pesticides in soil and water from selected obsolete pesticide stores in Pakistan. Environmental monitoring and assessment. 166 (1):191-199

Ahmad, R., M. Baloach, A. Ahmad, R. Rauf, H. Siddiqui and M. Khokar. 2004. Evaluation of toxicity due to commercial pesticides in female workers. Pakistan Journal of Medical Sciences. 20 (4):392-396

Ahsan, Z., U. Kalsoom, H.N. Bhatti, K. Aftab, N. Khalid and M. Bilal. 2021. Enzyme-assisted bioremediation approach for synthetic dyes and polycyclic aromatic hydrocarbons degradation. Journal of Basic Microbiology. 61 (11):960-981. doi:https://doi.org/10.1002/jobm.202100218

Ajiboye, T.O., A.T. Kuvarega and D.C. Onwudiwe. 2020. Recent strategies for environmental remediation of organochlorine pesticides. Applied Sciences. 10 (18):6286

Aktar, W., D. Sengupta and A. Chowdhury. 2009. Impact of pesticides use in agriculture: their benefits and hazards. Interdisciplinary toxicology. 2 (1):1-12

Amin, M., A.R. Gurmani, M. Rafique, S.U. Khan, A. Mehmood, D. Muhammad and J.H. Syed. 2021. Investigating the degradation behavior of Cypermethrin (CYP) and Chlorpyrifos (CPP) in peach orchard soils using organic/inorganic amendments. Saudi Journal of Biological Sciences. 28 (10):5890-5896

An, B. and D. Zhao. 2012. Immobilization of As (III) in soil and groundwater using a new class of polysaccharide stabilized Fe–Mn oxide nanoparticles. Journal of hazardous materials. 211:332-341

Anwar, T., I. Ahmad and S. Tahir. 2012. Determination of pesticide residues in soil of Nawabshah District, Sindh, Pakistan. Pakistan Journal of Zoology. 44 (1)

Asghar, K., N. Nawaz, F. Anjum and M. Ramzan. 2018. Knowledge, attitude and practices of pesticides used by farmers and its implications on their health in district Okara. Journal of Agricultural Research (03681157). 56 (2)

Azmi, M.A., S. Naqvi, M.A. Azmi and M. Aslam. 2006. Effect of pesticide residues on health and different enzyme levels in the blood of farm workers from Gadap (rural area) Karachi—Pakistan. Chemosphere. 64 (10):1739-1744

Badr, A.M. 2020. Organophosphate toxicity: Updates of malathion potential toxic effects in mammals and potential treatments. Environmental Science and Pollution Research. 27 (21):26036-26057

Baig, S.A., N.A. Akhter, M. Ashfaq, M.R. Asi and U. Ashfaq. 2012. Imidacloprid residues in vegetables, soil and water in the southern Punjab, Pakistan. Journal of Agricultural Technology. 8 (3):903-916

Bajwa, A., U. Ali, A. Mahmood, M.J.I. Chaudhry, J.H. Syed, J. Li, G. Zhang, K.C. Jones and R.N. Malik. 2016. Organochlorine pesticides (OCPs) in the Indus River catchment area, Pakistan: status, soil–air exchange and black carbon mediated distribution. Chemosphere. 152:292-300

Bajwa, U. and K.S. Sandhu. 2014. Effect of handling and processing on pesticide residues in food- a review. J Food Sci Technol. 51 (2):201-220. doi:10.1007/s13197-011-0499-5

Bernardes, M.F.F., M. Pazin, L.C. Pereira and D.J. Dorta. 2015. Impact of pesticides on environmental and human health. Toxicology studies-cells, drugs and environment.195-233

Bisbis, M.B., N. Gruda and M. Blanke. 2018. Potential impacts of climate change on vegetable production and product quality–A review. Journal of Cleaner Production. 170:1602-1620

Bradman, A., J.M. Schwartz, L. Fenster, D.B. Barr, N.T. Holland and B. Eskenazi. 2007. Factors predicting organochlorine pesticide levels in pregnant Latina women living in a United States agricultural area. Journal of exposure science & environmental epidemiology. 17 (4):388-399

Brandon, J. 2012. Asia: The World's Most Water-Stressed Continent. The Asia Foundation, March. 21

Butler, G.C. 1978. Principles of ecotoxicology. Wiley New York,

Cantrell, C.L., F.E. Dayan and S.O. Duke. 2012. Natural products as sources for new pesticides. Journal of natural products. 75 (6):1231-1242

Carvalho, F. and R. Hance. 1993. Pesticides in tropical marine environments: Assessing their fate. IAEA bulletin. 35 (2):14-19

Chatterjee, R. 2017. Bioremediation: A tribute to Green Chemistry. CONSCIENTIA.35

Chaudry, M.M. 1980 A. Chlorinated pesticides in soybeans, soybean oil, and its by-products during processing. B. Effect of thermal oxidation on mixtures of palm and soybean oil. University of Illinois at Urbana-Champaign,

Chawla, P., R. Kaushik, V.S. Swaraj and N. Kumar. 2018. Organophosphorus pesticides residues in food and their colorimetric detection. Environmental Nanotechnology, Monitoring & Management. 10:292-307

Choudhary, S., N.R. Yamini, S.K. Yadav, M. Kamboj and A. Sharma. 2018. A review: Pesticide residue: Cause of many animal health problems. Journal of Entomology and Zoology Studies. 6 (3):330-333

Chung, S.W. 2018. How effective are common household preparations on removing pesticide residues from fruit and vegetables? A review. Journal of the Science of Food and Agriculture. 98 (8):2857-2870. doi:https://doi.org/10.1002/jsfa.8821

Contreras, J.L. 2020. A Historical Note on The Assignment of Pesticide Common Names. Standards Engineering.11-14

Cycoń, M., A. Mrozik and Z. Piotrowska-Seget. 2017. Bioaugmentation as a strategy for the remediation of pesticide-polluted soil: A review. Chemosphere. 172:52-71

Damalas, C.A. and I.G. Eleftherohorinos. 2011. Pesticide exposure, safety issues, and risk assessment indicators. International journal of environmental research and public health. 8 (5):1402-1419

Daniel, T., A. Sharpley and J. Lemunyon. 1998. Agricultural phosphorus and eutrophication: A symposium overview. Journal of environmental quality. 27 (2):251-257

De la Cruz, E., V. Bravo-Durán, F. Ramírez and L.E. Castillo. 2014. Environmental hazards associated with pesticide import into Costa Rica, 1977-2009. Journal of Environmental Biology. 35 (1):43

Deshmukh, R., Khardenavis, A. A., & Purohit, H. J. 2016. Diverse metabolic capacities of fungi for bioremediation. Indian journal of microbiology. 56 (3):247-264

Ejaz, S., W. Akram, C.W. Lim, J.J. Lee and I. Hussain. 2004. Endocrine disrupting pesticides: a leading cause of cancer among rural people in Pakistan. Exp Oncol. 26 (2):98-105

El Ghachtouli, N., N.T. Joutey, W. Bahafid and H. Sayel. 2013. Biodegradation: Involved Microorganisms and Genetically Engineered Microorganisms. Chapters.

Eqani, S.A.M.A.S., R.N. Malik and A. Mohammad. 2011. The level and distribution of selected organochlorine pesticides in sediments from River Chenab, Pakistan. Environmental Geochemistry and Health. 33 (1):33-47

Eze, W.U., R. Umunakwe, H.C. Obasi, M.I. Ugbaja, C.C. Uche and I.C. Madufor. 2021. Plastics waste management: A review of pyrolysis technology. Clean Technol. Recycl. 1:50-69

Faheem, N., A. Sajjad, Z. Mehmood, F. Iqbal, Q. Mahmood, S. Munsif and A. Waseem. 2015. The pesticide exposure through fruits and meat in Pakistan. Fresenius Environmental Bulletin. 24 (12):4555-4566

Farrow, R.P., F.C. Lamb, R.W. Cook, J.R. Kimball and E.R. Elkins. 1968. Removal of DDT, malathion, and carbaryl from tomatoes by commercial and home preparative methods. Journal of Agricultural and Food Chemistry. 16 (1):65-71. doi:10.1021/jf60155a006

Fragoeiro, S.I.d.S. 2005 Use of fungi in bioremediation of pesticides. CRANFIELD UNIVERSITY,

GC, Y.D. and B.R. and Palikhe. 2021. From the field to dining table: Pesticides residues. Journal of Agriculture and Environment. 22 (1):1-16

Gupta, P.K. 2018. Toxicity of herbicides. In: Veterinary toxicology. Elsevier, pp 553-567

Gupta, R.C. 2011. Toxicology of organophosphate and carbamate compounds. Academic Press,

Gupta, S. and A. Dikshit. 2010. Biopesticides: An ecofriendly approach for pest control. Journal of Biopesticides. 3 (Special Issue):186

Gurikar, C., M. Naik and M. Sreenivasa. 2016. Azotobacter: PGPR activities with special reference to effect of pesticides and biodegradation. In: Microbial inoculants in sustainable agricultural productivity. Springer, pp 229-244

Hamilton, D. and S. Crossley. 2004. Pesticide residues in food and drinking water: human exposure and risks. John Wiley & Sons,

Hassaan, M.A. and A. El Nemr. 2020. Pesticides pollution: Classifications, human health impact, extraction and treatment techniques. The Egyptian Journal of Aquatic Research. 46 (3):207-220

Huang, P.M. and I.K. Iskandar. 1999. Soils and groundwater pollution and remediation: Asia, Africa, and Oceania. CRC Press,

Imam, A., S. Kumar Suman, P.K. Kanaujia and A. Ray. 2022. Biological machinery for polycyclic aromatic hydrocarbons degradation: A review. Bioresource Technology. 343:126121. doi:https://doi.org/10.1016/j.biortech.2021.126121

Ismail, M., S. Alam, M.S. Khan, L.A. Shah, S.M. Shah, M. Wahab, G. Rukh, N.u. Rahman, N. Rehman and N.u. Amin. 2021. Levels and Potential Health Hazards of Chlorinated Pesticides in Surface Water Samples of Charsadda Area of Pakistan Using SPME-GC-ECD Technique. Water. 13 (18):2468

Jabbar, A. and S. Mallick. 1994. Pesticides and environment situation in Pakistan. JSTOR,

Jan, M.R., M. Nafees, J. Shah, S. Begum and S. Rehman. 2003. Determination of pesticide content in selected soils and water samples. American Laboratory. 35 (2):21-22

Jayaraj, R., P. Megha and P. Sreedev. 2016. Organochlorine pesticides, their toxic effects on living organisms and their fate in the environment. Interdisciplinary toxicology. 9 (3-4):90-100

Jiandani, M.A. 2015 Soil adsorption of pesticides used on vegetables in southern Sindh. University of Sindh Jamshoro, Sindh,

Joko, T., S. Anggoro, H.R. Sunoko and S. Rachmawati. 2017. Pesticides usage in the soil quality degradation potential in Wanasari Subdistrict, Brebes, Indonesia. Applied and Environmental Soil Science. 2017

Joutey, N.T., W. Bahafid, H. Sayel and N. El Ghachtouli. 2013. Biodegradation: involved microorganisms and genetically engineered microorganisms. Biodegradation-life of science. 1:289-320

Kachhawa, D. 2017. Microorganisms as a biopesticides. J Entomol Zool Stud. 5 (3):468-473

Kaur, S. and A. Roy. 2021. Bioremediation of heavy metals from wastewater using nanomaterials. Environment, Development and Sustainability. 23 (7):9617-9640

Kaushik, G., S. Satya and S.N. Naik. 2009. Food processing a tool to pesticide residue dissipation – A review. Food Research International. 42 (1):26-40. doi:https://doi.org/10.1016/j.foodres.2008.09.009

Kemona, A. and M. Piotrowska. 2020. Polyurethane recycling and disposal: Methods and prospects. Polymers. 12 (8):1752

Khan, D.A., I. Hashmi, W. Mahjabeen and T.A. Naqvi. 2010. Monitoring health implications of pesticide exposure in factory workers in Pakistan. Environmental monitoring and assessment. 168 (1):231-240

Khan, M.I., M.A. Shoukat, S.A. Cheema, H.N. Arif, N.K. Niazi, M. Azam, S. Bashir, I. Ashraf and R. Qadri. 2020. Use, contamination and exposure of pesticides in Pakistan: a review. Pakistan Journal of Agricultural Sciences. 57 (1)

Khan, N. and A. Bano. 2016. Role of plant growth promoting rhizobacteria and Ag-nano particle in the bioremediation of heavy metals and maize growth under municipal wastewater irrigation. International Journal of Phytoremediation. 18 (3):211-221

Kharat, M.G., S. Murthy and S.J. Kamble. 2017. Environmental applications of nanotechnology: A review. ADBU Journal of Engineering Technology. 6 (3)

Kumar, A., B. Bisht, V. Joshi and T. Dhewa. 2011. Review on bioremediation of polluted environment:: A management tool. International journal of environmental sciences. 1 (6):1079

Kumar, S., S. Prasad, K.K. Yadav, M. Shrivastava, N. Gupta, S. Nagar, Q.-V. Bach, H. Kamyab, S.A. Khan and S. Yadav. 2019. Hazardous heavy metals contamination of vegetables and food chain: Role of sustainable remediation approaches-A review. Environmental research. 179:108792

Kumari, S., R. Jamwal, N. Mishra and D.K. Singh. 2020. Recent developments in environmental mercury bioremediation and its toxicity: A review. Environmental Nanotechnology, Monitoring & Management. 13:100283

Liu, W. and R. Qiu. 2007. Water eutrophication in China and the combating strategies. Journal of Chemical Technology & Biotechnology: International Research in Process, Environmental & Clean Technology. 82 (9):781-786

Mani, D. and C. Kumar. 2014. Biotechnological advances in bioremediation of heavy metals contaminated ecosystems: an overview with special reference to phytoremediation. International journal of environmental science and technology. 11 (3):843-872

McLellan, J., S.K. Gupta and M. Kumar. 2019. Feasibility of using bacterial-microalgal consortium for the bioremediation of organic pesticides: application constraints and future prospects. In: Application of Microalgae in Wastewater Treatment. Springer, pp 341-362

Mohiuddin, H., R. Siddiqi and P. Aijaz. 2016. Pesticide poisoning in Pakistan: the need for public health reforms. Public health. 141:185

Nafees, M. and M. Jan. 2009. Residues of cypermethrin and endosulfan in soils of Swat valley. Soil Environ. 28 (11):113-118

Narenderan, S., S. Meyyanathan and B. Babu. 2020. Review of pesticide residue analysis in fruits and vegetables. Pre-treatment, extraction and detection techniques. Food Research International. 133:109141

Negrete-Bolagay, D., C. Zamora-Ledezma, C. Chuya-Sumba, F.B. De Sousa, D. Whitehead, F. Alexis and V.H. Guerrero. 2021. Persistent organic pollutants: The trade-off between potential risks and sustainable remediation methods. Journal of Environmental Management. 300:113737

Nie, J., Y. Sun, Y. Zhou, M. Kumar, M. Usman, J. Li, J. Shao, L. Wang and D.C. Tsang. 2020. Bioremediation of water containing pesticides by microalgae: mechanisms, methods, and prospects for future research. Science of The Total Environment. 707:136080

Nikel, P.I. and V. de Lorenzo. 2018. Pseudomonas putida as a functional chassis for industrial biocatalysis: From native biochemistry to trans-metabolism. Metabolic Engineering. 50:142-155. doi:https://doi.org/10.1016/j.ymben.2018.05.005

Nzila, A. 2017. Mini review: Update on bioaugmentation in anaerobic processes for biogas production. Anaerobe. 46:3-12

Ortiz-Hernández, M.L., E. Sánchez-Salinas, E. Dantán-González and M.L. Castrejón-Godínez. 2013. Pesticide biodegradation: mechanisms, genetics and strategies to enhance the process. Biodegradation-life of Science. 10:251-287

Parte, S.G., Mohekar, A. D., & Kharat, A. S. 2017. Microbial degradation of pesticide: A review. African Journal of Microbiology Research. 11 (24):992-1012. doi:https://doi.org/10.5897/AJMR2016.8402

Patel, A.K., R.R. Singhania, F.P.J.B. Albarico, A. Pandey, C.-W. Chen and C.-D. Dong. 2022. Organic wastes bioremediation and its changing prospects. Science of The Total Environment.153889

Pimentel, D., H. Acquay, M. Biltonen, P. Rice, M. Silva, J. Nelson, V. Lipner, S. Giordano, A. Horowitz and M. D'amore. 1992. Environmental and economic costs of pesticide use. BioScience. 42 (10):750-760

Ratcliffe, D. 1967. Decrease in eggshell weight in certain birds of prey. Nature. 215 (5097):208-210

Rizwan, S., I. Ahmad, M. Ashraf, S. Aziz, T. Yasmine and A. Sattar. 2005. Advance effect of pesticides on reproduction hormones of women cotton pickers. Pak J Biol Sci. 8 (11):1588-1591

Ruiu, L. 2015. Insect pathogenic bacteria in integrated pest management. Insects. 6 (2):352-367

Saeed, M.F., M. Shaheen, I. Ahmad, A. Zakir, M. Nadeem, A.A. Chishti, M. Shahid, K. Bakhsh and C.A. Damalas. 2017. Pesticide exposure in the local community of Vehari District in Pakistan: an assessment of knowledge and residues in human blood. Science of the Total Environment. 587:137-144

Sajjad, A., F. Iqbal, Q. Mahmood and A. Waseem. 2015. The Pesticide Exposure Through Fruits and Meat in Pakistan.

Sarker, A., R. Nandi, J.-E. Kim and T. Islam. 2021. Remediation of chemical pesticides from contaminated sites through potential microorganisms and their functional enzymes: Prospects and challenges. Environmental Technology & Innovation. 23:101777

Sehgal, S.A., S. Kanwal, R.A. Tahir, Z. Khalid and M.A. Hammad. 2018a. In silico elucidation of potential drug target sites of the Thumb Index Fold Protein, Wnt-8b. Tropical Journal of Pharmaceutical Research. 17 (3):491-497

Sehgal, S.A., A.H. Mirza, R.A. Tahir and A. Mir. 2018b. Quick guideline for computational drug design. Bentham Science Publishers,

Shakoori, A., H. Yazdanpanah, F. Kobarfard, M.H. Shojaee and J. Salamzadeh. 2018. The Effects of House Cooking Process on Residue Concentrations of 41 Multi-Class Pesticides in Rice. Iran J Pharm Res. 17 (2):571-584

Solyanikova, I.P. and L.A. Golovleva. 2004. Bacterial Degradation of Chlorophenols: Pathways, Biochemica, and Genetic Aspects. Journal of Environmental Science and Health, Part B. 39 (3):333-351. doi:10.1081/PFC-120035921

Songa, E.A. and J.O. Okonkwo. 2016. Recent approaches to improving selectivity and sensitivity of enzyme-based biosensors for organophosphorus pesticides: A review. Talanta. 155:289-304

Street, J.C. 1969. Methods of removal of pesticide residues. Can Med Assoc J. 100 (4):154-160

Syed, J.H., A. Alamdar, A. Mohammad, K. Ahad, Z. Shabir, H. Ahmed, S.M. Ali, S.G.A.S. Sani, H. Bokhari and K.D. Gallagher. 2014. Pesticide residues in fruits and vegetables from Pakistan: a review of the occurrence and associated human health risks. Environmental Science and Pollution Research. 21 (23):13367-13393

Tahir, R.A., A. Bashir, M.N. Yousaf, A. Ahmed, Y. Dali, S. Khan and S.A. Sehgal. 2020. In Silico identification of angiotensin-converting enzyme inhibitory peptides from MRJP1. PloS one. 15 (2):e0228265

Tahir, R.A. and S.A. Sehgal. 2018. Pharmacoinformatics and molecular docking studies reveal potential novel compounds against schizophrenia by target SYN II. Combinatorial chemistry & high throughput screening. 21 (3):175-181

Tahir, R.A., H. Wu, N. Javed, A. Khalique, S.A.F. Khan, A. Mir, M.S. Ahmed, G.E. Barreto, H. Qing and G.M. Ashraf. 2019. Pharmacoinformatics and molecular docking reveal potential drug candidates against Schizophrenia to target TAAR6. Journal of cellular physiology. 234 (8):13263-13276

Tariq, M.I., S. Afzal and I. Hussain. 2004. Pesticides in shallow groundwater of bahawalnagar, Muzafargarh, DG Khan and Rajan Pur districts of Punjab, Pakistan. Environment International. 30 (4):471-479

Tariq, M.I., S. Afzal, I. Hussain and N. Sultana. 2007. Pesticides exposure in Pakistan: a review. Environment international. 33 (8):1107-1122

Tyagi, M., M.M.R. da Fonseca and C.C. de Carvalho. 2011. Bioaugmentation and biostimulation strategies to improve the effectiveness of bioremediation processes. Biodegradation. 22 (2):231-241

Walker, C.H., R. Sibly and D.B. Peakall. 2005. Principles of ecotoxicology. CRC press,

Wuana, R.A. and F.E. Okieimen. 2011. Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation. International Scholarly Research Notices. 2011

Xie, Y., J. Fan, W. Zhu, E. Amombo, Y. Lou, L. Chen and J. Fu. 2016. Effect of heavy metals pollution on soil microbial diversity and bermudagrass genetic variation. Frontiers in plant science. 7:755