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Heavy metal toxicity in the soil of Amroha district of Uttar Pradesh, India

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Abstract

Background: Increased pollution of soil heavy metals in India has formed a most significant concern as a result of growing industrialization, urbanization, and intensive agriculture.

Objective: To establish the impact of contamination in the research region, an environmental geochemistry investigation was conducted in and around the Amroha district industrial growth area of Uttar Pradesh.

Materials and Methods: Using a Philips PW 2440 X-ray fluorescence spectrometer, soil samples obtained from the Amroha district industrial sector were tested for Cr, Pb, Cu, V, Sr, and Zn content. Samples were taken from the top soil 10 cm in the industrial sector of Amroha district. The majority of the samples were taken along small streams near industrial areas and the Son River.

Results: 240 mg/kg Cr, 293 mg/kg Pb, 298 mg/kg Cu, 377 mg/kg V, 2,694 mg/kg Sr, and 1,364 mg/kg Zn were discovered to have considerably greater levels in soils around the industrial region than their typical distribution.

Conclusion: The toxicity development in farm products is caused by high concentrations of these toxic components in soil, which has an impact on human life. The article discusses the distribution of metals, their contents in various areas, the association of soil heavy metals, and their effect on people's health.

Keywords: Toxic metals, Amroha district, India, Soil contamination,

1.0 Introduction

Human health has been linked to a number of heavy metals and wildlife health when found in high amounts in the environment. Many factory complexes' surrounding areas are particularly vulnerable to harmful heavy metals high levels resulting from the liquid effluents that haven't been properly treated end up on the ground discharge. The heavy metals presence in any high amounts above their usual soil distribution generally indicates that the soil in the research region has been contaminated. Heavy metals such as (zn,pb,sr) deposited on the surface of soil undergo downhill transportation, according to McLean and Bledsoe (1992), which doesn't occur to such higher extent until the capacity of soil's heavy metal retention is overwhelmed or interaction of metal with related waste matrix promotes mobility. Heavy metal pollutants can come from a variety of places, including deposition, wastewater leachate, and surface runoff. Because of their toxicity and accumulation, heavy metals have a significant ecological impact today. These essential elements can leak into ground or surface water , be absorbed by the plants, released into the surrounding or atmosphere as gases, or link semi-permanently with components of soil like organic matter or clay, all of which have an impact on human health. The purpose of this study is to examine heavy metal contamination in soils in the Amroha district industrial region, as well as to investigate their likely sources and health impacts on humans, in order to better target medical investigations.

2.0 Research and Methodology

The "Central Pollution Control Board" of New Delhi has classified the Amroha industrial region as one of the contaminated areas. The Amroha district has a boundary with six Uttar Pradesh districts. The research region is located within the Bandi River catchment, the Ramganga tributary, After and during monsoons, which is at most large river that recharges groundwater. About three hundred enterprises produce chemicals, textiles, paints, dyes, and the marble-based factories in this industrial region. In the studied region, the average annual rainfall is 490 mm. In the Son River and other bodies of water, "rainwater" is the raw water supply. Surface water is used only for factory purposes as well as being the primary supply of home and agricultural water. Near the industrial sector, The treated sewage is combined with urban sewage sludge as well as deposited into the "Son River", which eventually connects the Ramganga at a "Common Effluent Treatment Plant" (CETP).

Granite is the most common rock type in the area. In the research region, there is also a succession of shale, quartzite, metasedimentary synsedimentary volcanics, tuffs, and phyllite.

2.1 Research Approach

Due to anthropogenic (industrial) and natural processes activity, heavy metal buildup in the soil has quickly grown. Because Heavy metal is a non-biodegradable substance, they can survive in the surrounding, Crop plants allow pests to enter the nutrients food chain, and finally gather in the human body through biomagnification. The contamination of Heavy metal and it has posed an acute threat to people's health or the environment because of their poisonous nature. Therefore, land contamination must be remedied as soon as possible. Phytoremediation is an environmentally benign strategy that could also be a cost-effective solution to soil that has been contaminated by heavy metals should be replanted. A deeper understanding of these mechanisms behind the heavy metal tolerance and accumulation in the plants is needed to improve phytoremediation efficiency. We detail the mechanisms by which Heavy metal is gaining popularity, detoxified and translocated in plants in this review. We concentrate on solutions that use microbe-assisted, chelate-assisted and genetic engineering ways to develop the phytoextraction and phytostabilization efficiency.

2.2 Population and Sample

After removing surface contamination, samples of soil were taken from the external surface, at a depth of 05–15 cm. Metal utensils were not used for sampling; instead, a plastic spatula was used. These samples were gathered in “self-locking polythene bags” that were double-bagged. samples of soil were dried at 60°C for two days. With a pestle and mortar, The sample of dry soil was broken down. Using a grinding mill which is swing, these samples were finely pulverised to –two hundred fifty mesh size (United State Standard). Boric acid was used as a foldable aluminium cup as a backer, which were pressed at a pressure of 20 tonnes; sample pellets were made for XRF spectrometry characterization of trace and main elements. The pellets were prepared for XRF examination using a hydraulic press.

2.3 Research Tools

The principal trace elements and oxides in the samples of soil were determined using a “Philips MagiX PRO Model PW 2440 X-ray Fluorescence Spectrometer” and a sample changer that works automatically 2540 PW. The “MagiX PRO” is a consecutive tool with a one measuring channel based on a goniometer that covers the complete elemental range.

For optimum flexibility, the device is microprocessor operated. In the X-ray tube, a Rhodium (Rh) anode is employed, which can run at approximately 60 kV and currents approximately125 mA, with a 4 kW maximum output.

“The United State Geological Survey, Canadian Geological Survey (SO-1, SO-2, SO-3, SO-4), International Working Group France, and National Geophysical Research Institute” of India worked together to produce calibration curves only for most significant trace and assess elements the correctness of analytical information (NGRI-U and NGRI-D) used “International Soil Reference materials from the US Geological Survey, Canadian Geological Survey (SO-2, SO-3, SO-4), International Working Group France, and National Geophysical Research Institute, India”.

2.4 Data Collection Method

Between October 2017 and May 2020, samples were taken. 15 (0 to 10 cm in depth) surface-level soil samples (three replicates) were obtained from several locations or areas to cover factories, residential and commercial regions. The procedure for determining soil metals and samples of dust was carried out to the published method. The samples of soil dust were crushed and sieved before being used. The sieved materials were dried for 24 hours at 70 degrees Celsius. 10 mL nitric acid concentrate was heated to dryness and then cooled on one gramme of dirt. This method was carried out once more with 10 mL concentrated nitric acid and 10 mL 12 N HCl. To re-dissolve the metal salts, the digested soil and dust samples were reheated in 20 mL of 2 N HCl. The volume was also adjusted to twenty five milliLiter including 1.5 percent HNO3 after the extracts were fully filtered by using the Whatman no. 40 filter paper. The amounts of heavy metals "Atomic emission spectroscopy" in an inductively "coupled plasma" was used to determine the concentrations in each (ICP-AES) fraction with multiple determinations and the blanks use to account for other causes and background of error. The pH of the soil was measured using an electrode (glass) and a water or soil slurry that is (1:10).

2.5 Statistical Analysis

Heavy metals accumulate in the soil environment as a result of anthropogenic activity. Soil pollution has a severe negative impact on environmental quality and human health. For analysis of the heavy metal, samples of soil were obtained from several areas in the Amroha district of uttarpradesh, India. The materials were evaluated using "energy dispersive X-ray fluorescence (EDXRF) spectroscopy" for 12 heavy metals (Al, Mg, K, Ti, Ca, Fe, Cr, Mn, V, Co, Zn and Ni). To measure metal accumulation, dispersion, and pollution status in soil, researchers used the enrichment factor, contamination factor, pollution load index and geo-accumulation index. Soil quality recommendations based on intervention values and target of Dutch soil standards were used to assess heavy metal toxicity risk. Natural sources largely influenced the concentrations of Ni, Co, Zn, Cr, Mn, Fe, Ti, K, Al, and Mg. Sources of Heavy metal (natural/anthropogenic origin) were identified using multivariate statistical approaches for example correlation matrix, cluster analysis and the analysis of principal component. Hot regions of metal pollution in road areas were detected using geostatistical approaches such as kirging, which were influenced mostly by the presence of natural rocks.

3.0 Results and Discussion

Table 1 summarizes the soil metal levels at several sampling points, while (**Table 2)** summarizes the range values and averages. The statistics show that total heavy metal concentrations were considerably high for all elements. Heavy metal enrichment levels in soil that surpass the generally expected distribution raise concerns about the soil's appropriateness for developing crops. These elements in high quantities have been found in few pockets **(Fig. 3)** only adjacent to pesticide, dye, and chemical manufacturing facilities. The amounts of strontium in the blood ranged from "200 to 2,694 mg/kg", including 954.9 mg/kg an average . Sr levels were consistently high in almost all of the samples. In samples through sites JP-10 and JP-9, heavy metals Zr and Sr total concentrations were much higher, as shown in **Figure 3**. Sr concentrations this high are frequent in the acidic rocks like granite,that is the area of a prevalent rock. Such aberrant Sr readings could be attributable to granite erosion surrounding the research location rather than any anthropogenic source. Sr distribution in soil is 200 mg/kg on average. Excess strontium is especially hazardous when the diet lacks calcium due it substitutes only for "calcium" in the developing bone in an inefficient way and interferes with regular calcium uptake. Chromium levels ranged from 40 to 240 mg/kg in the study area, including erosion of 156.10 mg/kg average shown in (**Table 2),** and were significantly larger in the place surrounded by the granitic rocks. In soils, the 100 mg/kg Cr typical range. In soils, 2 oxidation states Cr exist: hexavalent (VI) Cr and trivalent (III) Cr. Hexavalent (VI) Cr is more dangerous than trivalent (III) Cr because it is mobile and exceedingly poisonous (III). It isn't possible to extract such chromium high levels through rocks because the atmospheric rocks are mostly granite, with chromium concentrations mostly below 50 mg/kg. As a result, the Cr source shows to be "anthropogenic", with few steel and textile companies in the vicinity. In some industrial locations of India, Ansari and colleagues (1999) found exceptionally high Cr levels in soil, up to 1,220 mg/kg. Chromium is a trace element that is required for lipid and protein metabolism as well as maintaining a proper glucose tolerance factor. Chromium in high concentrations damages the liver and kidneys, and the chromate dust particle is said to be "carcinogenic". In almost all of the samples, copper and zinc levels were found to be elevated. The usual distribution of Cu and Zn in soil has a mean value of roughly 30 mg/kg and 200 mg/kg, respectively. Copper levels in the samples of soil in the vicinity range from 10 298 mg/kg to 48 to 1,364 mg/kg, including an average range of Cu 96.9 mg/kg and Zn 359.7 mg/kg. Zinc and Copper soil concentrations usually show those found in the parental rocks. "igneous basaltic rocks" (90 mg/kg) Zinc levels and the soils derived from the calcareous rocks are typically greater. Copper is preserved in soils by a variety of methods, including exchange and specific adsorption. Clay minerals and carbonates quickly absorb zinc. The presence of high quantities of Zn and Cu in this location has been linked to surrounding industrial districts, indicating that the source is man made rather than natural. Furthermore, acidic rocks are highly unlikely to contain copper 300 mg/kg and zinc 1,364 mg/kg. Copper and zinc in large doses are also known to be poisonous and cancerous. Copper overdoses can also cause neurological problems, hypertension, and liver and renal problems. Hematological diseases are caused by higher zinc pollution. In samples near farmland and some pesticide production industries, levels of soil lead range from 10–293 mg/kg, including an average value of 59.07 mg/kg. The common distribution of the soil lead has a 29 mg/kg mean value, whereas lead levels in the research area are as big as -293 mg/kg. Therefore this large value could be attributable to a chemical fertiliser manufacturer; these fertilisers are utilised in agricultural applications such as insecticides. The normal trace metals found in rock superphosphate and phosphate include Cd, As, and Pb. These fertilisers Increased use may result in soil pollution from these metals. Hence the lead presence lowers the biota's enzymatic activity, resulting in the accumulation of partially digested soil organic material. Pb is the poisonous metal least mobile, which is due to the heavy metal's affinity for organic materials. Finally, the soil organic matter connects the complex lead and absorbs it into the soil, removing it from the water. Lead had long been known as a health danger in the workplace. Pb obstructs the synthesis of haemoglobin and builds up in the red cells and bones, causing anaemia, headaches, and dizziness. The research area had vanadium levels ranging from “43 to 377 mg/kg”, including a 104.9 mg/kg soil average. The amount of soil vanadium is determined by the “pedogenic process” and the “parent material” that led to its formation. The parent material composition has less of an impact on the Vanadium content of developed, mature soils. In soils, the V normal distribution is 100 mg/kg. Vanadium is used in a variety of industries, including dyeing, electronics and metallurgy. The bulk of the factories are dye-related, indicating that the source is anthropogenic and derived from a dye-related sector in the vicinity. ; Strontium with Zinc, Zirconium; Copper with Chromium, Lead; and Vanadium with Lead, Chromium are shown in scatter diagrams in **Fig. 2**. Sr vs. Zn, Zr; Cu vs. Cr, Pb; and V vs. Pb, Cr have a high association in general. A straight line indicating a positive association between Sr and Zr implies a shared geogenic source from natural action in the surrounding granite rocks. Cr, Pb, V, Sr, and Zr have similar general geochemical behaviour, and these essential elements appear to percolate and migrate together into surface water, contaminating the surface water table. The amounts of trace metals in some clean water bodies in the Amroha district were also measured, and the outcomes were compared to WHO standards of drinking water. Pichola Lake and Hathinikund Dam water is also used oly for the “civil supply”, and the mean Pb concentration was shown to be larger throughout the tests. The seasonal Ramganga received the city's complete factory waste, with Pb, Ni, and Zn levels being greater. Textile dyeing and printing are the most important businesses in Amroha, and because textile production necessitates a huge amount of freshwater , these factories are typically located along riverbanks with access to transportation. At last, wastewater discharge through these units of textile carries effluents to the soil, resulting in water quality degradation and the surface water table additional contamination in the area.

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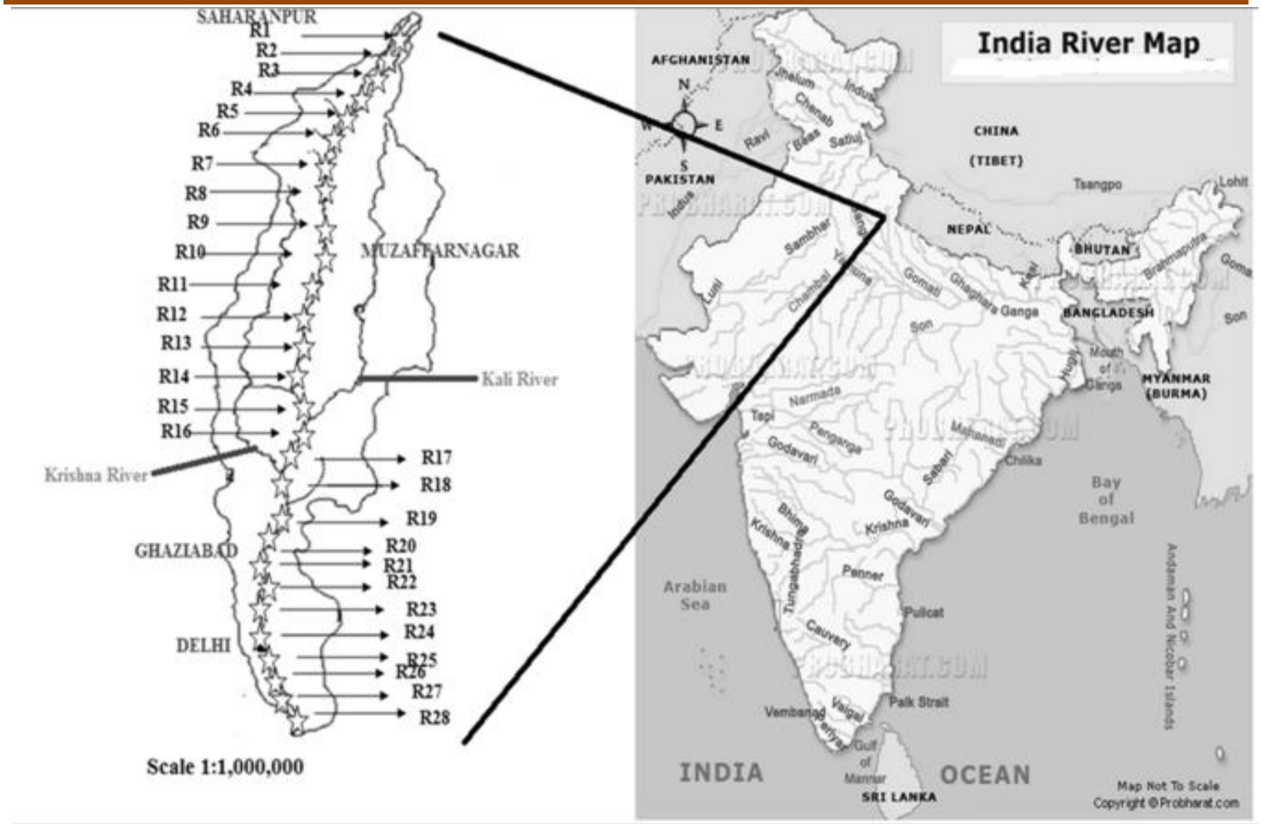

Figure 1: The research area is depicted on a map.

Seq.	Sample	Cu	Cr	Pb	Sr	V	Zn	Zr
1	JP-1	41.5	56.0	48.6	1,257	178.2	286.7	969.6
2	JP-2	42.5	52.2	19.0	377.9	51.5	124.3	753.6
3	JP-3	49.3	77.3	32.1	224.0	77.8	59.0	659.7
4	JP-4	61.4	84.0	65.5	1,928	99.5	356.1	1,407
5	JP-5	58.6	41.2	52.9	502.5	51.0	108.3	577.2
6	JP-6	63.9	45.9	61.5	431.4	51.9	113.8	517.7
7	JP-7	62.0	63.9	29.1	644.2	90.6	449.1	912.4
8	JP-8	95.8	83.5	50.6	714.4	133.8	479.6	1,004
9	JP-9	13.5	41.4	31.7	2,464	43.9	278.7	2,094
10	JP-10	10.6	42.5	43.8	2,694	51.2	640.9	2,046
11	JP-11	48.1	57.5	22.8	221.9	73.8	47.8	681.8
12	JP-12	93.3	181.5	42.3	1,627	85.8	414.5	1,240
13	JP-13	93.5	45.2	58.5	1,711	53.0	472.5	1,330
14	JP-14	67.0	54.6	85.0	1,650	88.9	292.3	1,520
15	JP-15	50.2	72.6	18.1	274.3	81.9	57.5	705.7
16	JP-16	66.5	59.4	24.1	367.7	69.2	72.9	750.7
17	JP-17	213.4	79.4	55.0	481.3	89.7	324.5	628.6
18	JP-18	69.9	56.0	10.9	414.9	65.6	91.0	801.4
19	JP-19	113.5	66.3	76.8	624.3	71.8	254.1	728.9
20	JP-20	135.4	65.1	35.1	1,321	79.1	177.5	1309
21	JP-21	294.2	92.4	65.3	812.1	147.6	229.5	810.9
22	JP-22	100.5	73.6	51.0	603.5	104.7	464.0	795.9
23	JP-23	298.3	241.9	292.6	711.5	377.5	739.2	696.0
24	JP-24	74.6	193.6	108.3	1,139	212.8	1,364	973.0
25	JP-25	69.4	100.3	60.2	710.4	181.3	68.6	655.6
26	JP-26	150.2	54.5	42.6	859.3	60.3	1,329	897.2

Table 1: XRF data for trace elements in soil samples (values reported in mg/kg)

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	cu	cr	pb	sr	v	zn
Soil-average	96.9	156.10	59.07	954.9	104.9	359.7
Soil-range	12-300	42-242	12-295	224-2596	45-379	50-1366

Table 2: Metal concentrations in soils (mg/kg) and their averages and ranges

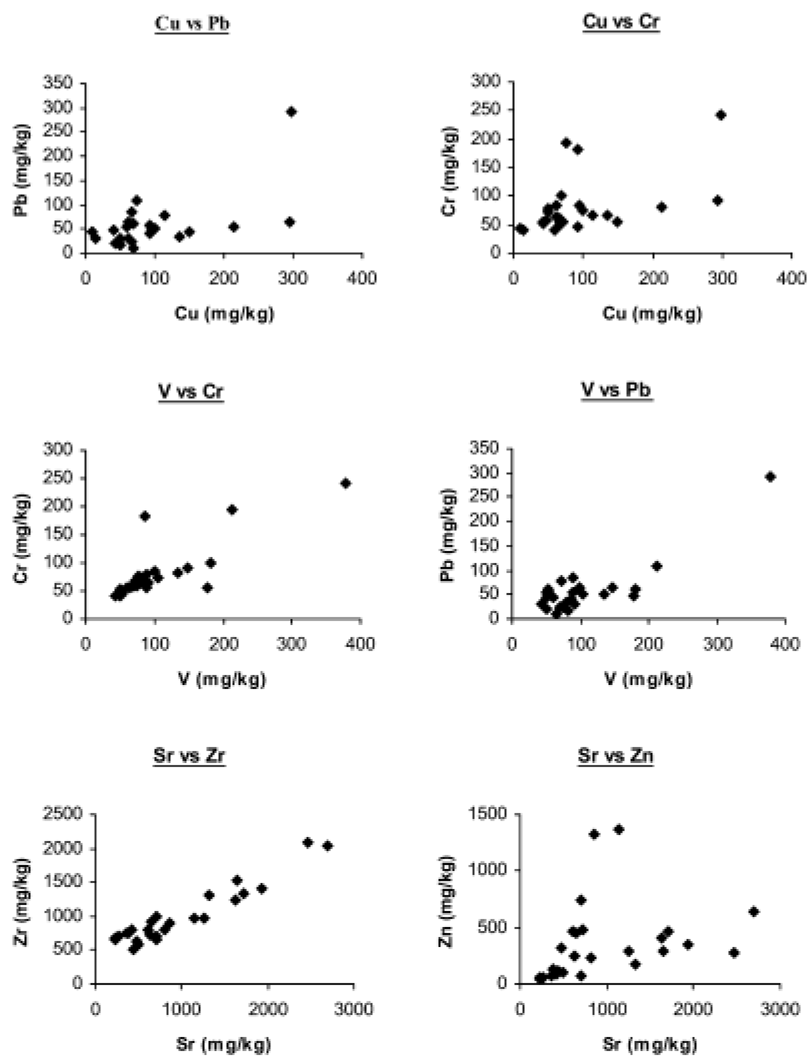

Figure 2: Correlation of (Sr vs Zr, Zn); (V vs Cr, Pb); (Cu vs Pb,Cr) diagrams depicting the relationship between two variables.

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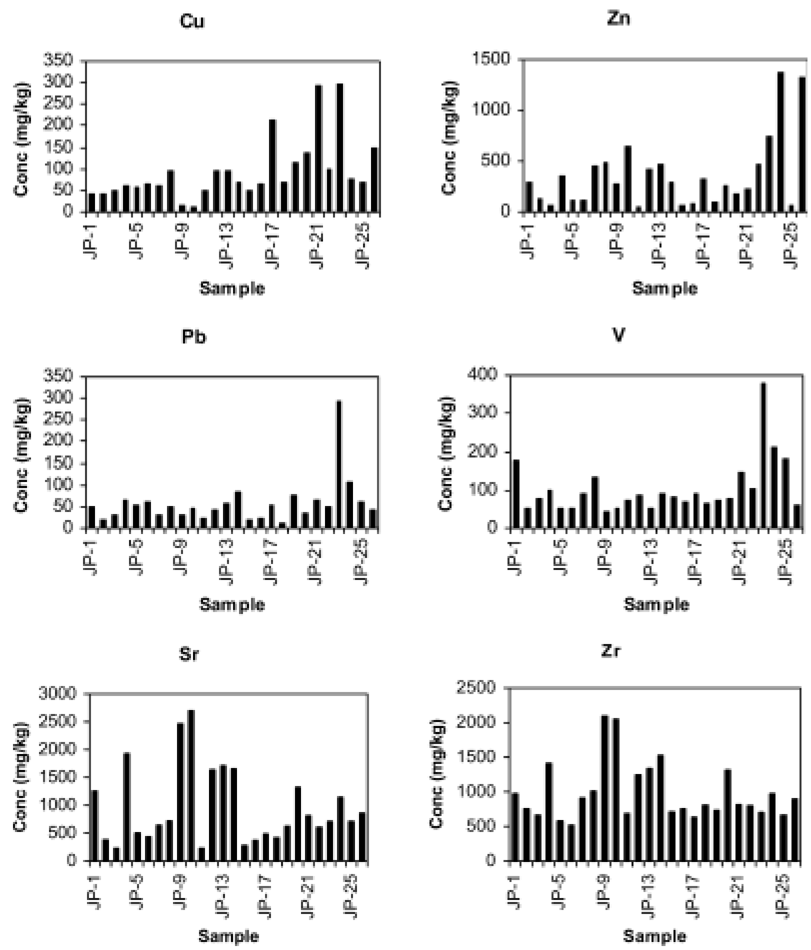

Figure 3: Metal distribution and sample metal content at different locations.

4.0 Conclusion

The study's findings suggest that the soils in and around the Amroha factory region have also been poisoned with soil heavy metals for example cu,pb,sr,zn,v and zr at a high level significantly beyond background quantities in soil, potentially posing health risks. Before dumping harmful metals in CETP, toxic metals in industrial effluents should be measured. It's also a good idea to inspect the CETP's output water after treatment to make sure that no dangerous chemicals are released into the nearby river. According to the study, all heavy metals such as Zr and Sr are not caused by factory effluents and have a geogenic origin, hence factories are not responsible for all concentrations of heavy metal. The area soil needs to be remedied in order to meet environmental quality standards. In addition, regular monitoring of harmful metal concentration in the area is required.

5.0 Implication of the study

Plant Growth Effects of Heavy Metal Polluted Soil

Plants can absorb heavy metals which are available in the solution of soil as the soluble components or heavy metal are easily soluble by the root exudates. Although few heavy metals are necessary for plant maintenance and growth, high quantities of these heavy metals can also be harmful to plants. Plants can acquire both essential and non-essential metals due to their propensity to accumulate vital metals. Due metals cannot easily be broken down, they have indirect and direct detrimental impacts on plants when their concentrations exceed optimal limits.

Excessive concentrations of metal can cause cytoplasmic enzyme inhibition and the oxidative stress leads to damage to structures of the cell, among other things. An indirect detrimental consequence is the essential nutrients replacement at the plant cation sites exchangeFurthermore, heavy metals' negative effects on soil microorganism activity and growth may have "an indirect" effect on growth of plant. Excessive concentrations of metal, for example, may cause a reduction in the beneficial soil microorganisms number, resulting in an organic matter breakdown reduction and the soil nutrient losses.Interference with the soil microorganisms activities by heavy metals may also block enzyme activity required for the plant metabolism. Also these harmful impacts (both indirect and direct) cause a reduction in plant development and, in some cases, death of plants.

The impact of heavy metal toxicity on plant growth varies depending on which heavy metal is involved in the process. The harmful impacts of particular metals on plant development, physiology and biochemistry are summarised in Table 1. Metals such as Pb, Cd, Hg, and As, which have no helpful role in plant growth, have been found to have negative impacts at the growth media low concentrations. Rice plants developing in polluted soil including 1 mgHg/kg showed a substantial drop in height, according to Kibra. At this level of Hg in the soil, tiller and panicle development were similarly reduced. When Cd levels in the solution of soil were as less as 5 mg/L, wheat plants saw a decline in shoot and root growth. Lower activities of photosynthesis, plant mineral food nutrition, and decreased enzyme activity account for the majority of the drop in plants growing growth parameters in polluted soils.

In the case of other metals that are helpful to plants, "low" concentrations in the soil may actually boost plant development and growth. Plant growth has been observed to be reduced at these metals' higher concentrations. For example, Jayakumar et al. found that at 50 mgCo/kg, the tomato plant's nutritional content increased when compared to the control. Plant nutrient content was reduced from 100 mgCo/kg to 250 mgCo/kg, on the other hand. Similarly, at 50 mgCo/kg concentration of soil, growth of plant, biochemical content, nutrient content, and enzyme activities which are antioxidants (catalase) increased, while at “100 mgCo/kg to 250 mgCo/kg” concentration of soil, growth of plant, biochemical content, nutrient content, and enzyme activities which are antioxidants (catalase) decreased. Cluster bean growth and physiology have also been observed to improve with a 25 mg/L Zn concentration in the solution of soil. When the soil solution held 50 mgZn/L, however, growth inhibition and unfavourable effects on the plant's physiology began.

It's worth noting that in most real-world circumstances (such metal mining and sewage sludge disposal waste disposal), where the earth may be contaminated with many heavy metals, both antagonistic and synergistic connections between the heavy metals can affect toxicity of plant metal. Mal and Nicholls found that combining Cu and Pb at low concentrations (500 mg/kg) and high concentrations (1000 mg/kg each) caused the stem and leaves of Lythrumsalicaria to die quickly and completely. The scientists concluded that having no synergistic connection between these metals, owing to the high doses utilised in the research, prevented an interacting link between the metals from being observed. Another study looked at the impact of six heavy metals on maize growth (Cd, Co, Cr, Mn, and Pb). These metals' presence in the soil lowered maize development and the protein content, according to the findings. “Cd > Co > Hg > Mn > Pb > Cr”. The combined impact of two or more of these heavy metals was as damaging as the most poisonous heavy metal effect, according to this study. This conclusion, according to the researcher, is due to the “antagonistic” interaction that exists between the heavy metals.

It's worth noting that few plants can withstand high quantities of heavy metals such as zn in their surroundings.these plants, according to Baker, can survive these metals by three mechanisms:

(i) exclusion: Over a huge range of concentrations of soil, preventing metal movement and also maintaining a steady concentration of the plant shoot heavy metal;

(ii) inclusion: a linear correlation between concentrations of metal in the shoot and those in the solution of soil; and

(iii) bioaccumulation:metal growth in the plant's roots and shoots at high and low concentrations of soil.

6.0 Recommendation

For the effective remedial selection approaches, background understanding of the chemistry, origins, and It is important to investigate the potential hazards of toxic heavy metals in polluted soils. To minimize associated dangers, create land resources present for agricultural growth, address the land tenure problem and grow food security, and heavy metal- soil contamination must be remedied.. Immobilization, phytoremediation and soil washing are usually mentioned as some of the finest accessible procedures for removing heavy metal polluted soils, however they have only been proved in industrialized countries. These technologies are suggested for commercialization and field application in developing countries, where urbanization, industry and agriculture are wreaking havoc on the environment.

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