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Assessment of soil Contamination due to release of heavy metals from industries

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ABSTRACT

This research work involves ten representative soil samples from the industrial area of Mysore city, Karnataka, to determine the total heavy metal content and general properties related to fertility of the soil. For digestion of heavy metals tri-acid mixture method was used. The results showed that, the iron content is higher at the range of 2.5gm/kg to 6.03gm/kg in rainy season and 3.3gm/kg to 6.0gm/kg in pre-monsoon season, for copper it ranges from 13.55mg/kg to 20.15mg/kg and 14.5mg/kg to 18.9mg/kg for rainy season and pre-monsoon season respectively. Chromium is also present in the concentration of 6.3mg/kg to 18.3mg/kg in rainy season and 6.9mg/kg to 22.5mg/kg in pre-monsoon season, zinc concentration varies from 61.9mg/kg to 109.4mg/kg and 64.3mg/kg to 112.3mg/kg for rainy season and pre-monsoon season respectively and presence of nickel varied from 9.1mg/kg to 16.05mg/kg in rainy season and 11.4mg/kg to 17.2mg/kg for and pre-monsoon season. From this study, finally we concluded that, the heavy metal concentration is little more in pre-monsoon season than that of rainy season and the heavy metal concentration is in the sequence of Fe>Zn>Cu>Cr>Ni. It reveals that presence of heavy metal has been observed from the different industries with different processes in which the industries have involved so many operations during production of materials and improper disposal of waste materials.

Introduction

Soil is defined as dynamic natural bodies composed of mineral and organic solids, gases, liquids and living organisms which have properties resulting from integrated effects of climate, organisms, parent material and topography over periods of time and which can serve as a medium for plant growth. The components of soils are mineral material, organic matter, water and air, the proportions of which vary and which together form a system for plant grow. Soil is a dynamic system because of the presence of microorganisms and their biochemical activities liberating a lot of enzymes in soil, which become stabilized in soil by binding to soil components. Soil is a crucial component of rural and urban environments, and in both places land management is the key to soil quality. Today with the rapid growth of industries (tyre, sugar, paper, tannery, textile, sago, dye industries) in the country, pollution of natural resources like air, water, soil has increased tremendously. Soil pollution and contamination is a serious problem especially in country as densely populated as India. Due to rapid industrialization, the soils in the industrial areas are polluted by various toxic substances such as heavy metals, pesticides, dioxins, polyvinyl compounds etc. from diverse sources. Soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease causing agents, which have adverse effects on plant growth and animal health.

Waste management strategies adopted in India have failed to keep pace with the industrial growth and urbanisation. This has resulted in the accumulation of toxic metallic contaminants with a consequent loss in quality of soil, for the past few decades. The problem of environmental pollution due to toxic metals has begun to cause concern now in most major metropolitan cities. The toxic heavy metals entering the ecosystem may lead to geo-accumulation, bioaccumulation and biomagnifications. Heavy metals like Fe, Cu, Zn, Ni and other trace elements are important for proper functioning of biological systems and their deficiency or excess could lead to a number of disorders. The ecological effects of heavy metals in soils are closely related to toxic effects on plants, animals, and humans.

Pollution of soil is having a devastating effect on the agriculture land as well as people consuming products grown in such land. It is very difficult to pin point the exact effects of soil pollution on humans, animals or even plants, yet the effects are out there for everyone to see. This fact evoked the interest of scientists to investigate the effect of industrialization and its fate on the environment, especially the soil environment. The present work advocates on studying industrial zone soil with special reference to the pollution due to heavy metals.

Heavy metal contamination of soil will be arise from the anthropogenic activities such as mining (M.C.Navarro *et al.*,2008), smelting in industries during the production (G.Brumelis *et al.*,1999) and pesticide, insecticide usage in agriculture (S.Vaalgamaa *et al.*,2008) and by natural activities. Chemical and metallurgical industries are the most important sources of heavy metals in the environment (O.E.J.Cortes *et al.*,2003). The metals which are having specific gravity of more than 5g/cm3 are classified as “heavy metals”. Heavy metals get accumulated in soils and plants and finally it would have a negative effect on physiological activities of plants such as photosynthesis, gaseous exchange, and nutrient absorption. It may further leads to the reductions in plant overall growth and yield (B.Devkota *et al.*,2000, A.J.M.Baker *et al.*,1988). In small concentrations, the traces of the heavy metals in plants or animals are not toxic (W.De Vries *et al.*,2008) . Lead, cadmium and mercury are the exception metals even in very low

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concentrations. Every 1000kg of "normal soil" contains 200g chromium, 80g nickel, 16 g lead, 0.5g mercury and 0.2 g cadmium, theoretically (IOCC 1996). Monitoring the soil with heavy metals is a interesting and very difficult task due to their influence on groundwater (J.Wieting 1998, R.Clemente *et al.*,2008, C.Boukhalfa *et al.*,2007) and also on plants and their growth (E.Stimpfl *et al.*,2006, J.Pandey *et al.*,2008, K.Stobrawa *et al.*,2008), animals and humans (M,Lagisz *et al.*,2008, H.M.Korashy *et al.*,2008). The main goal of the present work is to assess the heavy metals concentration in industrial area soil of Mysore city, India. Impacts of Industrial Activity on Soil Soil quality can be severely impacted by a wide range of industrial and manufacturing activities. In addition, transport is responsible for a significant proportion, for example, the precursors of acid deposition and greenhouse gases. The abandonment of land, build-up of toxic chemicals in soil, atmospheric deposition of pollutants and climate change may all have serious implications for soil quality. Radioactive contamination of soil has come mainly from former industrial processes such as luminising using radium, gas mantle manufacture, phosphate manufacture and use, metal ore refining and various other industrial and medical uses of radioisotopes. Other human sources of radioactivity to the land surface include fallout from. Pollution can take many forms and can be point source or transboundary. For example, point source pollution such as accumulation of heavy metals in one part of a foundry may lead to pollution of groundwater or toxic effects on human health, as well as a negative impact on soil quality. Transboundary pollution, such as deposition of acidifying compounds on areas remote from pollutant sources, may lead to soil acidification, leaching of toxic chemicals to surface waters and vegetation change. A wide range of compounds are emitted to the atmosphere from industry and transport. Their deposition to the land surface can have a range of impacts on soil quality including soil acidification and eutrophication, changes to the rates of biogeochemical cycling and loss of ecosystem function. In turn, these effects can have a negative impact on the air and water environments, on biodiversity and on human health. For example, soil acidification and eutrophication can lead directly to the leaching of nitrate and aluminium to surface waters, the emission of the greenhouse gas nitrous oxide to the atmosphere, and changes in the species distribution and biodiversity of vegetation in sensitive ecosystems.

Materials and Methods

Study Area:

The study area Mysore is having more than 10 lakh populations and was capital of former state and 11^o6^1 latitude and 77^o7^1 longitude and general elevation is little more than 1800 feet above sea level. The climate of the city is moderated throughout the year with temperature during summer ranging from 30^oC to 34^oC. The rainy season is from June to October. Summer season starts from February to June. The source of water for domestic purpose is mainly from the Cauvery River and ground water. Mysore is having industrial areas, which have been majorly divided in to 3 regions as follows :

1. *Metagalli industrial area*
2. *Hebbal Industrial area*
3. *Hootagalli Industrial area*

Metagalli Industrial area consisting of industries like tyre manufacturing, aluminium industries, electrical appliances industry and metal industry. In Hebbal industrial area apart from metal, lighting etc types of industries small scale industries more in number than Metagalli industrial area. Hootagalli industrial area is smaller in its size as compared to Metagalli and Hebbal industrial areas. Here the industries like textile, heavy earth movers manufacturing industry and very few small scale industries are situated.

The samples were collected in polythene covers and brought to the laboratory for analysis. All the samples were dried in oven and passed through a 2-mm sieve. Aliquots of about 1gm of soil sample were digested with tri-acid mixture for total heavy metal analysis. The concentrations of Fe, Cu, Cr, Zn and Ni were determined by using atomic absorption spectroscopy (AAS). In the present study, sampling locations are included in all the three major industrial areas of Mysore city. Sampling site from 1 to 5 belongs to the Hootagalli and Hebbal industrial area and 6 to 10 samples were belonging to different industrial site of Metagalli industrial area. The samples were collected during pre-monsoon season and rainy season. The samples were analysed using standard methods to determine the physico-chemical properties and results were tabulated.

Determination of Total Heavy Metals:

Initially 1g of soil sample was taken in to the conical flask / test tube and mixed well with the concentrated H_2SO_4, Perchloric acid and Nitric acid. Heat the conical flask / test tube content till the solution become whitish color. If white color appears, it indicates that the soil sample has digested completely. Cool the solution to room temperature and filter the solution using whatman filter paper. Make up the filtered solution to 100ml using distil water and take the readings after injecting the solution to AAS.

Results and Discussion

The soil resource is a vital component of our environment and the monitoring of soil properties is essential in achieving sustainable land use. During sampling period (rainy season of 2010 and pre monsoon of 2011), wet season had dilution of water due to influx of rain water in surrounding areas. Fresh water diluted and washed away much of the pollutants. But it was not enough to completely wash pollutants away. As water receded, the pollution load increased in the dry season than that the rainy season. The physico-chemical analysis also shows the lesser values in organic carbon and organic matter content. For any good healthy soil the organic matter content is important for the growth of the plants and it will helps in sustaining of soil microbes. But our main stream of research is on the heavy metal contaminant in the industrial area.

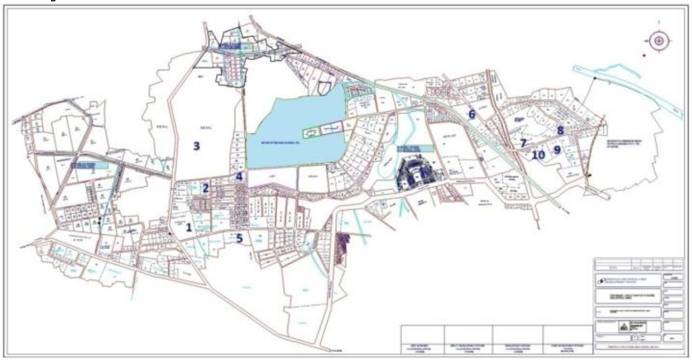
Electrical conductivity:

Electrical conductivity (EC) is a measure of ions present in water/soil. The conductivity of a solution increases with the increases amount of ions in the solution. In the agricultural sector electrical conductivity plays an important role, due to its salinity aspect. The salinity content restricts the availability of water to plants by lowering the total water potential in the soil. The salinity of a solution/soil also has an impact on crop physiology. The yield of a plant gradually decreases to zero as the salt concentration increases to the level of which cannot be tolerated by a given crop. In the present study, EC of industrial zone soil shows a range from 75.5-84µs/cm in monsoon, and 75-96µs/cm in pre monsoon.

Organic Carbon and Organic matter.

Soil carbon is the last major pool of the carbon cycle. The carbon that is fixed by plant is transferred to the soil via dead plant matter including dead roots, leaves and fruiting bodies. Soil carbon is primarily composed of biomass and non-biomass carbon sources. Some of the substrates carbon will bound to the mineral soil becoming encapsulated in soil aggregates or chemical complexing.

Soil organic carbon improves the physical properties of soil. It increases cation exchange capacity and water holding capacity of sandy soil and it contributes to the structural stability of clays soil by helping to bind particles in to aggregates. Soil organic matter of nutrients, cations and trace elements that are of importance to plant growth. It prevents the nutrient leaching and if integral to the organic acids that make minerals available to plants. It is widely accepted that the carbon content of soil is a major factor in its overall health.



Source : KIADB

Figure 1. Sampling location of study area

The results of organic carbon of study area, shows a highest range of 0.693% in rainy season at sampling station no. P10 and least amount of 0.094% at sampling station number P5. The low amount of organic carbon were recorded of 0.096% at P3 and maximum of 0.576% at P4 in pre monsoon. Due to lack of fertility in the soil, the organic carbon would differ from season to season with the additional factor of moisture content in soil.

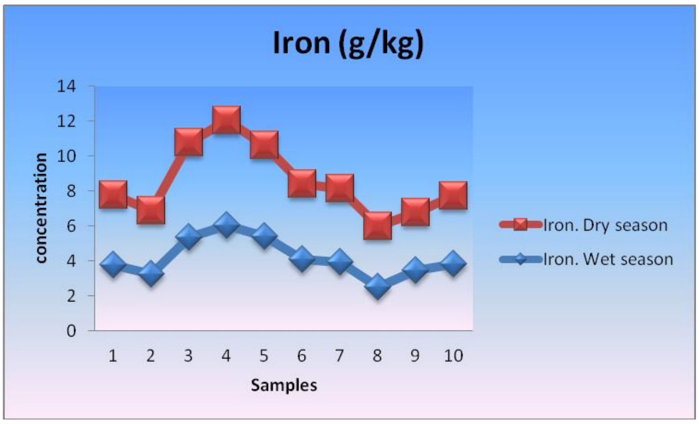


Figure 2 concentration variation of Iron

Table 1: Total Heavy metal concentration in industrial area soil during rainy season(mg/kg)

Sampling Station	Fe	Cr	Cu	Zn	Ni
P1	3.75	9.75	20.15	73.8	12.45
P2	3.25	6.3	13.55	61.9	14.5
P3	5.35	8.7	16.5	65.3	12.1
P4	6.03	13.2	14.05	84.9	11.45
P5	5.415	18.3	17.6	95.0	16.05
P6	4.09	10.05	14.35	97.9	14.3
P7	3.94	11.05	10.05	91.3	10.25
P8	2.50	15.75	17.5	85.1	9.1
P9	3.48	12.25	16.4	109.4	11.8
10	3.82	14.1	13.55	100.9	12.45

Heavy metals

Iron

Iron is an essential mineral that is required for human life for their growth. Much of the iron in the body is found in red blood cells and carries oxygen to every cell in the body. Iron also is involved in producing ATP (adenosine triphosphate, the body's energy source). Extra iron is stored in the liver, bone marrow, spleen & muscles. In the present study on iron gives a detail account on concentration in the study area. Here the iron was found with the range of 3.3gm/kg to 6.0gm/ in the dry season and 2.5gm/kg to 6.03gm/kg in wet season (Fig.2).

Copper

Copper is naturally present in soils with the range of 0 to 250 mg/g (B.J.Alloway 1995). Mcgrath And Loveland (1992) reported the range of 1.2 to1507.7 mg/kg for copper in the soils of England and Wales and its amount in urban and roadside soils is reported to be 5–10 times higher than the normal concentrations (D.E.Baker 1995). The copper content in the industrial area soils during wet season ranged from 13.55mg/kg to 20.15mg/kg and varied up to 14.5 mg/kg to 18.9 mg/kg for dry season (Fig.3).

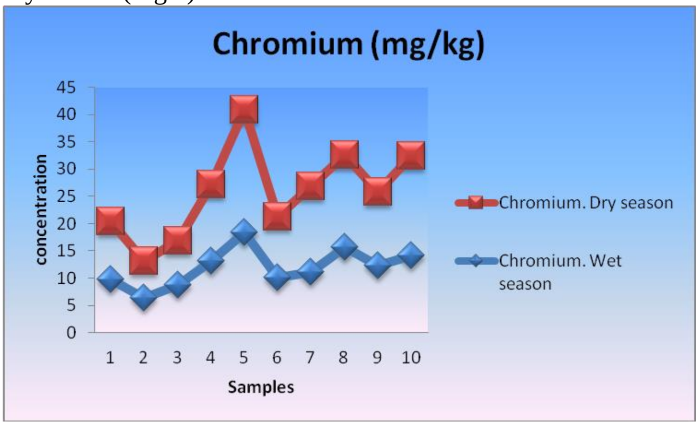


Figure 3. Concentration variation of Chromium

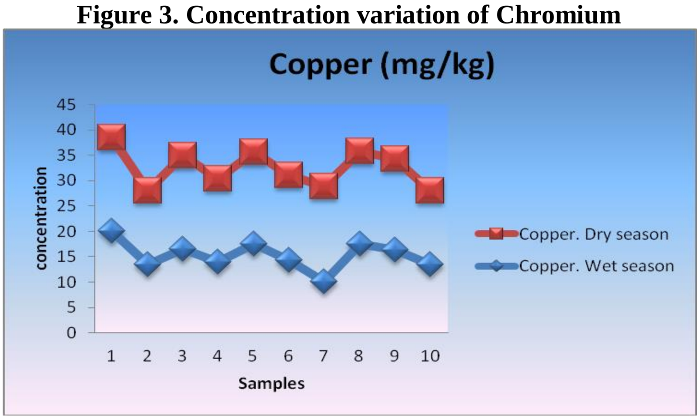


Figure 4. Concentration variation of Copper

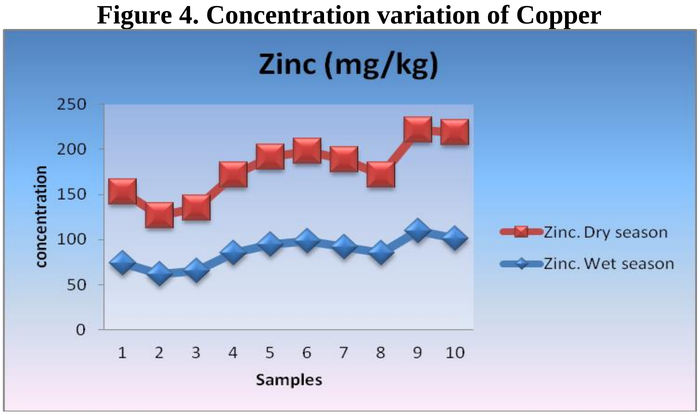


Figure 5. Concentration variation of Zinc

Chromium

The strengthening effect of forming stable metal carbides at the grain boundaries and the strong increase in corrosion resistance made chromium an important alloying material for steel in the industrial sector. The high speed tool steels contain between 3 and 5% chromium. Stainless steel, the main corrosion-proof metal alloy, is formed when chromium is added to iron in sufficient concentrations, usually above 11%. Also nickel-based alloys will increase in strength due to the formation of discrete, stable metal carbide particles at the grain boundaries. Because of the excellent high temperature properties of these nickel super alloys, they are used in jet engines and gas turbines in lieu of common structural materials. In the present study chromium was found with the concentration of 6.3mg/kg to 18.3 mg/kg in wet season and 6.9 mg/kg to 22.5 mg/kg in dry season. The mean value of chromium was found to be 13.79mg/kg in dry season and 11.94mg/kg in wet season (Fig.4).

Table 2: Total Heavy metal concentration in industrial area soil during pre-monsoon season (mg/kg)

Sampling Station	Fe	Cr	Cu	Zn	Ni
P1	4.0	10.6	18.4	79.0	13.0
P2	3.6	6.9	14.5	64.3	16.9
P3	5.4	8.1	18.4	70.0	13.2
P4	6.0	13.9	16.4	86.9	12.3
P5	5.2	22.5	18.0	96.0	17.2
P6	4.3	11.2	16.7	99.9	16.9
P7	4.2	15.8	18.9	96.9	14.5
P8	3.5	16.9	18.3	87.0	11.4
P9	3.3	13.6	17.8	112.3	14.1
P10	3.9	18.4	14.4	117.7	14.5

Zinc

Normal concentrations of zinc in soil ranges from 1 to 900 mg/g (B.J.Alloway 1995). Mcgrath And Loveland (1992) reported that the zinc concentration in the soils of England and Wales ranged from 5mg/kg to 3648 mg/kg. In the present study, the concentration of zinc little lies above the range. This may be due to the higher input of zinc in the roadside environments by motor vehicles and from the industrial production and other activities. Kiekens (1995) stated that the total zinc levels in polluted soils in industrialised countries may account for hundred to thousand times higher than those in unpolluted soils. Aksoy (1996) reported the mean zinc concentration of 410 μg/g in soils collected from urban roadside soils in Bradford. In the present study zinc was found with the range from 61.9 mg/kg to 109.4 mg/kg and 64.3 mg/kg to 112.3 mg/kg for wet season and dry season respectively. The mean value of zinc was found to be 91mg/kg in dry season and 86.55mg/kg in wet season (Fig.5).

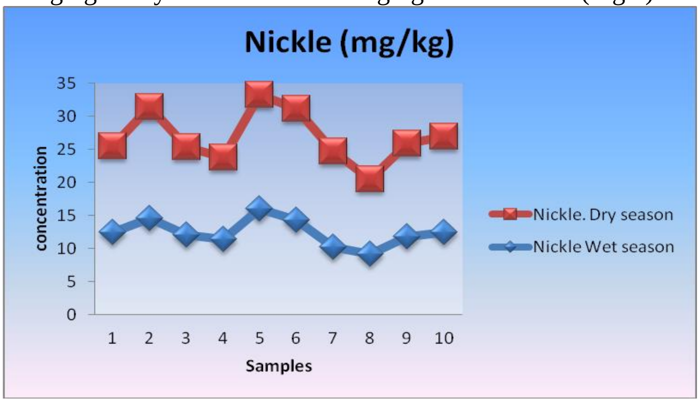


Figure 6. Concentration variation of Nickel

Nickel

Nickel's slow rate of oxidation process at room temperature, it is considered corrosion-resistant. Historically this has led to its use for plating metals such as iron and brass, and it will use in certain alloys that will retain a high silvery polish, such as German silver. About 6% of world nickel production is still used for corrosion-resistant pure-nickel plating. Nickel was used as a common component of coins, but in later days it has largely replaced by cheaper iron for this purpose. In the present work, nickel was found with the range of 9.1mg/kg to 16.05 mg/kg and 11.4 mg/kg to 17.2 mg/kg for wet season and dry season respectively The mean value of nickel was found to be 14.4mg/kg in dry season and 12.445mg/kg in wet season (Fig.6).

Table 3: Physico-chemical properties of rainy season soil sample.

	pH	EC (μs/cm)	Lime content (mg/kg)	OC (%)	OM (%)
P1	6.95	80.5	2.695	0.409	0.7051
P2	6.8	79.5	1.21	0.1015	0.1749
P3	6.55	75.5	1.76	0.109	0.1879
P4	7.5	86	7.235	0.501	0.8637
P5	7.25	83.5	6.06	0.094	0.1620
P6	6.9	80.5	2.555	0.4935	0.8507
P7	6.9	81	2.305	0.3995	0.6887
P8	7.15	82.5	5.15	0.3015	0.5197
P9	7.35	84	5.345	0.317	0.5465
P10	7.1	81.5	3.915	0.693	1.1947

Table 4: Physico-chemical properties of pre-monsoon season soil sample

	pH	EC	Lime content	OC	OM
		(μs/cm)	(mg/kg)	(%)	(%)
P1	7.08	81	3.46	0.312	0.537
P2	6.92	80	1.82	0.101	0.174
P3	6.32	75	2.32	0.0906	0.165
P4	7.921	96	7.81	0.576	0.99
P5	7.35	86	5.98	0.096	0.165
P6	6.78	79	3.42	0.412	0.71
P7	6.6	76	2.21	0.297	0.512
P8	7.19	82	5.86	0.196	0.337
P9	7.6	87	6.03	0.197	0.339
P10	7.2	84	5.91	0.516	0.889

Table 4: Physico-chemical properties of pre-monsoon season soil sample

	pH	EC	Lime content	OC	OM
		(μs/cm)	(mg/kg)	(%)	(%)
P1	7.08	81	3.46	0.312	0.537
P2	6.92	80	1.82	0.101	0.174
P3	6.32	75	2.32	0.0906	0.165
P4	7.921	96	7.81	0.576	0.99
P5	7.35	86	5.98	0.096	0.165
P6	6.78	79	3.42	0.412	0.71
P7	6.6	76	2.21	0.297	0.512
P8	7.19	82	5.86	0.196	0.337
P9	7.6	87	6.03	0.197	0.339
P10	7.2	84	5.91	0.516	0.889

Table 5: Correlation matrix of physico-chemical properties of soil sample. (Pre-monsoon)

	pH	EC	L.C	O.C	O.M
pH	1				
EC	0.9649	1			
L.C	0.8875	0.8888	1		
O.C	0.4028	0.4782	0.4501	1	
O.M	0.3973	0.4741	0.4469	0.9999	1

Table 6: Correlation matrix of physico-chemical properties of soil sample. (Rainy season)

	pH	EC	L.C	O.C	O.M
pH	1				
EC	0.9746	1			
L.C	0.9303	0.8609	1		
O.C	0.3001	0.3869	0.1625	1	
O.M	0.2998	0.3867	0.1620	0.9999	1

Table 7: Correlation matrix of total heavy metals of soil sample. (Rainy season)

	Fe	Cr	Cu	Zn	Ni
Fe	1				
Cr	0.1591	1			
Cu	-0.035795	0.21934	1		
Zn	-0.064729	0.59396	-0.15511	1	
Ni	0.32997	-0.050209	0.13755	-0.036316	1

Table 8: Correlation matrix of total heavy metals of soil sample. (Pre monsoon season)

	Fe	Cr	Cu	Zn	Ni
Fe	1				
Cr	0.082392	1			
Cu	0.12768	0.1408	1		
Zn	-0.23561	0.64914	-0.083613	1	
Ni	-0.063736	0.035701	-0.36085	0.092465	1

Conclusion

Soil is an important component which supports the natural vegetation, agriculture and forestry upon which people and wildlife depend. Inspite of playing an important role soil has not been afforded the same level of protection as the water and air environments. Contaminated soils may occur at old landfill sites that to particularly those that accepted industrial wastes dumped places, usage of insecticides, pesticides containing pollutants as an active ingredient, fields that had past applications of waste water or municipal sludge for the purpose of agriculture, gardens near by the industrial areas where wastewater used as source for the gardening, industrial areas where chemicals may have been dumped on the ground as a waste. The heavy metals will be introduced in to soil is mainly by the activities like Mining, manufacturing, and the use of synthetic products like pesticides, paints, batteries, industrial waste, and land application of industrial or domestic sludge etc. Heavy metals also occur in soil naturally, but it is very rarely at toxic levels. When the heavy metals present in the natural condition they do not act as toxic up to certain extent. When the concentration reaches the maximum level, heavy metals will be converted in to toxic in nature. Heavy metal contamination in the industrial areas of Mysore city showed that the heavy metal concentration is slightly higher in dry season compared with wet season. It's all due to the dilution of the soil in wet season leads to low concentration. Acid rainfall can cause a large increase in acidity and a corresponding increase in the amount of heavy metals becoming soluble in rainy season. These concentrations however were below the maximum levels, above which toxicity is possible through the percolation to ground water and it leads to ground water pollution. But precautionary measurement should be taken for future safe and healthy environment.

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