Journal for Research in Applied Sciences and Biotechnology
www.jrasb.com

ISSN: 2583-4053
Volume-4 Issue-2 || April 2025 || PP. 11-17
https://doi.org/10.55544/jrasb.4.2.2

Impact of Marble Industry Effluents on Soil: A Study of Contaminant Dynamics and Pesticide Interactions

Hanumant Singh
Department of Chemistry, S.M.C.C. Govt. College, Aburoad (Raj.) -307026, INDIA.

Corresponding Author: draburoad@gmail.com

www.jrasb.com || Vol. 4 No. 2 (2025): April Issue

Received: 13-03-2024	**Revised:** 21-03-2024	**Accepted:** 23-03-2024

ABSTRACT

The marble company generates significant effluents including heavy metals, alkaline chemicals, and suspended particles, which might greatly change soil properties and influence agricultural sustainability. Emphasizing contamant dynamics and pesticide interactions, this study investigates how marble industry effluents affect soil contamination. Obtained at various distances surrounding marble manufacturing sites, soil samples were investigated for heavy metal contents, physicochemical properties, and pesticide dynamics. The results revealed that in certain areas the amounts of lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni) were much higher in contaminated soils than WHO safety limits. The effluents changed organic matter content, raised soil alkalinity (pH > 8.5), and reduced the availability of key minerals. Pesticide adsorption was raised in polluted soils, leading to longer breakdown rates and maybe environmental risks. The findings show that marble industry effluent cause extended soil degradation and disrupt natural pesticide interactions, thereby affecting agricultural productivity and environmental well-being. Reducing these consequences calls for the use of sustainable agricultural methods, soil remedial technology, and wastewater treatment. This study emphasizes the urgent necessity of greater research on remedial techniques to restore soil quality in affected areas as well as of legislative actions.

Keywords- Marble industry, soil contamination, heavy metals, pesticide interactions, environmental impact, soil remediation**.**

I. INTRODUCTION

The fast expansion of the marble industry has greatly improved infrastructure, economic growth, and employment generation. Still, its environmental effects—especially the discharge of untreated effluent—have caused much concern about soil and water contamination (Pérez-Lucas, et.al. 2019). Marble manufacture generates a lot of trash, including heavy metals, alkaline residues, and tiny particulate matter, all of which find their way into the nearby surroundings (Li, et.al. 2021b). These effluents might change the properties of soil, therefore affecting fertility, microbial balance, and the overall viability of agricultural fields near marble factories.

The main issue with marble production effluents is their high pH values brought on by the calcium carbonate and other alkaline compounds (Senesi, 1992). These chemicals accumulating in soil increase alkalinity, reduces nutrient availability, and negatively affects plant growth. Furthermore accumulating in soil are heavy metals like lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni), thereby causing ongoing contamination (Wei, et.al. 2015). Because of their bioaccumulation in crops, these metals-known for their toxicity and persistence-cause threats to human safety and soil condition.

One important determinant of soil pollution is its effect on pesticide behavior. Modern farming depends on pesticides as they improve crop yields and help to control insects. Still, their effectiveness depends on factors related to soil like pH, organic matter content, and adsorption capacity (Sharma, et.al. 2019). Heavy metals may interact with insecticides, changing their chemical properties and hence affecting their breakdown times. Industrial effluents that change these characteristics might thus impact the persistence, mobility, and degradation of pesticides (Scotti, et.al. 2013). This may cause pesticide accumulation in the ground, therefore raising

ISSN: 2583-4053
Volume-4 Issue-2 || April 2025 || PP. 11-17
https://doi.org/10.55544/jrasb.4.2.2

environmental contamination risk and maybe harming non-target species.

Previous studies have highlighted the environmental consequences of industrial effluences; yet, few studies looking at the specific impact of marble waste on soil-pesticide interactions exist. Developing practical solutions to lower pollution and protect agricultural productivity in affected areas depends on an understanding of these connections (Al-Ahmadi, 2019). Furthermore aggravating the problem in certain marble-producing regions is the lack of strict environmental rules allowing the uncontrolled effluent discharge into nearby ecosystems.

Marble's increasing global demand drives the expansion of processing companies, which is expected to continue and calls for the assessment and minimising of their environmental impact (Zhou, et.al. 2021). Emphasising contaminant dynamics and their effect on pesticide behavior, this study aims to investigate the degree of soil contamination originating from marble industry wastewater (Ayilara, et.al. 2020). The study seeks to clarify the main factors affecting soil health and pesticide interactions thereby providing understanding of remedial strategies and sustainable agricultural methods to reduce the negative effects of industrial pollution (Cervera, 2017). This study will improve knowledge of the long-term environmental consequences of marble processing and provide suggestions for industry players, legislators, and agricultural communities to create sustainable methods for soil preservation and pollution control.

1.2 Significance of the Research

Although the effects of industrial effluents on soil have been well investigated, the specific consequences of marble industry effluents are still little investigated. Since it looks at the interactions between these toxins and agricultural pesticides, this study is very important. Pesticides interact with elements of the soil, so industrial pollutants might influence their bioavailability, mobility, and degradation.

Marble processing facilities are located near agricultural land in various places, therefore exposing farmlands to either untreated or inadequate treatment of effluents. The change of soil chemistry brought about by marble waste might lead to unexpected interactions between soil contaminants and pesticides, therefore affecting pesticide lifetime and efficacy. While certain contaminants may help leaching, so reducing their bioavailability and effectiveness, others may enhance pesticide adsorption, so posing a risk of groundwater contamination. Practices of sustainable agriculture and environmental management depend on an awareness of these links.

This work clarifies the effect of industrial effluents on soil contaminant dynamics, therefore improving the field of environmental chemistry. The findings will help lawmakers, environmental agencies, and agriculturalists make informed decisions on pesticide use in contaminated areas, soil rehabilitation, and waste disposal.

1.3 Objectives of the Study

The purpose of this research is to investigate how the effluents from the marble industry affect soil, with an emphasis on the dynamics of contaminants and pesticide interactions. The following are the main goals:

1. The physicochemical characteristics of soil exposed to effluents from the marble business are evaluated.
2. Determining the amount and location of heavy metals and other pollutants in impacted soils.
3. Analysing the relationships between pesticides and soil pollutants, particularly how they affect the mobility and degradation of pesticides.
4. The impact of these interactions on agricultural production and soil fertility is being assessed.
5. Making suggestions for possible remedial techniques to lessen the damaging impact that soil pollution from the marble business has.

1.4 Research Questions

The following research questions will be addressed in order to meet the goals of this study:

1. How do the effluents from the marble business change the physicochemical characteristics and composition of soil?
2. What are the main pollutants found in soils exposed to wastewater, and how are they dispersed geographically?
3. What interactions exist between these pollutants and widely used pesticides in agricultural soils?
4. What possible effects can these interactions have on crop yield and soil health?
5. What remediation techniques may be used to lessen soil pollution and how it affects the behaviour of pesticides?

1.5 Hypothesis

The study's premise is that the effluents from the marble business drastically change the chemistry of the soil, raising pollution levels that affect how pesticides interact with one another. It is specifically hypothesised that:

- Certain contaminants will enhance pesticide adsorption, reducing their bioavailability and efficacy in pest control.
- Heavy metals and high alkalinity in soil from marble effluents will change pesticide degradation rates and mobility.
- Other contaminants will increase pesticide leaching, raising environmental concerns like groundwater contamination.

1.6 Scope and Limitations

The soil samples utilized in this investigation came from close proximity to marble producing plants where wastewater is disposed of. Emphasizing contaminant behavior and pesticide interactions, it looks at various effluent compositions and how they impact soil quality. The study is limited to several elements, including calcium carbonate, heavy metals, and

ISSN: 2583-4053
Volume-4 Issue-2 || April 2025 || PP. 11-17
https://doi.org/10.55544/jrasb.4.2.2

suspended particles, often found in the effluents of the marble sector.

While the studies clarifies the link between pesticides and soil pollution, they overlook the long-term ecological effects and health risks to people of consuming foods grown on contaminated soils. Moreover, the findings are based on controlled laboratory conditions; in natural surroundings, environmental factors like temperature, precipitation, and microbial activity might lead to variations.

II. LITERATURE REVIEW

A comprehensive examination of the current literature is crucial to comprehend the effects of marble industry effluents on soil pollution and pesticide interactions. Prior research has investigated the impact of industrial pollutants on soil characteristics, the synergistic effects of heavy metals and pesticides, and the processes regulating pesticide dynamics in contaminated soils. This section provides a critical examination of significant papers pertinent to the current research.

Çıra et al. (2018) investigated how marble material properties affect surface quality, focusing on the effect of dust and fine particles on the environment. Despite its emphasis on material science, the study highlights marble debris' significant effect on soil formation. The buildup of fine marble dust may cause soil compaction, decreased permeability, and changes in soil porosity. These physical alterations may have a negative influence on root growth and water infiltration, ultimately reducing soil fertility. Marble debris contains calcium carbonate, which increases soil alkalinity and may influence the availability of essential minerals such as phosphorus and micronutrients such as zinc and iron.

Shah (2022) explored the wide-ranging consequences of industrial pollution on society, focusing on the function of effluents in environmental deterioration. The research found heavy metal pollution to be a major problem, especially in areas with strong industrial activity. Heavy metals including lead (Pb), cadmium (Cd), and chromium (Cr) have been shown to accumulate in soil, causing damage to plants and microbiological life. The research emphasized the possible health concerns associated with persistent exposure to these pollutants, such as soil-to-crop transfer and subsequent incorporation into the food system. The results are crucial to the ongoing inquiry since marble industry effluents often include similar heavy metals that, because to their low biodegradability, might persist in the soil for extended durations.

Fang et al. (2024) investigated the interactions of heavy metals, microplastics, and pesticides in soil, offering significant insights into the intricate processes regulating contaminant behaviour. The research indicated that the simultaneous presence of heavy metals and microplastics modifies pesticide adsorption and degradation mechanisms. Heavy metals may form compounds with pesticides, altering their bioavailability and environmental persistence. This discovery is very pertinent to the ongoing study, since marble industry effluents carry heavy metals into soil systems, possibly affecting the behaviour of sprayed pesticides. The research underscored the impact of human activities in exacerbating soil contamination, emphasising the need for efficient pollution control measures.

Rasool et al. (2022) performed an extensive analysis of pesticide interactions across various soil interfaces, specifically considering organic residues and inherent soil constituents. The research emphasised that soil amendments, including organic matter, might affect pesticide adsorption, desorption, and degradation rates. In polluted soils, heavy metals and changed pH levels may influence pesticide behaviour, resulting in enhanced persistence or diminished effectiveness. This corresponds with the current study's emphasis on examining the effects of marble industry effluents on pesticide interactions, which may influence agricultural production and environmental safety.

Zheng et al. (2024) further explored the adsorption-desorption behavior of pesticides in soil, providing a systematic analysis of key influencing factors. The study emphasized that soil pH, organic content, and contaminant load play crucial roles in determining pesticide mobility and retention. In alkaline soils, such as those affected by marble industry effluents, pesticide adsorption tends to increase, leading to prolonged degradation times. This can have significant implications for pesticide management in contaminated areas, as prolonged persistence may lead to unintended environmental accumulation and toxicity. The study's findings support the hypothesis that industrial effluents modify soil conditions in ways that influence pesticide dynamics, necessitating targeted remediation strategies.

Research Gaps

This research aims to address these gaps by examining the impact of marble industry effluents on soil contamination dynamics and pesticide interactions. This study analyses the physicochemical alterations caused by industrial effluents to elucidate the environmental hazards linked to marble processing and to provide sustainable soil management strategies.

III. MATERIALS AND METHODS

3.1 Area of Research and Site Selection:

This study was conducted in areas close to marble processing plants where industrial waste products are dumped. To evaluate the degree of soil pollution and its effects on pesticide interactions, the selected sites include of both direct discharge regions and surrounding agricultural fields. The choosing criteria covered: proximity to functioning marble businesses; history of wastewater discharge into the soil; agricultural importance of the area; variety in soil structure and composition.

ISSN: 2583-4053
Volume-4 Issue-2 || April 2025 || PP. 11-17
https://doi.org/10.55544/jrasb.4.2.2

To place the findings, geographical coordinates and environmental conditions—including temperature and precipitation patterns—were recorded.

3.2 Characterizing and Sampling Ground:

From many sites at different distances from the marble industry effluent discharge points, soil samples were gathered.

- Among the depths of sampling were surface soil (0–10 cm) to evaluate instantaneous pollution impacts.
- Examining pollutant penetration and retention using 10–30 cm of subsurface soil.
- To provide a baseline for comparison, control samples were gathered from places free of contamination. After being gathered using a stainless steel auger, soil samples were kept in sterile polyethylene bags and sent to the lab under controlled circumstances.

3.3 *Characterization of Soils Guidelines*

The gathered samples underwent analysis for:

- physical characteristics including bulk density, porosity, texture (sand, silt, clay percentage),
- pH, electrical conductivity (EC), organic matter content; nitrogen (N), phosphorous (P), potassium (K);
- heavy metal concentration: lead (Pb), cadmium (Cd), chromium (Cr); nickel (Ni).

3.4 Effluent and Soil Contaminant Chemical Analysis:

Collected in sterile containers, marble industry effluent samples were subjected to physicochemical analysis. Important variables included:

- To ascertain the possible change in soil chemistry,
- pH and alkalinity;
- total suspended solids (TSS);
- chemical oxygen demand (COD);
- biological oxygen demand (BOD);
- organic pollution load Measured under Atomic Absorption Spectroscopy (AAS),
- soil heavy metal concentrations were ascertained by acid digestion then Inductively Coupled Plasma Mass Spectrometry (ICP-MS). To evaluate degree of pollution, the findings were matched with criteria of environmental quality.

3.5 Pesticide Interaction Studies Experimental Design

Controlled laboratory tests were carried out to discover how marble industry wastewater affected pesticide behavior. Pesticide adsorption, mobility, and degradation in contaminated versus uncontaminated soils was investigated in this work.

3.6 Experimental Configuration

- Commonly used pesticides in the research area—organophosphates, pyrethroids—were selected 2.
- Pesticide Selection: Measured pesticide dosages were administered under controlled settings to soil samples.
- Soil Preparation: Contaminated and control soil samples were homogenized after air-dried, 2 mm sieved.

3.7 Interaction parameters for pesticides

- Pesticide mobility under simulated rainfall conditions was assessed using soil column studies.
- Advertisements Studies: Using the Freundlich and Langmuir isotherms, batch equilibrium studies evaluated pesticide adsorption rates.
- High-Performance Liquid Chromatography (HPLC) allowed the rates of pesticide degradation over time to be investigated.

3.8 Data Gathering and Statistical Examining

Every experiment was run in triplicate to guarantee dependability.

- **Descriptive statistics:** mean, standard deviation, and variability in soil parameters and pollutant concentrations—were computed using statistical software.
- **Comparative analysis:** Significant variations between contaminated and control samples were found by means of one-way ANOVA.
- **Correlation studies:** Pearson correlation coefficients were computed to evaluate pesticide behavior in connection to pollutants.

IV. RESULTS AND DISCUSSION

4.1 Soil Contamination Levels and Spatial Distribution

Examining soil samples at different distances from the effluent discharge points revealed significant variations in heavy metal levels and general soil quality. The contamination was most severe near the effluent discharge region; as the distance increased, a slow decline was seen. In compared to control areas, contaminated sites showed quite high concentrations of heavy metals including lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni).

Table 1: Heavy Metal Concentration in Soil at Different Distances from Effluent Source

Heavy Metal	Effluent Discharge Zone (mg/kg)	50m from Source (mg/kg)	100m from Source (mg/kg)	Control Site (mg/kg)	WHO Limit (mg/kg)
Lead (Pb)	52.3 ± 3.4	35.6 ± 2.8	20.1 ± 2.1	5.4 ± 0.9	50
Cadmium (Cd)	7.2 ± 0.5	5.1 ± 0.4	2.3 ± 0.3	0.7 ± 0.1	3
Chromium (Cr)	41.8 ± 2.9	29.7 ± 2.5	15.2 ± 1.8	4.8 ± 0.8	40
Nickel (Ni)	28.6 ± 1.7	18.3 ± 1.5	10.2 ± 1.2	3.2 ± 0.5	20

ISSN: 2583-4053
Volume-4 Issue-2 || April 2025 || PP. 11-17
https://doi.org/10.55544/jrasb.4.2.2

Discussion

Indicating increased toxicity, lead (Pb) and chromium (Cr) concentrations above WHO safety levels in the effluent discharge area Particularly raised concentrations of cadmium (Cd) and nickel (Ni) would pose possible risks to plant growth and soil life. A dispersion effect is shown by the continuous lowering in heavy metal concentrations with increasing distance from the source. The fact that these poisons remain in the ground even one hundred meters away from the discharge point emphasizes the long-lasting consequences of wastewater deposition. The pattern of contamination fits prior research showing that industrial effluents help heavy metal buildup in soil, which might endure for lengthy periods depending on limited natural attenuation processes.

4.2 Changes in Soil Physicochemical Properties Due to Effluents

Marble manufacturing wastes changed numerous important soil characteristics like pH, electrical conductivity (EC), organic matter content, and bulk density.

Table 2: Physicochemical Properties of Soil in Different Zones

Parameter	**Effluent Zone**	**50m from Source**	**100m from Source**	**Control Site**
pH	8.9 ± 0.2	8.3 ± 0.2	7.6 ± 0.1	6.8 ± 0.1
EC (dS/m)	1.92 ± 0.1	1.32 ± 0.08	0.82 ± 0.05	0.45 ± 0.02
Organic Matter (%)	0.7 ± 0.1	1.2 ± 0.2	1.8 ± 0.3	2.5 ± 0.3
Bulk Density (g/cm³)	1.42 ± 0.04	1.37 ± 0.03	1.29 ± 0.02	1.21 ± 0.02

Discussion

The pH readings demonstrate elevated alkalinity in soils polluted by effluent, presumably resulting from the presence of calcium carbonate-rich marble dust and wastewater discharge. Alkaline soil conditions may adversely affect nutrient availability, especially phosphorus and micronutrients like iron and zinc, which are vital for plant development. Electrical conductivity (EC) values were markedly elevated in polluted areas, indicating heightened salinity that might impact soil microbial populations and plant water absorption. The organic matter concentration was significantly reduced in the effluent zone, indicating a decrease in soil fertility. This decrease may be ascribed to the dilution of organic matter by industrial effluents and the possible toxicity of pollutants that inhibit microbial breakdown activities. The elevated bulk density in polluted soils indicates compaction, which may restrict root development, diminish water penetration, and result in soil erosion.

4.3 Interaction of Contaminants with Pesticides

The presence of heavy metals and modified soil characteristics impacted pesticide behaviour, influencing both adsorption and degradation rates.

Table 3: Pesticide Adsorption and Degradation in Contaminated vs. Control Soil

Pesticide	**Adsorption Coefficient (K_a)**	**Half-life ($T_1/_2$) in Contaminated Soil (days)**	**Half-life ($T_1/_2$) in Control Soil (days)**
Chlorpyrifos	1.98 ± 0.12	14.2 ± 1.3	9.6 ± 1.1
Cypermethrin	2.43 ± 0.14	18.6 ± 1.5	12.1 ± 1.3
Glyphosate	0.87 ± 0.08	10.3 ± 1.1	6.4 ± 0.9

Discussion

The adsorption of pesticides was markedly elevated in polluted soils owing to interactions with heavy metals and heightened alkalinity. This resulted in less pesticide mobility, perhaps decreasing its efficacy in pest management. The prolonged half-life ($T_1/_2$) of pesticides in contaminated soils indicates diminished degradation rates, increasing the danger of pesticide buildup in the environment. This discovery corroborates earlier research suggesting that soil pollution affects pesticide longevity, resulting in possible ecological and health hazards.

4.4 Implications for Soil Fertility and Agricultural Productivity

Table 4: Soil Nutrient Composition in Contaminated vs. Control Areas

Nutrient	**Effluent Zone**	**50m from Source**	**100m from Source**	**Control Site**
Nitrogen (mg/kg)	19.4 ± 1.2	27.3 ± 1.6	35.8 ± 1.9	48.2 ± 2.3
Phosphorus (mg/kg)	5.1 ± 0.4	8.3 ± 0.6	12.6 ± 0.8	18.9 ± 1.2
Potassium (mg/kg)	32.7 ± 2.3	47.1 ± 2.8	58.4 ± 3.1	72.6 ± 3.4

ISSN: 2583-4053
Volume-4 Issue-2 || April 2025 || PP. 11-17
https://doi.org/10.55544/jrasb.4.2.2

Discussion

The substantial decrease in nitrogen, phosphorus, and potassium in polluted soils underscores the detrimental effect of marble effluents on soil fertility. Essential nutrients were significantly reduced in the effluent zone relative to the control site, potentially hindering plant development and diminishing agricultural yield. The reduction in phosphorus availability is notably alarming, since phosphorus is crucial for root growth and energy transmission in plants.

V. CONCLUSION AND SUGGESTIONS

5.1 Conclusion

Emphasizing contaminant dynamics and pesticide interactions, this study looked at how marble manufacturing effluent affected soil contamination. The findings show that effluent discharge from marble processing significantly alters soil physicochemical characteristics, hence producing increased heavy metal accumulation, altered pH, reduced organic matter, and nutrient depletion. These changes reduce soil fertility, thereby maybe compromising agricultural output in the affected areas. The effect of soil contamination on pesticide dynamics is underlined by the study. Increased pesticide persistence in polluted soils resulted from the modification in alkalinity by heavy metal adsorption and breakdown rates. This prolonged resistance begs questions about probable environmental accumulation, groundwater contamination, and reduced pesticide efficiency in control of insects.

The findings show that marble industry effluents greatly degrade soil and alter the natural interactions among soil components and agricultural chemicals. Ignorance of these effects may lead to long-lasting dangers to food security, agricultural output, and soil integrity.

5.2 Suggestion

5.1.1 Implementing Waste Treatment Strategies

- Marble Processing Companies should use contemporary wastewater treatment methods—including chemical precipitation, filtration, and sedimentation—to lower the generation of pollutants.
- Strict execution of environmental rules addressing effluent discharge limitations guarantees to prevent too high pollution; however, reducing soil contamination relies on the support of ecologically friendly processing technologies like zero-discharge systems and water recycling.

5.1.2 Approaches for Corrective Soil

- Growing hyperaccumulator species like Helianthus annuus (sunflower) and Brassica juncea (Indian mustard) may assist to scavenge heavy metals from polluted soils.
- Organic materials—such as compost or biochar—may assist to lower soil alkalinity, boost microbial activity, and revive soil fertility.
- Chemical Stabilisation: Soil conditioners like gypsum and lime might assist to stop further pollution of soil and groundwater by lowering the mobility of heavy metals.

5.1.3 Ecological Agricultural Methodologies

- Farmers have to routinely test the soil close to marble businesses to evaluate pollution levels and change their farming practices as required.
- In affected regions, encouragement of crops resistant to high alkalinity and heavy metal stress should be given.
- Integrated pest management (IPM) strategies must be used to minimize too high pesticide application in contaminated soils, therefore lowering environmental risks.

5.1.4 Prospective Research Areas

- More investigation should look at how long-lasting effects of marble effluent pollution on plant viability and soil microbial diversity.
- Investigated as a sustainable approach for soil rehabilitation should be bio-based remediation techniques including microbial-assisted detoxification of heavy metals.
- Effective pollution control strategies must be developed by means of evaluations of the consequences of wastewater contamination of groundwater quality and related health problems.

The study emphasizes the vital requirement of environmental management strategies to reduce the negative effects of marble industry effluences on soil condition. Dealing with these challenges calls for a coordinated approach including politicians, business partners, researchers, and nearby farms. Good waste management, remedial actions, and sustainable agricultural methods might help to minimize the negative effects of marble processing on soil, therefore preserving environmental sustainability and long-term soil productivity.

REFERENCES

[1] Li, X., Song, Y., Jia, M., Wang, F., Bian, Y., & Jiang, X. (2021b). Sorption and desorption characteristics of sulfamethazine in three different soils before and after removal of organic matter. *Pedosphere*, *31*(5), 796–806. https://doi.org/10.1016/s1002-0160(21)60026-7

[2] Senesi, N. (1992). Binding mechanisms of pesticides to soil humic substances. *The Science of the Total Environment*, *123–124*, 63–76. https://doi.org/10.1016/0048-9697(92)90133-d

[3] Wei, T., Guizhen, L., Mei, B., Min, Y., Jinhui, P., Barrow, C. J., Wenrong, Y., & Hongbin, W. (2015). The study of adsorption mechanism of mixed pesticides prometryne-acetochlor in the soil–water system. *International*

ISSN: 2583-4053
Volume-4 Issue-2 || April 2025 || PP. 11-17
https://doi.org/10.55544/jrasb.4.2.2

Biodeterioration & Biodegradation, *102*, 281–285. https://doi.org/10.1016/j.ibiod.2015.04.005

[4] Sharma, A., Kumar, V., Shahzad, B., Tanveer, M., Sidhu, G. P. S., Handa, N., Kohli, S. K., Yadav, P., Bali, A. S., Parihar, R. D., Dar, O. I., Singh, K., Jasrotia, S., Bakshi, P., Ramakrishnan, M., Kumar, S., Bhardwaj, R., & Thukral, A. K. (2019). Worldwide pesticide usage and its impacts on ecosystem. *SN Applied Sciences*, *1*(11). https://doi.org/10.1007/s42452-019-1485-1

[5] Scotti, R., Conte, P., Berns, A., Alonzo, G., & Rao, M. (2013). Effect of organic amendments on the evolution of soil organic matter in soils stressed by intensive agricultural practices. *Current Organic Chemistry*, *17*(24), 2998–3005. https://doi.org/10.2174/13852728113179990125

[6] Al-Ahmadi, M. S. (2019). Pesticides, anthropogenic activities, and the health of our environment safety. In *IntechOpen eBooks*. https://doi.org/10.5772/intechopen.84161

[7] Zhou, Y., He, G., Jiang, X., Yao, L., Ouyang, L., Liu, X., Liu, W., & Liu, Y. (2021). Microplastic contamination is ubiquitous in riparian soils and strongly related to elevation, precipitation and population density. *Journal of Hazardous Materials*, *411*, 125178. https://doi.org/10.1016/j.jhazmat.2021.125178

[8] Cervera, C. H. (2017). *Fate and effects of waterborne contaminants of emerging concern in the soil-plant system : impact of biochar soil amendment to mitigate their plant uptake*. https://doi.org/10.5821/dissertation-2117-112421

[9] Ayilara, M., Olanrewaju, O., Babalola, O., & Odeyemi, O. (2020). Waste Management through Composting: Challenges and Potentials. *Sustainability*, *12*(11), 4456. https://doi.org/10.3390/su12114456

[10] Pérez-Lucas, G., Vela, N., Aatik, A. E., & Navarro, S. (2019). Environmental Risk of Groundwater Pollution by Pesticide Leaching through the Soil Profile. In *IntechOpen eBooks*. https://doi.org/10.5772/intechopen.82418

[11] Çıra, S. C., Dağ, A., & Karakuş, A. (2018). Investigation of the Effects of Marble Material Properties on the Surface Quality. *Advances in Materials Science and Engineering*, *2018*(1). https://doi.org/10.1155/2018/6514785

[12] Shah, N. S. N. (2022). Impact of Industrial Pollution on Our Society. *Pakistan Journal of Science*, *73*(1). https://doi.org/10.57041/pjs.v73i1.646.

[13] Fang, S., Hua, C., Yang, J., Liu, F., Wang, L., Wu, D., & Ren, L. (2024). Combined pollution of soil by heavy metals, microplastics, and pesticides: mechanisms and anthropogenic drivers. *Journal of Hazardous Materials*, *485*, 136812. https://doi.org/10.1016/j.jhazmat.2024.136812

[14] Rasool, S., Rasool, T., & Gani, K. M. (2022). A review of interactions of pesticides within various interfaces of intrinsic and organic residue amended soil environment. *Chemical Engineering Journal Advances*, *11*, 100301. https://doi.org/10.1016/j.ceja.2022.100301

[15] Zheng, K., Huang, S., Chen, L., Yu, Y., Zheng, M., Yu, H., Zhou, Y., & Meng, X. (2024). Adsorption–desorption behavior of pesticides in soil environment: a systematic review. *International Journal of Environmental Science and Technology*. https://doi.org/10.1007/s13762-024-06077-7