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Research Article

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Impact of Pesticides Residues on Soil Bacterial Populations in Selected Communities of Ondo South, Nigeria

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Abstract

Farmers use natural and synthetic pesticides to protect crops against rodents, insects, and disease-causing microbes. With an increasing human population, large quantities of pesticides are used to control pests and increase food yields. Pesticides have been linked to numerous environmental problems, including water, soil and air contaminations, biodiversity loss, and pest resistance. Despite the known risks, farmers in most nations are increasing their pesticide use. This study aims to evaluate the amount of pesticides in selected soil samples and its impact on the microbial population of the soil. Soil samples from ten communities designated A to J were collected with soil auger from tillage and rooting depth of plants (0 – 21cm) into sterile polytene bags in triplicates. Cultural, morphological and biochemical reactions were used for bacterial identification, while Gas Chromatography - Mass Spectrometry (GC-MS) was used in the pesticide analysis. In the control community (OAUSTECH), bacterial population range from 90.00 x 10^5±0.00 cfu/g to 92.67x 105±0.58cfu/g across the eight locations while the population ranged from 16.67x10^5±1.16 to 71.33 x 10^5±1.16 in the treatment communities. The bacterial number in the treatment communities differ significantly ($P < 0.005$) compared to the control. For pesticide analysis, Endosulfan ether range from 0.01 ±0.006ppm to 0.04 ±0.006ppm; Dieldrin from 0.03±0.0012ppm to 0.05 ±0.0010ppm; a P-DDT from 0.03 ±0.0012ppm to 0.06±0.0025ppm and Endrin ketone from 1.20 ±0.0037ppm to 2.06 ±0.015ppm. The results of this study, which show that pesticides negatively affect soil microbial populations, validate and support current environmental concerns.

Keywords: Crops, Pesticides, Agricultural loss, Pollution, Bacteria.

1. Introduction

Since the turn of the last century, worldwide grain production has climbed from 500 million tons to the current level of 700 million tons per year [1]. Cereals, in particular, make up over 80% of the food consumed by humans worldwide [2]. Pests can cause damage to crops even when they are growing or in storage. For instance, China is primarily an agricultural nation, but every year, a variety of insect pests waste 40 million tons of the country's entire grain output [3]. India averages 250 million tons of grain production year but it loses 11-15% of that total, or roughly 27.5-37.5 million tons, to pests and other reasons. Agricultural and domestic pests are commonly controlled with pesticides to prevent losses of this nature [4]. Pesticides are natural or synthetic compounds that are used to destroy insects, disease causing microorganisms, rats and weeds. They include insecticides, herbicides, nematicides, fungicides, molluscicides, rodenticides, plant growth regulators, and other compounds [5-7]. The term "pest" is used to describe any organism, plant or animal, that causes harm to humans or other animals hence pesticides are used by farmers to destroy or inhibit the development of pests. (USEPA, 2004). The persistent use of chemical inputs like pesticides has damaged the environment, harmed human health, decreased agricultural output, and lowered the sustainability of farming [8-11]. Several pests and illnesses have flourished due to the elimination of their helpful predators by pesticides in agricultural ecosystems. Although, the use of chemical inputs such as pesticides has increased agricultural production and productivity. Immediate benefits, such as increased crop yields and quality as a result of insect elimination, are the principal benefits of employing pesticides in farming. Pesticides are also used to prevent illnesses spread by vectors, including crop protection, food preservation, and significant roles in commercial as well as food based industrial practices, i.e., aquaculture, agriculture, food processing, and storage [12-14]. This is why, despite all the risks, the use of pesticide is on the increase across the nations particularly the developing ones while biological methods of pest control are increasingly limited.

About 4.19 million metric tons of pesticides were used worldwide in 2019, with China using the most (1.76 million metric tons), followed by the United States (408,000 tons), Brazil (377,600 tons), and Argentina (204,600 tons) [15]. According to the World Health Organization, pesticide use is rising annually in southeast Asia, with 20% of developing countries being consumers [16-17]. The average annual usage of pesticides was 2.784 kg ha^{-1} between 2010 and 2014, with a cost-benefit ratio of 0.645 g of total pesticides per kilogram of crop production with highest usage by Japan (18.94 kg ha^{-1}) and least usage by India (0.26 kg ha-1) as shown in Figure 1 while the classification of pesticides and its impacts on human is as shown in figure 1. The drawbacks associated with the use of pesticides are caused by improper use, a lack of information on how to use them in terms of quantity, a high amount of discharge into water bodies, and pesticides that are adsorbed, desorbed, and broken down as they travel through the soil. The occurrence of these phenomena is contingent on pesticide properties such as persistence, bioaccumulation, and toxicity. As a result of this process, soils become secondary sources of contaminants in terms of air-soil exchange [18]. Pesticide bioavailability in the food web, pesticide assimilation, toxic kinetics, dispersion, metabolism, and excretion all have an effect on species. On numerous crop species, pesticides are used excessively and arbitrarily, harming beneficial biota such as microorganisms, honeybees, predators, birds, plants, and small animals [19].

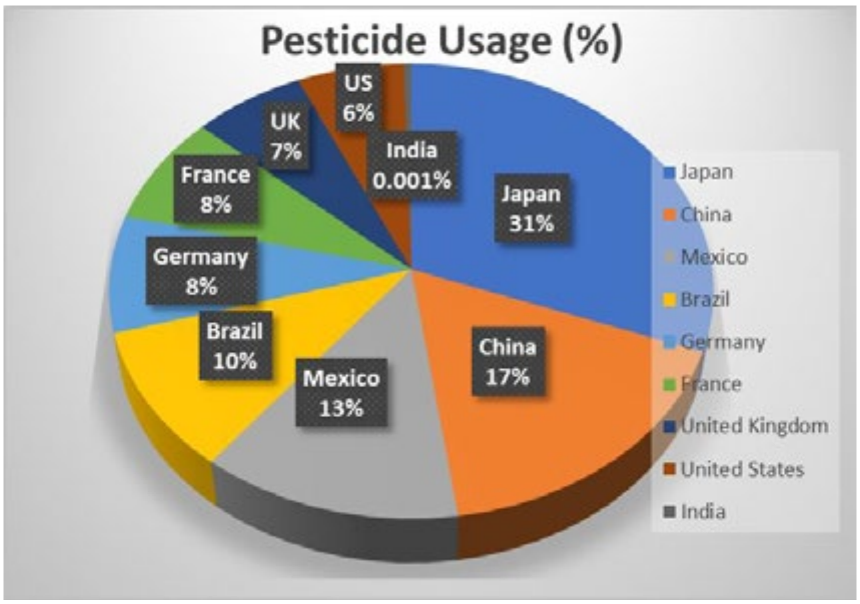

Figure 1: (%) of pesticide usage across the world. (Zhang, 2018).

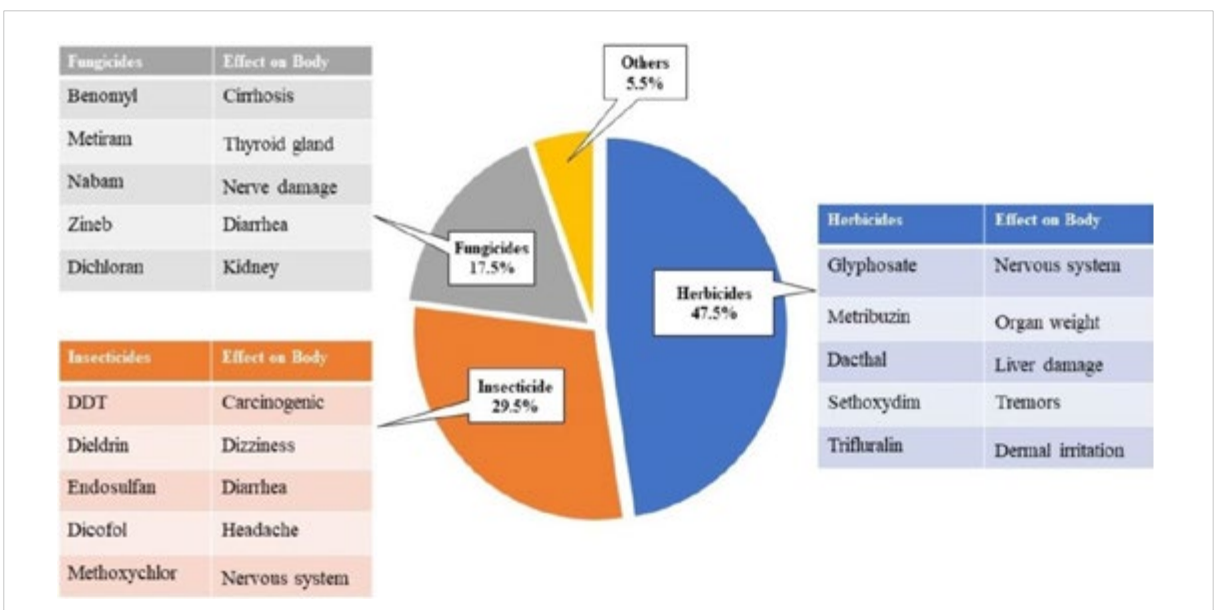

Figure 2: Percentage distribution of types of pesticides and its effects on man (Nicolopoulou-Stamati et al.,2016;Alengebawy et al.,2021).

1.1 Study Area

Soil samples for this study were collected across two Local Government Areas (LGAs) in Ondo Southern senatorial districts. Nine of the communities are located in Ilaje LGA of Ondo State at between long (6°12°E and 60 30°E) and lat (4°10°N and 4°6°N) of the Equator. The communities are Ojumole (B), Awoye (C), Odofado (D), Ugbonla (E), Odonla (F), Idi – Ogba G), Ile pete(H) Odonla (I) and Oroto (J) while the tenth community Olusegun Agagu University of Science and Technology OAUSTECH designated as (A) was the control and it is located in Okitipupa LGA of Ondo State. In the OAUSTECH control community, the use of pesticides to manage weeds is not allowed because to the community's awareness of the hazards connected with pesticide use. However, in the other nine trial communities, farmers are permitted to freely use pesticides for pest control.

2. Materials and Methods

Using a soil auger, triplicate soil samples from ten communities designated A to J were collected from the tillage and rooting depth of plants (0 – 21cm) and transmitted to the OAUSTECH laboratory for analysis. To eliminate debris, the soil was sieved through a 2-millimeter mesh.

2.1 Organic Pesticide Determination Using Gas Mass Spectrometry (Gc-Ms)

Two grams (2g) of soil samples each is weighed into a conical flask, 20ml of dichloromethane (DCM) was added, and the flask was deposited on an ultrasonic bath. The sample was sonicated for approximately 25 minutes, after which the clear portion was transferred to a clean beaker. The procedure was repeated with an additional 25ml of solvent. The clear liquid in the receptacle was centrifuged for 10 minutes at 4000rpm. In a dry receptacle, the supernatant was collected. By loading a column with silica gel, anhydrous sodium sulphate, and cotton wool, the sample was purified. The cleansed sample was concentrated to approximately 1 ml and prepared for GC-MS analysis of pesticides. Triple quadrupole (QqQ) which is the mass analyzer operating in the selected reaction monitoring (SRM) mode was then used to detect and measure the quantities of pesticide residues in the samples.

2.2 Bacterial Analysis

Standard plate count procedures were used to assess bacterial population [20]. Nutrient agar (NA) was utilized to evaluate the bacterial population. One gram (1g) of each soil sample was measured into a test tube containing 9 ml of sterile distilled water, serially diluted to a dilution factor of 105, and 1 ml of the appropriate dilutions was pipetted onto a sterilized plate containing NA and incubated at 30oC. Each plate was incubated upside-down. At 48 hours, bacterial counts were carried out

2.3 Statistical Analysis

The data obtained were subjected to analysis of variance and the means were compared using the Duncan Multiple range test. A significant level of 0.05 was used. The experiments were all designed as a complete randomized design (CRD).

3. Results and Discussions

Table 1: Amount of Residual pesticides in selected soil samples

S/N	Communities	Endosulfan ether(ppm)	Dieldrin (ppm)	Dichlorodiphenyltrichloroethane (DDT) ppm	Endrin ketone (ppm)
A	OAUSTECH (Control)	0.01 ± 0.006^{a}	0.00 ± 0.006^{a}	0.00 ± 0.000^{a}	0.00 ± 0.000^{a}
B	Ojumole	0.02 ± 0.012^{b}	0.03 ± 0.0012^{b}	0.03 ± 0.006^{b}	1.20 ± 0.0037^{b}
C	Awoye	0.04 ± 0.015^{c}	0.05 ± 0.0010^{d}	0.06 ± 0.015^{e}	2.06 ± 0.015^{j}
D	Odofado	0.03 ± 0.012^{bc}	0.03 ± 0.0012^{bc}	0.04 ± 0.012^{c}	2.00 ± 0.0012^{i}
E	Ugbonla	0.02 ± 0.012^{b}	0.04 ± 0.0010^{c}	0.03 ± 0.006^{b}	1.80 ± 0.015^{e}
F	Odonla	0.03 ± 0.012^{bc}	0.04 ± 0.0010^{c}	0.06 ± 0.015^{e}	1.60 ± 0.0058^{c}
G	Idi - Ogba	0.03 ± 0.012^{bc}	0.03 ± 0.0012^{bc}	0.05 ± 0.015^{d}	1.98 ± 0.0012^{gh}
H	Ilepete	0.04 ± 0.018^{cd}	0.05 ± 0.0010^{d}	0.05 ± 0.018^{de}	1.82 ± 0.015^{ef}
I	Obenla	0.02 ± 0.012^{b}	0.04 ± 0.0010^{c}	0.04 ± 0.012^{cd}	1.95 ± 0.0012^{g}
J	Oroto	0.03 ± 0.012^{bc}	0.04 ± 0.0010^{c}	0.06 ± 0.015^{e}	1.65 ± 0.0087^{d}

Values are Mean±SD. Means with different letter(s) in a column are significantly different with Duncan's Multiple Range Test (DMRT) ($p<0.05$).

Table 2: Bacterial populations at the various locations in the communities

Communities	L1	L2	L3	L4	L5	L6	L7	L8
OAUSTECH	91.33±0.58^{e}	80.00±0.00^{f}	72.67±3.06^{g}	96.00±1.00^{g}	82.33±4.04^{g}	73.67±1.12^{g}	81.00±0.00^{h}	73.67±0.58^{e}
Ojumole	62.33±2.08^{d}	57.33±1.53^{d}	55.00±1.73^{ef}	71.33±1.16^{f}	62.67±1.16^{f}	65.67±1.16^{f}	65.00±1.00^{g}	54.00±0.00^{d}
Awoye	31.67±1.16^{a}	36.67±1.16^{a}	37.00±1.00^{b}	30.67±1.16^{a}	38.00±1.00^{b}	37.00±0.00^{c}	33.00±1.00^{a}	34.00±3.00^{a}
Odofado	62.33±1.53^{d}	63.67±2.08^{e}	58.00±1.73^{f}	55.00±1.73^{e}	56.00±1.00^{d}	48.00±1.00^{e}	47.33±0.58^{f}	37.33±1.16^{b}
Ugbonla	35.67±3.06^{b}	40.67±1.16^{b}	46.33±1.53^{d}	44.00±1.73^{c}	60.00±0.00^{e}	46.33±2.31^{de}	38.67±0.58^{c}	36.33±1.16^{ab}
Odonla	42.00±0.00^{c}	36.67±1.16^{a}	52.00±1.73^{e}	46.33±0.58^{d}	37.33±0.58^{b}	45.00±1.73^{d}	43.67±1.16^{e}	45.00±2.00^{c}
Idi-Ogba	34.00±1.73^{a}	40.67±1.16^{b}	52.33±2.52^{e}	38.33±0.58^{b}	16.67±1.16^{a}	26.00±1.73^{a}	37.67±1.16^{bc}	47.67±2.31^{c}
Ilepete	43.33±1.53^{c}	37.67±1.53^{a}	42.67±1.16^{c}	37.33±1.53^{b}	37.67±1.16^{b}	38.33±0.58^{c}	39.00±0.00^{c}	33.33±2.31^{a}
Obenla	42.00±1.00^{c}	40.33±0.58^{b}	52.00±1.00^{e}	55.67±1.16^{e}	57.67±0.58^{de}	33.33±2.31^{b}	37.00±0.00^{b}	34.67±0.58^{ab}
Oroto	42.00±0.00^{c}	44.67±2.52^{c}	32.33±1.53^{a}	38.00±1.00^{b}	44.33±1.16^{c}	36.67±0.58^{c}	42.33±0.58^{d}	35.33±1.16^{ab}

Values are Mean±SD. Means with different letter(s) in a column are significantly different with Duncan's Multiple Range Test (DMRT) ($p<0.05$). L=Location

Table 1 revealed the amount of residual pesticides in the soil samples. Endosulfan ether, Dieldrin, dichloro-diphenyl-trichloroethane (DDT) and Endrin ketone were the major pesticides in the soil samples. The amount of pesticide residues in the soil samples are not significantly different across the soils of OAUSTECH used as control. Values of each of the residual pesticides in the treatments are much higher and differ significantly ($P < 0.005$) compared to the control. Literature extensively documents the occurrence of residual insecticides in soil. Naturally produced pesticides, referred to as biopesticides, are synthesized by many organisms, including plants, bacteria, and fungi inside the soil [21-22]. Residues of synthetic pesticides in the soil have been documented in studies conducted by Gill and Garg, Zhang and Sharma [13-23]. These documented reports agree with the findings of this research. According to reports, Endosulfan Sulfate has been found to have an impact on human respiration and has the potential to be absorbed via the skin. Prolonged and significant exposure to Endosulfan Sulfate has been associated with several adverse health effects, including but not limited to headache, dizziness, impaired eyesight, feelings of nausea, episodes of vomiting, instances of diarrhea, and muscular debility. Severe poisoning has been associated with several adverse health outcomes, including but not limited to leukemia, convulsions, prostate cancer, non-Hodgkin lymphoma, ovarian cancer, coma, and mortality [24-29]. Several studies have demonstrated that dichlorodiphenyltrichloroethane (DDT) and its metabolites might potentially cause detrimental effects on multiple organs and tissues in animals, such as the neurological system, liver, kidney, reproductive system, endocrine system, and immune system [30-33]. The accumulation of pesticides within the human body can lead to adverse health effects, which may manifest over an extended duration of exposure, even when exposed to very low quantities. Previous research in the field of animal studies has documented many adverse effects observed in animals subjected to differing levels of aldrin or dieldrin exposure. These effects include convulsions, tremors, cognitive impairments, hepatic injury, and reproductive complications [34-36]. Pesticides that have a high propensity to infiltrate soils can provide toxicity risks to various organisms such as arthropods, earthworms, fungus, bacteria, and protozoa. These organisms play a crucial role in ecosystems as they exert significant influence over both the composition and operation of natural systems. Honeybees, which play a crucial role in the pollination of various agricultural products such as fruits and vegetables, have adverse effects from the majority of insecticides employed. Agricultural losses can also occur as a result of diminished insect pollination of crops caused by the application of pesticides [37-39]. The bacterial population in different places of both the control and trial communities is presented in Table 2. Research findings indicate that the inclusion of pesticides resulted in a decrease in the number of bacteria across all types of pesticides. In the OAUSTECH control community, there is no statistically significant difference in bacterial counts among the majority of the locations ($P>0.05$). Nevertheless, when the control locations are contrasted with the trial sites, there is a notable disparity in bacterial loads ($P< 0.05$) across all the locations.

These findings align with the conclusions of which indicate that the presence of glyphosate leads to a reduction in bacterial count, microbial biomass, and acidobacteria population [40-45]. For a considerable duration, it was considered that a decrease in the population of bacteria may potentially undermine some biogeochemical activities carried out by these microorganisms. Pathak documented that the harmful impacts of pesticides arise from their ability to hinder the production of amino acids through the shikimic acid pathway [23]. Nicoleta also reported that the presence of Cypermethrin and thiamethoxam in pesticides inhibits the metabolic process and significantly decreased ammonifying, nitrifying and denitrifying bacteria compared to the untreated sample [45]. Conversely, other studies have demonstrated significant increase in bacteria count after pesticide treatments. Reportedly, bacteria can exploit the pesticide as a source of nutrition, produce water and carbon dioxide, and therefore circumvent the pesticide's negative effects on the environment. These pesticides build up in the soil and provide carbon and electrons to the microbes that live there. For bacteria to biodegrade effectively, several aspects must be considered, including the type of bacteria involved, the environmental circumstances, the amount and duration of pesticide exposure, and growth parameters including temperature, pH, moisture, nutrients, and water availability [46-50].

4. Conclusion

Pesticides have a substantial impact on the amount of bacteria present in soils. Pesticide use can result in a reduction in soil bacteria populations, hence adversely affecting soil health and fertility. The influence of pesticides on soil microorganisms is contingent upon various elements, such as the specific type of pesticide, its concentration, and the mode of administration. Implementing organic farming techniques can mitigate the adverse impact of pesticides on soil microbes and foster sustainable agricultural practices. Hence, it is crucial to meticulously assess the utilization of pesticides and contemplate alternative methodologies that can aid in preserving robust soil ecosystems. In order to resolve the conflict between high-yield or stable production in agriculture and environmental damage, researches must keep tending towards finding and developing pesticides with low toxicity, high effectiveness, and low pesticide residues while we also keep finding and developing strategies to degrade the attending pesticides residues[51-55].

References

1. FAO (2018). Food and Agriculture organizations of the United Nations.Available
2. Solà, M., Riudavets, J., & Agustí, N. (2018). Detection and identification of five common internal grain insect pests by multiplex PCR. Food Control, 84, 246-254.
3. Pimentel, D., McNair, S., Janecka, J., Wightman, J., Simmonds, C., O'connell, C., ... & Tsomondo, T. (2001). Economic and environmental threats of alien plant, animal, and microbe invasions. Agriculture, ecosystems & environment, 84(1), 1-20.
4. Singh, B. K., & Walker, A. (2006). Microbial degradation of organophosphorus compounds. FEMS microbiology reviews, 30(3), 428-471.
5. Zhan, H., Huang, Y., Lin, Z., Bhatt, P., & Chen, S. (2020). New insights into the microbial degradation and catalytic mechanism of synthetic pyrethroids. Environmental research, 182, 109138.
6. Bhatt, P., Zhou, X., Huang, Y., Zhang, W., & Chen, S. (2021). Characterization of the role of esterases in the biodegradation of organophosphate, carbamate, and pyrethroid pesticides. Journal of hazardous materials, 411, 125026.
7. Zhang, W., Li, J., Zhang, Y., Wu, X., Zhou, Z., Huang, Y., ... & Chen, S. (2022). Characterization of a novel glyphosate-degrading bacterial species, Chryseobacterium sp. Y16C, and evaluation of its effects on microbial communities in glyphosate-contaminated soil. Journal of Hazardous Materials, 432, 128689.
8. Chen, C., Zou, W., Cui, G., Tian, J., Wang, Y., & Ma, L. (2020). Ecological risk assessment of current-use pesticides in an aquatic system of Shanghai, China. Chemosphere, 257, 127222.
9. Woodrow, J. E., Gibson, K. A., & Seiber, J. N. (2019). Pesticides and related toxicants in the atmosphere. Reviews of Environmental Contamination and Toxicology Volume 247, 147-196.
10. Socorro, J., Durand, A., Temime-Roussel, B., Gligorovski, S., Wortham, H., & Quivet, E. (2016). The persistence of pesticides in atmospheric particulate phase: An emerging air quality issue. Scientific reports, 6(1), 33456.
11. Rosell, G., Quero, C., Coll, J., & Guerrero, A. (2008). Biorational insecticides in pest management. Journal of Pesticide Science, 33(2), 103-121.
12. Sharma, A., Kumar, V., Shahzad, B., Tanveer, M., Sidhu, G. P. S., Handa, N., ... & Thukral, A. K. (2019). Worldwide pesticide usage and its impacts on ecosystem. SN Applied Sciences, 1, 1-16.
13. Mieldazys, A., Mieldazys, R., Vilkevicius, G., & Stulginskis, A. (2015). Agriculture-Use of pesticides/plant protection products. EU-OSHA.
14. Fernández, L. (2021). Global pesticide use by country | Statista.
15. Schreinemachers, P., & Tipraqsa, P. (2012). Agricultural pesticides and land use intensification in high, middle- and low-income countries. Food policy, 37(6), 616-626.
16. Schreinemachers, P., Afari-Sefa, V., Heng, C. H., Dung, P. T. M., Praneetvatakul, S., & Srinivasan, R. (2015). Safe and sustainable crop protection in Southeast Asia: status, challenges and policy options. Environmental Science & Policy, 54, 357-366.
17. Pokhrel, B., Gong, P., Wang, X., Chen, M., Wang, C., & Gao, S. (2018). Distribution, sources, and air–soil exchange of OCPs, PCBs and PAHs in urban soils of Nepal. Chemosphere, 200, 532-541.
18. Alengebawy, A., Abdelkhalek, S. T., Qureshi, S. R., & Wang, M. Q. (2021). Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications. Toxics, 9(3), 42.
19. Adesina, G. O., & Adelasoye, K. A. (2014). Effect of crude oil pollution on heavy metal contents, microbial population in soil, and maize and cowpea growth. Agricultural sciences, 2014.
20. Abubakar, Y., Tijjani, H., Egbuna, C., Adetunji, C. O., Kala, S., Kryeziu, T. L., ... & Patrick-Iwuanyanwu, K. C. (2020). Pesticides, history, and classification. In Natural remedies for pest, disease and weed control (pp. 29-42). Academic Press.
21. Bhatt, P., Zhou, X., Huang, Y., Zhang, W., & Chen, S. (2021). Characterization of the role of esterases in the biodegradation of organophosphate, carbamate, and pyrethroid pesticides. Journal of hazardous materials, 411, 125026.
22. Gill, H. K., & Garg, H. (2014). Pesticide: environmental impacts and management strategies. Pesticides-toxic aspects, 8(187), 10-5772.
23. Zhang, J., Huang, X., Liu, H., Liu, W., & Liu, J. (2018).

Novel pathways of endocrine disruption through pesticides interference with human mineralocorticoid receptors. Toxicological Sciences, 162(1), 53-63.
24. Leonel, A. C., Bonan, R. F., Pinto, M. B., Kowalski, L. P., and Perez, D. E. (2021). The pesticides use and the risk for head and neck cancer: a review of case-control studies. Med. Oral. Patol. Oral. Cir. Bucal. 26, e56–e63.
25. Lerro, C. C., Freeman, L. E. B., DellaValle, C. T., Andreotti, G., Hofmann, J. N., Koutros, S., ... & Ward, M. H. (2021). Pesticide exposure and incident thyroid cancer among male pesticide applicators in agricultural health study. Environment international, 146, 106187..
26. Pardo, L. A., Beane Freeman, L. E., Lerro, C. C., Andreotti, G., Hofmann, J. N., Parks, C. G., ... & Koutros, S. (2020). Pesticide exposure and risk of aggressive prostate cancer among private pesticide applicators. Environmental Health, 19(1), 1-12.
27. Obiri, S., Cobbina, S. J., Armah, F. A., & Luginaah, I. (2013). Assessment of cancer and noncancer health risks from exposure to PAHs in street dust in the Tamale Metropolis, Ghana. Journal of Environmental Science and Health, Part A, 48(4), 408-416.
28. Amizadeh M, Askari Saryazdi G. (2011)Effects of Endosulfan on Human Health. WebmedCentral TOXICOLOGY 2011;2(12):WMC002617
29. Nandi, S., Gupta, P. S. P., Roy, S. C., Selvaraju, S., & Ravindra, J. P. (2011). Chlorpyrifos and endosulfan affect buffalo oocyte maturation, fertilization, and embryo development in vitro directly and through cumulus cells. Environmental toxicology, 26(1), 57-67.
30. Thuy, T. T. (2015). Effects of DDT on environment and human health. Journal of Education and Social Sciences, 2, 108-114.
31. Hashmi, Imran and Khan A. Dilshad (2011). Adverse Health Effects of Pesticides Exposure in Agricultural and Industrial Workers of Developing Country.
32. WHO, World Health Organization (2013) Childhood pesticide poisoning: Information for advocacy and action. http://www.who.int/ceh/publications/pestipoison/en/.
33. WHO, World Health Organisation (2011), DDT in indoor residual spraying: Human heath aspects. Environmental health criteria 241.
34. Shah, H. K., Sharma, T., & Banerjee, B. D. (2020). Organochlorine pesticides induce inflammation, ROS production, and DNA damage in human epithelial ovary cells: An in vitro study. Chemosphere, 246, 125691
35. Sarty, K. I., Cowie, A., & Martyniuk, C. J. (2017). The legacy pesticide dieldrin acts as a teratogen and alters the expression of dopamine transporter and dopamine receptor 2a in zebrafish (Danio rerio) embryos. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology, 194, 37-47.
36. Adeyemi, D., Ukpo, G., Anyakora, C., & Unyimadu, J. (2008). Organochlorine pesticide residues in fish samples from Lagos Lagoon, Nigeria. American Journal of Environmental Sciences, 4 (6) : 649-653.
37. Mwevura, H., Kylin, H., Vogt, T., & Bouwman, H. (2021). Dynamics of organochlorine and organophosphate pesticide residues in soil, water, and sediment from the Rufiji River Delta, Tanzania. Regional Studies in Marine Science, 41, 101607.
38. Thakur, S., Dhiman, M., & Mantha, A. K. (2018). APE1 modulates cellular responses to organophosphate pesticide-induced oxidative damage in non-small cell lung carcinoma A549 cells. Molecular and cellular biochemistry, 441, 201-216.
39. Želježić, D., Žunec, S., Bjeliš, M., Benković, V., Mladinić, M., Lovaković Tariba, B., ... & Kopjar, N. (2018). Effects of the chloro-s-triazine herbicide terbuthylazine on DNA integrity in human and mouse cells. Environmental Science and Pollution Research, 25, 19065-19081.
40. Pathak, V. M., Verma, V. K., Rawat, B. S., Kaur, B., Babu, N., Sharma, A., ... & Cunill, J. M. (2022). Current status of pesticide effects on environment, human health and it's eco-friendly management as bioremediation: A comprehensive review. Frontiers in Microbiology, 2833.
41. Tudi, M., Daniel Ruan, H., Wang, L., Lyu, J., Sadler, R., Connell, D., ... & Phung, D. T. (2021). Agriculture development, pesticide application and its impact on the environment. International journal of environmental research and public health, 18(3), 1112.
42. Thomas, P., & Dong, J. (2019). Novel mechanism of endocrine disruption by fungicides through binding to the membrane androgen receptor, ZIP9 (SLC39A9), and antagonizing rapid testosterone induction of the intrinsic apoptotic pathway. Steroids, 149, 108415.
43. Newman, M. M., Hoilett, N., Lorenz, N., Dick, R. P., Liles, M. R., Ramsier, C., & Kloepper, J. W. (2016). Glyphosate effects on soil rhizosphere-associated bacterial communities. Science of the Total Environment, 543, 155-160.
44. Nicoleta, F; Voia, S; Popescu, R. and Dumitrescu, G.(2015) The effect of some insecticides on soil microorganisms based on enzymatic and bacteriological analyses, Romanian Biotechnological Letters, 2: 10439-10447
45. Singh, D. V., Ali, R., Anita, Kulsum, M., & Bhat, R. A. (2020). Ecofriendly approaches for remediation of pesticides in contaminated environs. Bioremediation and Biotechnology, Vol 3: Persistent and Recalcitrant Toxic Substances, 173-194.
46. Deng, S., Chen, Y., Wang, D., Shi, T., Wu, X., Ma, X., ... & Li, Q. X. (2015). Rapid biodegradation of organophosphorus pesticides by Stenotrophomonas sp. G1. Journal of hazardous materials, 297, 17-24.
47. Adams, G. O., Fufeyin, P. T., Okoro, S. E., & Ehinomen, I. (2015). Bioremediation, biostimulation and bioaugmention: a review. International Journal of Environmental Bioremediation & Biodegradation, 3(1), 28-39.
48. Rani, K., & Dhania, G. (2014). Bioremediation and biodegradation of pesticide from contaminated soil and water—a noval approach. Int J Curr Microbiol App Sci, 3(10), 23-33.
49. Laura, M., Snchez-Salinas, E., Dantn Gonzlez, E., and Luisa,

M. (2013). "Pesticide biodegradation: Mechanisms, genetics and strategies to enhance the process," in Biodegradation: Life of Science, ed. R. Chamy (London: IntechOpen).

50. Bhatt, P., Bhatt, K., Huang, Y., Lin, Z., & Chen, S. (2020). Esterase is a powerful tool for the biodegradation of pyrethroid insecticides. Chemosphere, 244, 125507.
51. Nicolopoulou-Stamati, P., Maipas, S., Kotampasi, C., Stamatis, P., & Hens, L. (2016). Chemical pesticides and human health: the urgent need for a new concept in agriculture. Frontiers in public health, 4, 148.
52. United States. Environmental Protection Agency. Office of Pesticide Programs. (2004). Overview of the ecological risk assessment process in the Office of Pesticide Programs, US Environmental Protection Agency: Endangered and Threatened Species Effects Determinations. DIANE Publishing.
53. Walter, G. H., Chandrasekaran, S., Collins, P. J., Jagadeesan, R., Mohankumar, S., Alagusundaram, K., ... & Subramanian, S. (2016). The grand challenge of food security-general lessons from a comprehensive approach to protecting stored grain from insect pests in Australia and India. Indian Journal of Entomology, 78(special), 7-16.
54. Zhang, W. (2018). Global pesticide use: Profile, trend, cost/benefit and more. Proceedings of the International Academy of Ecology and Environmental Sciences, 8(1), 1.
55. Singare, P. U. (2016). Distribution and risk assessment of suspected endocrine-disrupting pesticides in creek water of Mumbai, India. Marine pollution bulletin, 102(1), 72-83.