PHYSICO-CHEMICAL ANALYSIS OF SOIL FROM CONTAMINATED SITES NEAR CEMENT INDUSTRIES

Charu Vyas[1], Ashwini A. Waoo[2]*

[1,2*] Department of Biotechnology, AKS University, Satna, (M.P.), India.

*Corresponding author: ashwiniwaoo@gmail.com, ORCID iD: 0000-0002-8772-3847

Abstract: The cement industry is a potential source of pollution from heavy metals contamination. The present study intends to find out the diffuse physio-chemical pollution and the accumulation concentrations of different heavy metals in the indigenous soil samples collected from cement dust industrially contaminated soils of cement industrial area, Satna, (M.P.), on paying proper attention to the availability of mineral resources in this region. Heavy metals in the soil samples were analyzed through ICP-MS by KED mode, which showed that Zn, Cr, and Pb concentrations were higher in the soil.

Extraction results of investigated heavy metals (Zn, Cr, Cu, Pb, B, Mo, and Cd) were compared to the control sample standards and were found above the permissible limits in indigenous soil, which may be the result of anthropogenic inputs in this area and showed that this area has been affected by activities of the cement industry resulting in high metals contents as compared to their background levels.

Various soil quality physicochemical parameters were also analyzed by using the conventional analytical methods as standard procedure. It was found that some of the soil quality parameters were above the permissible limit and some were not and concluded that the soils of these areas are contaminated.

This higher concentration of metals investigated in the soil is a great health risk not only for those people living in the vicinity of cement industries but also for those depending on crops such as wheat and mustard rice as a staple food. It is proposed from the aftereffects of the current research that appropriate observing of this source of contamination should be carried out routinely to prevent the ruinous influences concerning pollution.

Keywords: Cement industry, Chemical pollution, Ecosystem, Heavy metals, Microorganism, Physicochemical, Soil pollution, Spectrophotometer,

1. Introduction

The quality of soil is an important criterion for evaluating the suitability of soil for agricultural purposes. Concern over agricultural and industrial diffuse pollution sources in integrated soil has been growing recently. The diffuse toxic chemical pollution from cement enterprise in the Satna district, by paying proper attention to the availability of mineral resources in this region, based on the residential area and industrial area, leads to discharge that makes it challenging to detect, monitor, or regulate [1].

Polluted soil is now globally one of the most serious challenges and threats to human health. The enormous use of fertilizers, herbicides, and insecticides by industrialization to feed the world's expanding population has altered the physicochemical properties of the soil.

Concerning heavy metal contamination, the cement industry is one possible source of pollution. The current study is intended to find out the diffuse physio-chemical pollution and also the accumulation concentrations of different heavy metals in the indigenous soil samples collected from cement dust industrially contaminated soils of cement industrial area, Satna, (M.P.), were investigated on paying proper attention to the availability of mineral resources in this region.

Physiochemical Parameters of Soil

The soil is a naturally occurring collection of mineral and organic matter differentiated into horizons that vary from one another and underlying materials in their morphology, physical composition, chemical composition, and biological characteristics [1, 2]. Soil types are a central point in figuring out what kinds of plants will fill in a specific region as plants utilize inorganic components from the soil like nitrogen, potassium, and phosphorus. However, microorganisms like bacteria, fungi, and other tiny life forms found in the soil are also essential, therefore dirt is a dynamic environment composed of organic matter, minerals, water, air, and microorganisms.

Soil analysis is the best way to determine the accessible nutrient supplement status in soil and the only way to develop specific fertilizer recommendations. Sampling is perhaps the most important step in any soil evaluation. As a fairly small portion of the enormous dirt is being used for analysis, getting a truly representative field sample of dirt is crucial. Change-sensitive soil properties can be used as an indicator to improve soil quality.

It is a need of time to study the physicochemical characteristics of soil to determine its quality and is crucial for managing soil and plant growth to agricultural chemists. The usefulness of soil for its intended application and management requirements is largely determined by its properties and quality to keep it at its most productive.

Heavy metal pollution: a critical worldwide environmental hassle

Physico-chemical parameters of soil were found to influence the availability of heavy metals in plants [3]. The change in heavy metal concentrations can be attributed to a variety of causes, i.e., atmospheric deposition of heavy metals impacted by natural environmental conditions such as moisture, temperature, wind velocity, and physiochemical properties of soil [4]. Despite this, future research goals may include extracting or stabilizing heavy metals from polluted soils to identify the metabolic and absorption mechanisms used for the identification of metabolites and heavy metals.

The negative effects of these metals led to several environmental and public health issues, which put human life and aquatic biota in alarming situations. As a result, there is an increasing need for more awareness to assist in cleaning up the heavy metal-polluted surroundings. Therefore, to avoid contaminating the surroundings, it is imperative to eliminate or minimize excessive metallic pollution. For the sake of soil health, appropriate preventative actions are therefore advised. According to the established study, bioremediation on its own has been successful in converting contaminated soil into productive soil suitable for farming. This process is thought to be efficient and productive for recycling and reusing soil with little work.

Toxic effects of heavy metals

Soil Physico-chemical properties play a vital role in determining the extent to which the heavy metals pollution of soil occurs. Metals have accumulated in the environment as a result of human activity and industrial waste disposal. Cadmium, lead, chromium, copper, nickel, and other hazardous substances that are present in soluble form and damage the soils, groundwater, sediments, and surface waterways are just a few examples.

Cadmium

Cadmium has no vital biological function however it is exceptionally harmful to plants and animals. The soil standard levels of 0.06-1.1 mg/kg; can be considerably increased by deposition from the sludge application, industrial waste, and impurities from phosphates' fertilizers [5]. It has a high fixation on surface soils where it is maintained by organic matter. It can also travel down the soil profile depending on soil and site factors. In the soil solution, the Cd^{2+} free ion is the principal and most toxic species, but its organic and inorganic complexes also exist [6].

Chromium

Chromium which is a grey, hard metal generally occurs in the three most common forms: metallic (Cr^0) – does not exist naturally, trivalent (Cr^{+3}) – mostly found, nutrient, limited solubility, and hexavalent (Cr^{+6}) – are found in small quantities, water-soluble, highly toxic [7]. It is generally utilized in the industry because of its anti-corrosive properties like leather tanning, metal surface plating, textile production, glassware cleaning, etc. Acute poisoning of chromium causes vomiting, nausea, acute renal failure, contact dermatitis, irritation, allergies, reproductive toxicity, eczema, etc [8]. In the cement industry, the linings of the rotaries possess chromium, which could be liberated by constant use to produce chromium in the soil samples.

Lead

In soil, lead is a natural occurrence. Human activities are responsible for a sizable fraction of the lead fixations found in the environment. As a result outcome of using lead in gasoline, a synthetic lead cycle has emerged. Several negative consequences of lead intoxication include an increase in blood pressure, disruption of the biosynthesis of hemoglobin and anemia, miscarriages and subtle abortions, neurological system disturbances and brain damage, renal damage, etc. [8].

2. Methodology

The Vindhya Pradesh Plateau is environmentally important for understanding India's rich biodiversity and pervasive chemical pollution. Satna is a district in the state of Madhya Pradesh, India. Satna lying in the North-Eastern part of M.P. is located between 23058' to 25012', North latitude, and 80021' to 81023' East longitude. The district's economy is mainly dependent on the major and minor industries related to cement manufacture and lime kilns, as abound in natural resources like limestone, laterite, and silica sand i.e. silicates found extremely near to the human population and clearly show the decline in fertility and presence of different metals. Cement dust and smoking cause respiratory complications and other health problems for people and other living organisms [9, 10].

Because of industrialization and other anthropogenic exercises in Satna, the soil of the city gets polluted and hence it is more relevant to carry out soil investigation and analysis. Studying the Physicochemical features of soil pollution and the assessment of heavy metal pollution will be the main focus of the current work to determine the level of contamination of the soil study areas as a result of anthropogenic input from cement dust-contaminated soils/sediments from various locations around cement industrial zones of Cement Plants in Satna region with special reference to bioremediation.

Study Area: Cement dust contaminated sites near cement industries in Satna, (M.P.).

Sampling Procedure and Preparation of Soil Sample: The soil samples were randomly collected at a depth of 0–25 cm. The dry soil samples collected were entirely placed in clean, labeled plastic bags, sealed, and brought to the laboratory for further treatment and analysis. The chemicals and reagents used for evaluation have been of A.R. grade.

Physicochemical Analysis of Soil Quality Parameters': For the examination of physicochemical parameters of soil samples, the main emphasis was on those soil quality parameters that influence water movement and retention, which contribute to nutrient storage and supply while evaluating the physicochemical parameters of the soil samples.

In this study, various physical and chemical parameters were determined. Major physical and chemical soil quality parameters were examined in the collected samples like –

Physical Parameters: Temperature, Texture, Bulk density, Moisture content.

Chemical Parameters: pH, Organic matter, Available Nitrogen, Available Phosphorus, Potassium, Electrical Conductivity, Chloride, Fluoride, etc.

Assessment of the Heavy Metal Contamination Level in Near Areas of Cement Industries

Heavy metals were analyzed through ICP-MS by KED mode ICP-MS. The method used in detection for all analyzed heavy metals is Cadmium (Cd), Chromium (Cr), Lead (Pb), Zinc (Zn), Copper(Cu), Boron (B), Molybdenum(Mo) is USEPA 3050 B in mg/kg.

3. Results and Discussions

Physicochemical Analysis of Soil Quality Parameters

Analysis of soil is carried out for the study of various parameters. The values of physicochemical parameters are discussed as follows. The color of the soil sample was observed visually and it was found to be brownish-black to brown for all the samples. Here soil appearance was found to be granular particles with Hazen units. Soil with EC below 0.4µS/cm is considered marginally or non-saline, while soils above 0.8 µS/cm are considered severely saline. The conductivities recorded in the study areas ranged from 271.3 (µS/cm) to 438.2 (µS/cm). CEC values of the soil sites studied ranged from 363 (mg/kg) to 1321(mg/kg).

It can be seen that the moisture content at the sites was found to range from 1.60(g/100g) to 3.90(g/100g). The pH values for the soil samples under investigation are on the alkaline side. i.e., more than 7; in these circumstances, the minerals' solubility reduces, resulting in nutritional deficits in the soils. Iron, manganese, zinc, copper, and other mineral shortages therefore restrict plant growth. The organic matter content recorded at the sites ranges from 1.6(g/100g) to 3(g/100g) which is found to be very high.

In the study area nitrogen ranges from 670 (mg/kg) to 1116 (mg/kg) which is very high. From the analyzed samples, available potassium content ranges from 644.74 (mg/kg) to 1901.22 (mg/kg) which is also very high. Phosphorous in the present soils varies from 92.33 (mg/kg) to 206.96 (mg/kg) which is also very high. The chloride content was very variable at all the places, it ranged from 38.5 (mg/kg) to124 (mg/kg). The sodium content was very variable at all the places, it ranged from 0.32 (mg/kg) to 77.8(mg/kg). Sulfur content ranges at almost similar values of 5 (mg/kg) in all sites.

The calcium content was very variable at all the places, it ranged from 3122.18(mg/kg) to 16580.55(mg/kg). Magnesium content was very variable at all places, it ranged from 1964.53 (mg/kg) to 1598.72(mg/kg).

A great number of absorbed various components from the soil, but not all of them are necessary for the crop to flourish. Because since that they are present in the soil solution, elements are absorbed and those taking an active pent in the growth and developed processes are called the essential ones. Some of these are required in large amounts and some in traces.

Assessment of the heavy metal contamination level in nearby areas of cement industries

This study examined heavy metal contamination in soils near industrial areas. Heavy metal-contaminated waterways and soils are increasingly and progressively becoming an environmental, economic, health, and planning issue. Analysis of soil is carried out for the assessment of the heavy metals contamination level in nearby areas of cement industries. The values of assessment of the heavy metals in the cement dust-contaminated soil sediment from sampling sites are graphically represented in Figure 1.

Our findings demonstrate that there is a possibility that the investigation area runs a risk of Zn, Cu, Cr, and lead in soil samples at the study sites when compared to the control sample and is probably credited to the presence of cement industries. After extraction, following the analysis of heavy metals from industrially contaminated soil, the heavy metals chosen for further studies are Pd, Cd, and Cr.

The chromium concentration (figure 1) of the soil sample varied in the range of 15.75 mg/kg to 29.25 mg/kg. The lead concentration (figure 1) of the soil sample varied in the range of 9.37 mg/kg to 12.4 mg/kg.

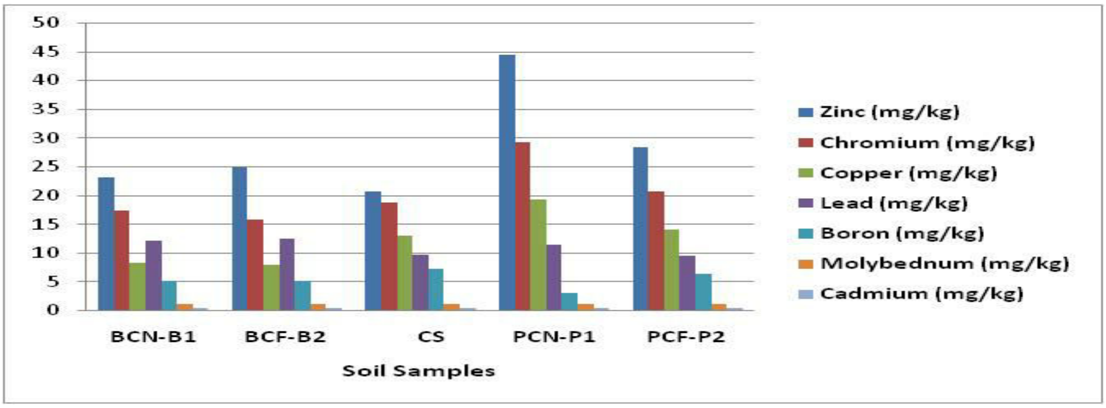

Figure 1: Analysis of heavy metals from industrially contaminated soil

The variations were seen in the concentration of all metals concerning direction and distance. The study showed that the soils near the cement manufacturing unit were more harmed and the extent of damage decreased with an increase in distance from the cement manufacturing unit. This outcome found that dust emissions from the cement factory have struck study location soils as compared to very low concentrations of heavy metallic contents in the control study vicinity. The fallout of cement dust pollutants a few meters away from the source, depending on the direction and velocity of the wind, is probably what causes the variation in metal concentration with distance.

The results are also supported by some previous research papers that soil contamination, due to cement, decreases sharply with distance from the factories and with increasing depth from the surface. Chaurasia et al. (2013) in the Kodinar region in Saurashtra of Gujarat, studied the effects of pollution from the cement industry on chlorophyll of Arachis Hypogaeo, Sesamum Indicum & Triticum Species over a distance of 0.5 km, 1 km, and 3 km, showed that crops near the cement factory were more damaged [11].

Okoro et al. (2017) reported the Assessment of Heavy Metals Contents in the Soil around the WAPCO Cement Factory in Ewekoro, Nigeria Using Pollution Indices. The analysis of heavy metals in the soils of commercial cement sites revealed that there were significant differences in the concentrations of heavy metals between sampling sites and that some heavy metals are present in the region's cement sites at levels that are several times higher than in natural control areas [12].

Shrivastava et al. (2008) studied the heavy metals in the river water of the Satna region where iron and zinc crossed the W.H.O. and BIS parameters [13].

Richhariya et al. (2012) studied the Determination of Metals (Pb, Ni, and Cd) of Toxicological Significance in Waste Water Irrigated Vegetables in the Satna Region where the veggies grown with wastewater had higher concentrations of metals than those irrigated with tube well [14].

Rai et al. (2013) observed the impact of the Maihar Cement plant in Satna District of Madhya Pradesh on the human health of the people living around it where the population of the sample area showed a greater incidence of respiratory diseases than other problems. It was concluded that the soil quality of the Satna District was not encouraging [15].

Dwivedi et al. (2016) reported the diffuse heavy metals Pollution in Central India. 50% of samples were higher than the permissible limit with heavy metals like Cd, Pb, and Fe. The sufferings of human beings with various diseases were an indication of increasing pollutants. Such a type of monitoring of soil samples is beneficial to knowing the concentrations of various parameters present in the soil [16].

Kehinde et al. (2020) investigated the effects of soil microorganisms' physicochemical characteristics on cement dust pollution resulting from the LARFAGE cement industry in Ewekoro. The locations 500 meters nearest to the plant site had the highest pH levels, according to the results 6.47. Except for Mg, Zn, and Na, the plant had higher amounts of heavy metals than the control. The amounts of Cr, Fe, Pb, Fe, Cd, Ca, and Cu were significantly higher in all locations compared to the Microbial control. The fungus and bacteria were influenced by the cement dust deposition. Distance from the factory gradually increased as the population variety rose. Accordingly, the variation is attributed to the microbial community's response to heavy metals and pH [17].

Silva et.al (2021) studied the deposition of potentially toxic metals in the soil from surrounding cement plants in a Karst Area of Southeastern Brazil. Large-scale cement production facilities are well-known for having been implemented in this area. The purpose of this study was to determine whether the PTM concentration in the soil around cement factories had increased and to calculate their detrimental effects on the ecosystem and the nearby human population. The potential toxic metal (PTM) concentrations of Cd, Pb, Co, Cu, Cr, Mn, Ni, and Zn were evaluated. According to the findings, PTM concentrations in the vicinity of the cement plant were all noticeably greater than those in the control locations [18].

The buildup of heavy metals in soil in a central South African industrial area was examined by Aloud et al. in 2022. According to the findings, the HMs content in the soil was in descending sequence (Fe > Ni > Zn > Pb > Cu > Cr > Cd). Up to 100%, 16.6%, and 6.2% of soil samples contained exceptionally high levels of Cd, Ni, and Pb, respectively [19].

Srivastava et al. (2023) investigated the influence of cement dust deposition on the chemical characteristics of soil near the Jai Laxmi cement mill in Ramnagar, Chandauli. Soil samples were collected, examined, and compared to the control location and standard soil categorization. A comparison of soil chemistry characteristics demonstrated that cement dust from the cement factory had an impact on the soil quality in the surrounding area. At the moment, it may not seem alarming, but if this tendency continues, soil qualities across a large area are likely to change, indirectly affecting plants, fauna, and humans.

The primary cause could be wind direction, which results in the settling of dust and effluents discharged by cement production sites over time [20]. In sediment, heavy metals have been observed to diminish in the order of Zn > Cr > Pb > Cu > B > Mo > Cd for contaminated sites.

4. Conclusion

The conclusion can be drawn that this study of physicochemical parameters of soil samples showed dissimilar values at different places. This could be a result of the irregularity of the distribution of different parameters found in soil. This type of soil sample monitoring is useful for determining the concentrations of various parameters contained in soil samples. The findings of this study will aid in determining the kind and severity of soil-related problems and make recommendations for appropriate reclamation measures, as well as determine suitability to cultivate crops. It will also aid in the investigation of soil genesis. As a result of this research, farmers can get a rough estimate of how much fertilizer and nutrients they'll require from the soil to boost crop yields by a percentage. Monitoring of micronutrients in the soils should be done periodically as it can be an efficient way to assess the qualitative and quantitative abundances of the metal concentrations.

The accumulations of heavy metals in the indigenous soil were examined in the current investigation. In terms of heavy metal contamination, it was observed that the cement industry could be a potential source of pollution. The concentrations of investigated heavy metals (Zn, Cr, Cu, Pb, B, Mo, Cd) were compared to the control sample standards and some metals have been observed above the permissible limits in indigenous soil. The values of Zn, Cr, Cu, and Pb are above the usual range in most of the soil samples which could be due to anthropogenic inputs in this area. The excessive levels of metal concentration confirmed that this region has been stricken by activities of cement enterprises resulting in excessive metal contents in comparison to their background levels. These higher concentrations of metal explored in soil are a great health risk not just for those individuals living nearby ventures in the vicinity of cement industries but also furthermore for those relying upon harvests like wheat and mustard as a staple food. It is recommended from the results of the current review that adequate monitoring of this source of pollution ought to be carried out regularly to stop the terrible effects of pollution. Investigating various gaseous contaminants in the air to assess their cumulative effects would also help to determine the overall effects of this industry on the encompassing native soil and biota.

5. Future Aspects

Satna city and nearby areas are some of the most important cement industrial hubs in the country. These areas comprise many enterprises and therefore, there may be a massive threat of environmental contamination which is exceptionally risky to our wellbeing. Many hazardous sites in the industrial areas in Satna require remediation. Yet, the truth of the matter is that industries and their businesses are expected for the economic system modernization and improvement and development of the metropolis like Satna

Mainly so far now, studies have been carried out for physicochemical properties and heavy metals analysis in soil and water of Satna district with results as heavy metals being found major pollutants in cement dust, but how to eco-friendly remediate or to make the environment healthier has still been a point to think seriously Looking at the city from the standpoint of the Satna region's cement industries thus far. As a result, appropriate safeguards are advised for soil health.

The answer to this issue comes from the idea of bioremediation. Bioremediation is an economical, environmentally favorable, pleasant strategy most suited for developing nations and communities like Satna. Bioremediation is the engineered use of biological agents to remove environmental pollutants from soil or water, such as heavy metals. Despite this potential, bioremediation is yet to turn into an industrially accessible innovation in India.

Despite this, future research goals may include extracting or stabilizing heavy metals from polluted soils, to identify the metabolic and absorption mechanisms used for the identification of metabolites and heavy metals, such as when creating a risk analysis plan for bioremediation technique. At the trial organized, bioremediation alone has been productive in changing debased soil into fertile rich soil suitable for farming. This procedure is considered useful, successful, productive, and effective in recycling and reusing soil without much effort.

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References

1. Joffe, J. S. Pedology. Pedology Publ., New Brunswick, N. J. 1949.
2. Solanki, H.A.; Chavda, N. H. Physicochemical analysis concerning seasonal changes in soils of Victoria Park reserve forest, Bhavnagar (Gujarat).Life Sciences Leaflets, 2012, 8:62-68.
3. Maphuhla, N.G.; Lewu, F.B.; Oyedeji, O.O. The Effects of Physicochemical Parameters on Analysed Soil Enzyme Activity from Alice Landfill Site. Int. J. Environ. Res. Public Health, 2021, 18, 221.
4. Sharma, R.K.; Agrawal, M.; Marshall, F.M. Heavy metals in vegetables collected from production and market sites of a tropical urban area of India. Food Chem. Toxicol., 2009, 47, 583-591.
5. Alloway B. J.; Alloway, B. Heavy metals in soils. Blackie, Glasgow. 1995.
6. Bada, B. S.; Raji, K. A. Phytoremediation potential of kenaf (hibiscus cannabinus l.) grown in different soil textures and cadmium concentrations. African Journal of Environmental Science and Technology, 2010, 4(5), 250–255.
7. Singh, M.; Bhatnagar, M. K.; Solanki, M. K. Heavy Metal Distribution in Soil of Jaypee Cement Industrial Area 2012 Rewa City, Mp, India. International Research Journal of Environmental Sciences, 2018, 7(6), 1-5.

8. Waoo, A.A.; Khare S.; Ganguli, S. Extraction and analysis of heavy metals from soil and plants in the industrial area Govindpura, Bhopal. J. Environ. Hum., 2014, 1(2). 158-164.

9. Oishimaya, S.N. What Are the Harmful Effects of Littering? World Atlas-Environment. Available online: www.worldatlas.com. 2020.

10. Bartkowiak, A.; Lemanowicz, J.; Siwik-Ziomek, A. Assessment of selected heavy metals and enzymes in soil within the range of impact of illegal dumping sites. Int. J. Environ. Res, 2016, 10, 245–254.

11. Chaurasia, S.; Karwaria, A.; Gupta, A. D. Effect of Cement Industry Pollution on Chlorophyll Content of Some Crops at Kodinar, Gujarat. Proceedings of the International Academy of Ecology & Environmental Sciences, 2013, 3(4), 288-295.

12. Okoro, H. K.; Orimolade, B. O.; Adebayo,G. B.; Akande, B. A.; Ximba,B. J.; Ngila, J. C. An Assessment of Heavy Metals Contents in the Soil around a Cement Factory in Ewekoro, Nigeria, Using Pollution Indices. Polish Journal of Environmental Studies, 2017, 26(1), 221–228.

13. Shrivastava, K. B. L.; Pandey, S. K.; Singh, B. P. Study of Heavy Metals in River Water of Satna Region. Current World Environment, 2008, 3(2), 297-300.

14. Richhariya, N.; Tamrakar, S. Determination of Metals of Toxicological Significance in Waste Water Irrigated Vegetables of Satna Region. Mat.Sci.Res.India, 2012, 9(2).

15. Rai, P.; Mishra, R. M.; Parihar, S. Quantifying the Cement Air Pollution Related Human Health Diseases in Maihar City, Mp, India. Research Journal of Recent Sciences, 2013, Vol. 2 (ISC-2012), 229-233.

16. Dwivedi, A. P. Assessment of Physico-Chemical Quality of Soil in Rewa District of Madhya Pradesh. International Journal of Advanced Research in Chemical Science (IJARCS), 2016, 3 (11), 9-13.

17. Kehinde, S., Suliat, M. S., Adewunmi, O. M., Oriyomi, F. A. and Lukman, A. S. (2020). The physio-chemical and microbiological characteristics of cement dust polluted soil around lafarge cement industry. Open Journals of Environmental Research (OJER) ISSN: 2734-2050 Article Ref. No.: OJER20200000 Volume: 1; Issue: 2, Pages: 1-11

18. Silva, T.A.d.C.; Paula, M.d., Jr.; Silva, W.S.; Lacorte, G.A. Deposition of Potentially Toxic Metals in the Soil from Surrounding Cement Plants in a Karst Area of Southeastern Brazil. Conservation 2021, 1, 137-150. https://doi.org/10.3390/conservation1030012.

19. Aloud, S.S.; Alotaibi, K.D.; Almutairi, K.F.; Albarakah, F.N. Assessment of Heavy Metals Accumulation in Soil and Native Plants in an Industrial Environment, Saudi Arabia. Sustainability 2022, 14, 5993. https://doi.org/10.3390/su14105993.

20. Srivastava, S., James, A., & Myrthong, I. (2023). Effect of Cement Dust on Soil Chemical Properties in the Vicinity of a Cement Factory, Ramnagar Chandauli, India. International Journal of Plant & Soil Science, 35(20), 103–112. https://doi.org/10.9734/ijpss/2023/v35i203790.