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Research Article

SPATIAL DISTRIBUTION OF HEAVY METALS DURING PRE-MONSOON AND POST-MONSOON SEASONS IN THE SOIL SAMPLES OF PEENYA INDUSTRIAL AREA, BENGALURU

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ABSTRACT

A comprehensive analysis of heavy metals was conducted in the soil samples of Peenya Industrial area of Bengaluru. The study performed at twenty different sampling locations along the industrial area of Bengaluru for the Pre-monsoon and Post-monsoon seasons during the year 2013. The results revealed that in the pre-monsoon season the heavy metals were recorded in the order of Zn>Fe>Pb>Cr>Ni>Cd>Cu>As and during Post-monsoon season the preference of heavy metals were in the sequence of Zn>Ni>Cr>Fe>Pb>As>Cd>Cu.. Higher values were mainly observed in the specified sites for heavy metals. These indicate that heavy metals contamination should be taken into account during development strategies to protect the habitat from long term contamination load.

Keywords: Heavy metals, Pre-monsoon season, Post-monsoon season, Peenya Industrial area, Soil Quality Index.

1. INTRODUCTION

Each individual is responsible for causing pollution and at the same time it is the responsibility of each individual to protect our environment. Controlling authorities are becoming helpless in environmental protection as people are damaging the environment in different directions with new ideas. Rapid industrialization, population growth, illiteracy and carelessness towards the policies are the main causes for rapid pollution problems met with.

Exploitation of natural resources is increasing day by day because of rapid urbanization, rapid industrialization, increasing water demand for various uses and improper environmental sanitation. The continuous exploitation of natural resources leads to depletion and degradation of the water sources. On the earth, groundwater forms the major portion of water and its availability and distribution varies to a large extent based on the geological and climatological factors. Treatment of the polluted surface or subsurface water discharged by industries is expensive in nature.

Rising costs of developing more distant fresh water resources threaten economic development while both visible effects of reckless waste disposal and inadequate environmental sanitation spread result in squalor and death. Man made activities and natural processes are the results affecting deterioration of the water quality and also reduced availability of potable water.

Cities are recognized as places of economic growth and social progress; still many urban residents lack access to potable water and proper sanitation. Sustainable water and sanitation cover are to be given to the poor people in urban areas. To maintain proper supply of potable water concerted action is very much needed in all fronts, which include forestry, power generation, transport, and agriculture, etc.

The rapidity of industrialization that has recently become the need of the hour, for a developing country like India has turned into a major source of water contamination. Huge inputs of pollutants from the industries have been taking the pollutant levels beyond the prescribed tolerable limits. The industries that induce the pollutants into the surface and groundwater sources from their activities do not strictly regulate their pollutant to safe limits [1].

2. MATERIALS AND METHODS

2.1. Study Area-Geology of Peenya industrial area

The Peenya industrial area is situated on the north-western periurban of Bengaluru between 13°0'0''N to 13°2'4''N latitude and 77° 30' 45''E to 77° 30' 45''E longitude. Lithologically, the Peenya industrial area is predominantly underlain by granites and gneisses with pockets of schistose rocks as well as migmatites of Archaean era. These gneisses are often found to be intruded by pegmatite, basic dykes, and aplitic veins with a common occurrence of basic xenolithic patches. There are some small elongated bodies of schists and amphibolites allied along a north-south trend through the centre of the city. The foremost strike path is northwest, with a subsidiary concentration of apparently mainly smaller structures having an east northeasterly strike. These rocks have undergone weathering and chemical decomposition in the plains and valleys, resulting in a weathered layer of thickness ranging from 10 to 30 metres generally. Laterites of Palaeozoic era are seen at places as cappings on the gneisses in the northern and eastern parts of the study area. Alluvium occurs as patches along the nallahs and stream courses, which is of limited areal extent in nature and do not form as potential of the study area (Fig. 1).

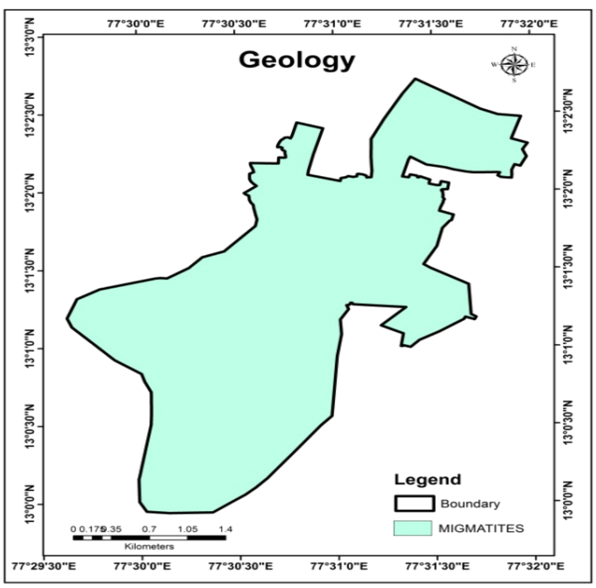

Fig. 1: Geological features of Peenya industrial area

2.2. Hydrogeology

Hydrogeological features like recharge to aquifers, groundwater occurrence and movement are based on geomorphological set up, fracture pattern, degree of weathering, and rainfall. Gneisses of peninsular gneissic class and granites constitute main aquifers in Bengaluru urban district. Groundwater occurs in phreatic conditions in the weathered zone and under confined to semi-confined conditions in fractured and jointed rock formations (Fig. 2). Laterites of Tertiary age occur as remote patches capping crystalline rocks in Bengaluru north taluk and groundwater occurs in phreatic condition.

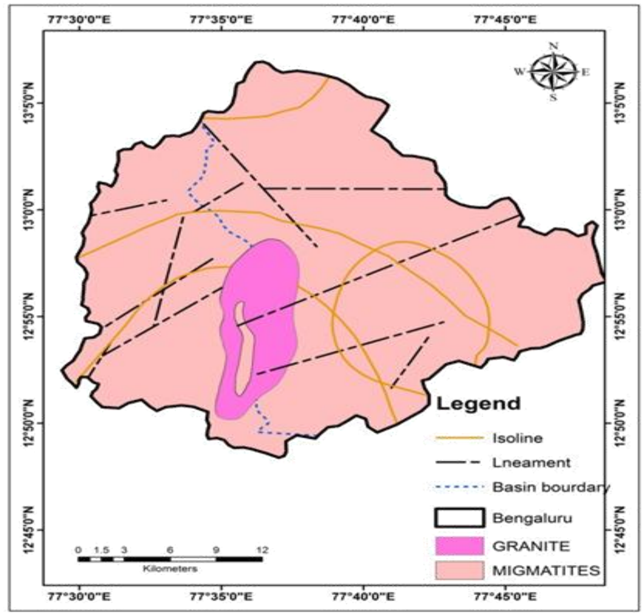

Fig. 2: Hydrogeology map of greater Bengaluru

2.3. Soils

The Bengaluru district, there are variety types of soils, viz., red loamy soil and lateritic soil. The soils of Bengaluru city can be broadly grouped as lateritic soil and red loamy soil. While lateritic soils covering more than 75% area occur in the upland and transitional zones, on the slopes and in the flood plains of streams with thickness ranging from 0.3 to 1.0 m, the red loamy soils are found to occur in the plain regions having thickness of range between 0.5 and 3.0 m. Red loamy soils normally occur on hilly and uneven land slope on gneiss and granitic terrain, it is mainly seen in the southern and eastern places of Bengaluru North and South taluks. Lateritic soils occur on undulating terrain forming plain to gently sloping geography of peninsular gneissic region. It is mainly covered in western parts of Bengaluru South and North taluks. In red loamy soils water holding capacity is observed to be more and are neutral to slightly acidic in nature. Lateritic soil types rich in aluminum and iron , formed in hot and wet tropical places. All laterites are found to be rusty-red due to iron oxides. They are created by serious and dependable enduring of the fundamental parent rock. Thick laterite layers are permeable and somewhat porous. The humidity maintenance limit of this soil is poor and they turned out to be hard during summer months. This soil contains sufficient amounts of natural matter. The investigation region has changed kinds of soils, viz., course loamy and sandy, loamy, loamy skeletal and fine loamy, loamy and coarse loamy, and red loamy. Fig. 3 shows the soil details of Bengaluru urban district. Figure.4 shows the soil details of the study area.

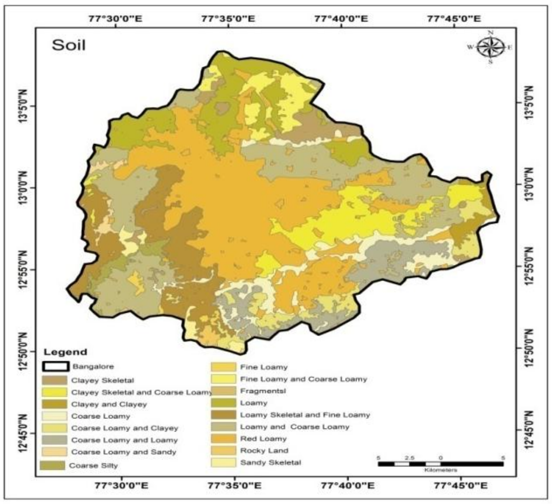

Fig. 3: Soil details of Bengaluru

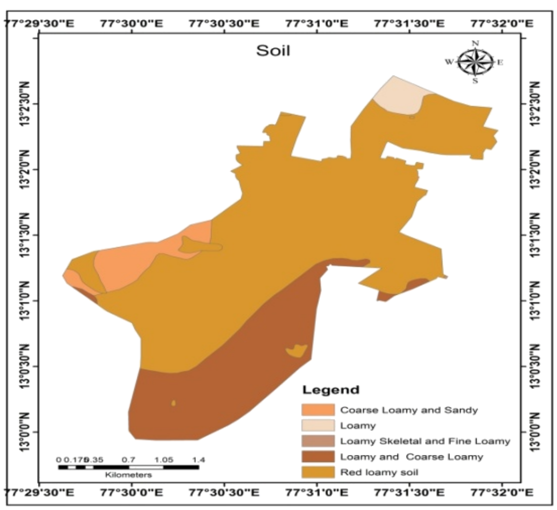

Fig.4: Soil details of the study area

2.4. Soil Analysis

The sampling station is cleaned on the surface up to 5cm to remove vegetation and organic matter. The soil sample is collected from a depth of 10 to 15cm below the earth surface. The quantity of samples is sufficient (nearly 5kg) for the analysis of various physico-chemical properties. The collected samples were packed in polythene covers so that moisture content is not lost and transported to the laboratory.

The analysis of the heavy metals like zinc, iron,lead, chromium, nickel, cadmium ,copper and arsenic were done by using AAS Atomic Absorption Spectrophotometer [2].

3. RESULTS AND DISCUSSION

Soil chemical properties vary from site to site due to varied texture or size of the mineral particles on the pattern these particles are arranged over the clay minerals and quantity of exchangeable ions absorbed over them, and organic matter present along with the minerals, absorption of pollutants generated in the environment by anthropogenic activities and natural forces [3]. In a good soil system all pollutants generated will be absorbed provided with high degree of treatment earlier to the pollutants reaching the groundwater table. If the pollutant concentration is more than the rate at which soil converts a pollutant into unpolluted state, pollutants will reach the ground water by infiltration.

Twenty collected soil samples from the study area during pre-monsoon season and post monsoon season of 2013 are analyzed using standard methods in certified laboratories. The parameters analyzed are pH, acidity, electrical conductivity, alkalinity, chlorides etc., as well as heavy metals like iron, copper, nickel, lead, zinc, cadmium, arsenic and chromium.

The results obtained from the analyses of soil samples collected during pre and post-monsoon seasons, for chemical properties are tabulated in Table 1 and 2 for pre-monsoon and post monsoon season respectively. The variation of concentrations of various parameters analyzed, are presented in Fig. 5 to 12.

The results obtained from the chemical analysis of soil samples collected from the study area are discussed below.

The range of pH of the soil samples collected from the Peenya industrial area during pre-monsoon season was 6.2 to 7.92 and during post-monsoon was 7.5 to 9.47. The values below 6.5 cause corrosion of metal pipes, resulting in the release of toxic metals such as lead, cadmium, copper etc.

The Electrical conductivity (EC) of soil samples are in the range of 1 to 5.8 during pre monsoon and 1.3 to 14mmhos/cm during post monsoon. The high value at these locations is attributed to the effluents from the pharmaceutical and drug industries.

Table 1: Results of chemical analyses of soil samples (pre-monsoon season-2013)

Sl. No.	p^H	Acidity mg/kg	EC mMhos/cm	Alkalinity mg/kg	Chlorides mg/kg	Iron mg/kg	Copper mg/kg	Nickel mg/kg	Lead mg/kg	Zinc mg/kg	Cadmium mg/kg	Arsenic mg/kg	Chromium Mg/kg	Soil Quality Index
SS-1	7.13	48	1.00	10	296	22.01	0.71	0.33	1.82	10.54	1.12	0.21	14.21	0.625
SS-2	7.7	100	2.42	60	354	21.72	2.11	1.74	2.75	14.54	1.29	0.32	12.20	0.375
SS-3	7.6	24	2.24	12	62	23.74	1.28	0.43	2.66	35.51	3.15	0.56	15.50	0.375
SS-4	7.84	68	2.49	20	212	22.21	2.49	1.90	2.41	36.83	4.03	0.08	14.70	0.375
SS-5	7.15	92	2.22	8	176	23.12	1.81	1.02	6.62	61.11	6.27	0.17	13.50	0.375
SS-6	7.99	20	2.78	36	200	20.21	2.08	1.73	2.01	32.01	1.18	0.61	17.02	0.375
SS-7	7.65	28	2.43	8	134	21.22	1.49	1.58	2.91	38.18	2.46	0.51	12.90	0.375
SS-8	7.53	56	2.34	8	378	23.01	2.37	1.10	2.40	22.38	3.17	0.28	12.45	0.375
SS-9	7.8	48	2.34	8	224	24.23	5.48	3.82	2.82	53.71	5.09	0.35	14.85	0.375
SS-10	7.65	152	2.84	16	1232	22.23	1.11	2.00	1.91	90.54	1.18	0.56	10.72	0.375
SS-11	7.42	92	2.31	16	442	23.51	2.21	2.53	6.66	71.33	3.47	0.85	16.13	0.375
SS-12	7.73	84	2.39	40	696	22.38	4.82	1.73	17.71	83.22	4.18	0.27	14.11	0.375
SS-13	7.62	92	2.73	20	880	23.45	2.41	1.35	8.21	78.91	2.49	0.44	3.71	0.375
SS-14	7.71	88	2.33	24	420	21.41	3.08	1.51	5.09	72.05	3.56	0.55	6.80	0.375
SS-15	7.67	52	2.20	20	400	23.42	3.61	1.09	2.10	28.15	4.32	0.38	14.20	0.375
SS-16	7.79	76	2.75	24	568	22.01	1.00	0.43	2.11	16.56	3.17	0.43	15.50	0.5
SS-17	7.92	52	5.80	8	256	24.92	3.91	12.15	5.35	51.84	1.21	0.86	17.09	0.25
SS-18	7.79	32	2.33	36	176	26.02	0.98	0.92	1.88	14.55	3.22	0.51	13.40	0.5
SS-19	7.23	80	2.20	52	276	27.03	3.09	3.92	2.52	28.56	6.14	0.38	12.80	0.375
SS-20	7.65	124	2.14	8	650	22.02	1.18	0.81	2.06	11.41	4.42	0.52	15.20	0.375

Table 2: Results of chemical analyses of soil samples (post monsoon season-2013)

Sl. No.	p^H	Acidity mg/kg	EC mMhos/cm	Alkalinity mg/kg	Chlorides mg/kg	Iron mg/kg	Copper mg/kg	Nickel mg/kg	Lead mg/kg	Zinc mg/kg	Cadmium mg/kg	Arsenic mg/kg	Chromium Mg/kg	Soil Quality Index
SS-1	8.17	20	1.56	140	188.8	50	0.5	20.43	21.45	43.18	0	0	49.57	0.5
SS-2	9.47	40	8.97	480	1424	67.575	1.91	26.45	22.16	30.41	0	0	28.3	0.125
SS-3	8.49	20	2.71	120	291.8	98.325	1.18	47.22	14.85	41.01	2.64	0	57.27	0.25
SS-4	8.13	32	1.34	192	240.3	124.54	1.89	14.72	64.72	78.19	0	0	44.27	0.375
SS-5	8.1	12	1.79	280	411.9	150	1.81	72.49	15.89	29.67	0	4.58	145.5	0.375
SS-6	7.89	4	3.19	204	291.8	150	1.98	559.6	82.93	324.5	2.74	36.67	83.64	0.25
SS-7	7.55	12	14	100	205.9	147.75	1.4	72.86	87.74	392.7	3.81	0	141.2	0.25
SS-8	8.42	8	1.39	196	532.6	124.5	1.87	9.2	16.92	28	0	0	176.1	0.375
SS-9	8.34	8	1.71	144	240.3	150	3.48	25.33	16.61	37.6	2.62	0	47.64	0.25
SS-10	7.74	12	2.08	80	171.6	124.5	0.91	13.5	18.32	38.85	0	0	88.55	0.375
SS-11	7.79	8	2.47	100	274.6	150	2.1	90.55	86.24	111.4	2.86	0	138	0.25
SS-12	8.18	20	1.47	132	103	150	3.82	61.78	28.72	70.53	0	0	90.17	0.375
SS-13	8.15	12	1.33	92	188.8	150	2.21	56.04	145.4	96.75	2.99	0	118.6	0.375
SS-14	8.25	4	1.38	80	257.4	150	2.08	76.87	119.9	126.4	3.04	0	203.6	0.375
SS-15	8.18	12	1.92	124	188.8	144.75	2.61	324.3	80.2	123.7	2.7	0	130.5	0.375
SS-16	7.5	12	1.8	100	360.4	140.63	0.8	80.66	789.3	615.9	4.85	0	123.5	0.5
SS-17	8.1	20	11.7	120	3261	127.13	2.91	45.2	45.6	40.58	0	0	92.56	0.25
SS-18	8.32	16	2.27	160	617.9	129.75	0.78	39.66	28.05	62.28	0	0	75.29	0.375
SS-19	8.02	12	1.56	180	274.6	142.5	2.79	31.2	26.81	48.83	2.64	0	67.57	0.375
SS-20	8.17	20	8.97	180	583.5	123.38	1.08	31.2	80.39	124	3.06	0	224.4	0.375

The Acidity values of soil samples analysed showed a minimum value of 20 mg/kg and a maximum value of 152 mg/kg during pre-monsoon and 4 mg/kg to 40 mg/kg during post monsoon season.

The Chloride content in the soil samples was observed in the range of 62 mg/kg to1232 mg/kg during pre-monsoon and 103ppm to 617.9 ppm during post monsoon season. Excessive chlorides are responsible for corrosion of steel. The higher concentration of chlorides can be attributed to the close proximity of these locations to various chemical industries and percolation of sewage into soil.

Iron content in the tested soil samples was in the range of 20.21 mg/kg to 27.03 mg/kg during pre monsoon and 50 mg/kg to150 mg/kg during post monsoon season.

Presence of Copper observed from the analyzed soil samples was in the range of 0.71 mg/kg to 5.48 mg/kg during pre-monsoon and 0.71 mg/kg to 5.48 mg/kg during post monsoon season. Copper is extremely used in electrical equipment and industrial machinery.

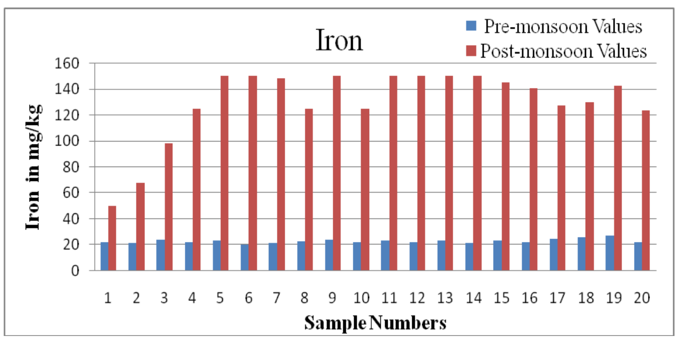

Fig. 5: Seasonal variation of iron in soil samples

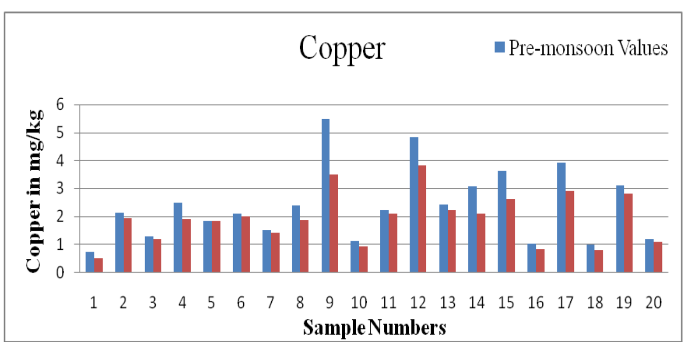

Fig. 6: Seasonal variation of Copper in soil samples

Presence of Nickel in the analyzed soil samples are in the range of 0.33 mg/kg to12.15 mg/kg. during pre-monsoon and 9.2 mg/kg to 559.6 mg/kg during in post monsoon season. The presence of nickel is in large quantity. Nickel is mainly used to manufacture alloys for automobile and for any machinery parts [4]. Nickel is used in metal plating industries and some other painting industries.

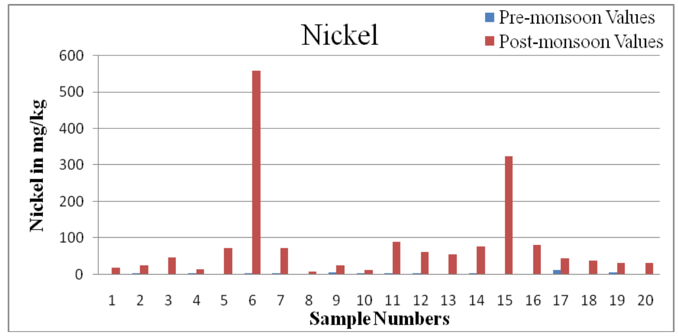

Fig. 7: Seasonal variation of Nickel in soil samples

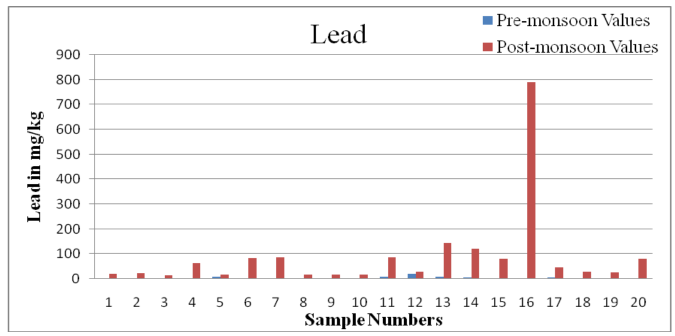

Fig. 8: Seasonal variation of Lead in soil samples

In the soil samples analysed, the presence of Lead was in the range of 1.82 mg/kg to 17.71 mg/kg during pre-monsoon and 14.85 mg/kg to 789.3 mg/kg during post monsoon season. Lead can enter into soil subsurface through corrosion of underground pipes and wastes discharged from lead-acid battery.

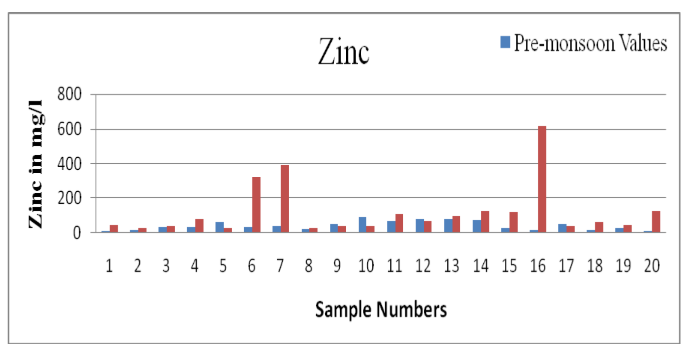

Fig. 9: Seasonal variation of Zinc in soil samples

The Zinc content observed in soil samples was between 10.54 mg/kg and 90.54 mg/kg during pre-monsoon and 28 mg/kg to 615.9 mg/kg during post monsoon season. Zinc increases acidity of soil which in turn affects the other properties of soil.

Cadmium content in the soil samples was in the range of 1.12 mg/kg to 6.27 mg/kg. during pre-monsoon and 0 mg/kg to 4.85 mg/kg during post monsoon season. Cadmium is extensively used in electro plating and coating industries. Cadmium coated plates are used in nuclear power plant as barrier as cadmium has ability to absorb neutrons.

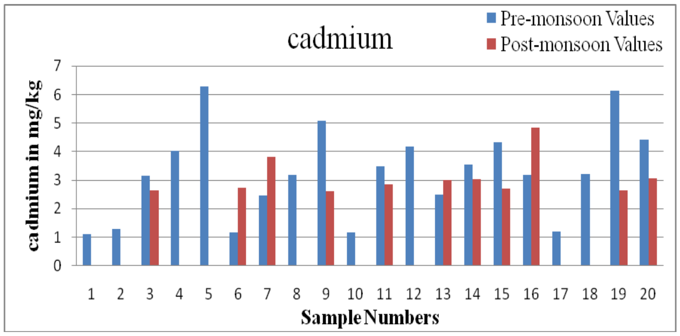

Fig. 10: Seasonal variation of Cadmium in soil samples

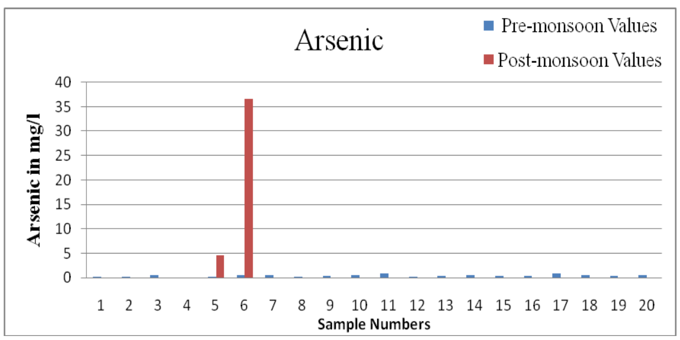

Fig. 11: Seasonal variation of Arsenic in soil samples

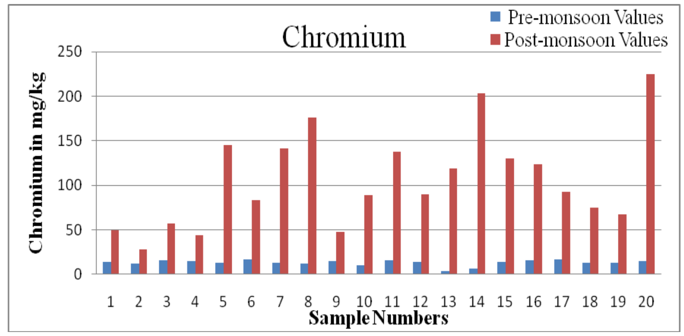

Fig. 12: Seasonal variation of Chromium in soil samples

Arsenic in the analyzed soil samples was in the range of 0.21 mg/kg to 0.61 mg/kg. during pre-monsoon and 0 mg/kg to 36.67 mg/kg during post monsoon season. Excess Arsenic may be due to contamination from a septic system, sewage and agricultural runoff that can leach and enter into the subsurface soil [5].

Chromium content in the soil samples was in the range of 3.71 mg/kg to 15.5 mg/kg. during pre-monsoon and 28.3 mg/kg to 203.6 mg/kg during post monsoon season. Acidification of soil is caused by chromium which affects the plant system.

Using GIS software maps of spatial distribution of heavy metals concentration for pre-monsoon season and post monsoon season were prepared and are shown in Fig. 13-Fig. 20.

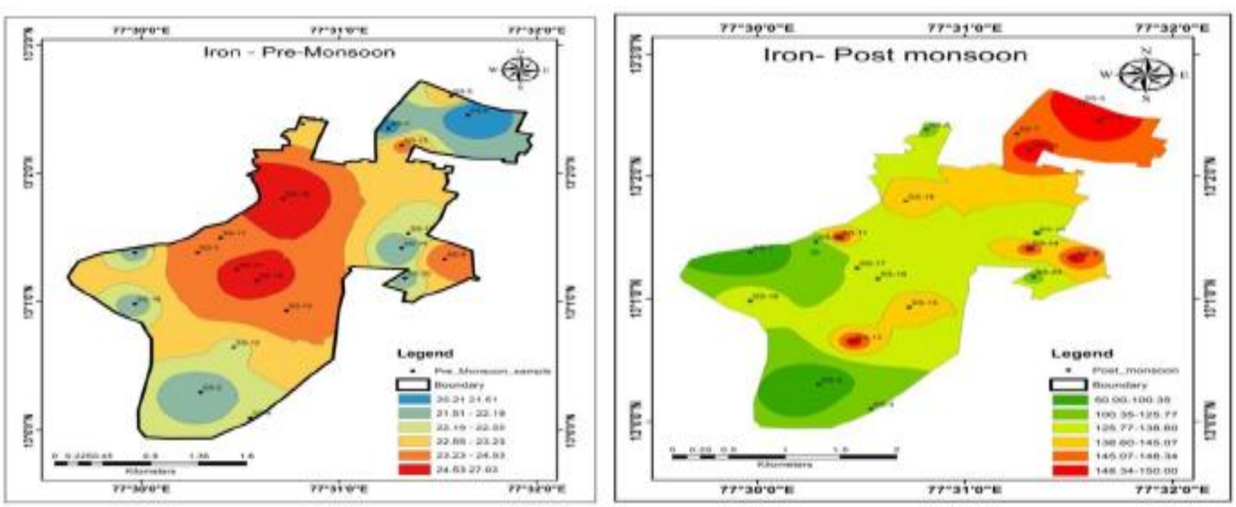

Fig. 13: Spatial distribution of Iron in soil of soils of Peenya industrial area during Pre-monsoon and Post monsoon seasons

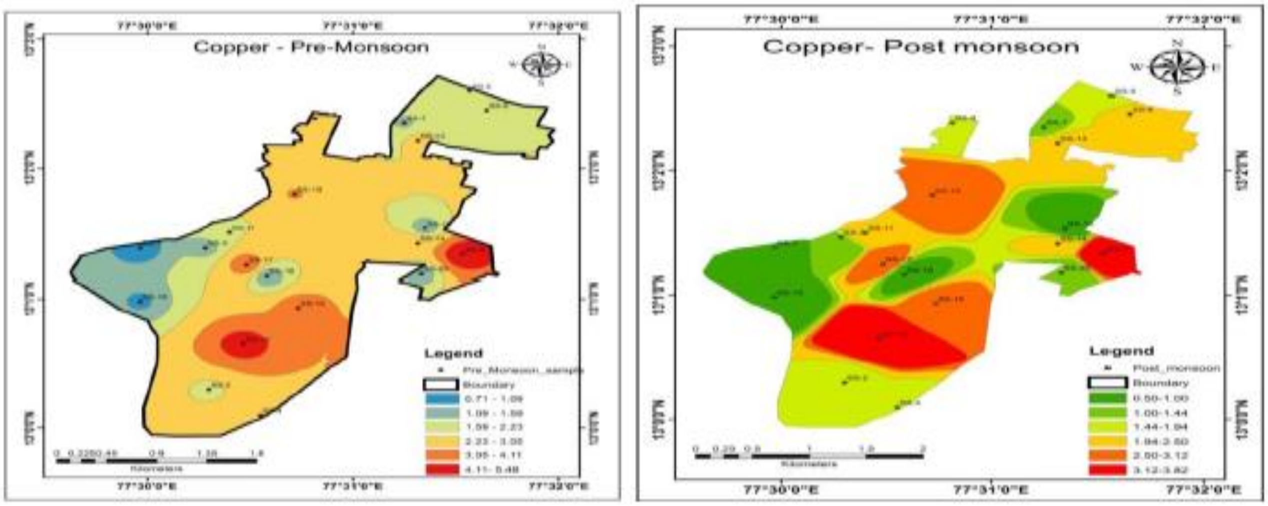

Fig. 14: Spatial distribution of copper in soil of Peenya industrial area during Pre-monsoon and Post monsoon seasons

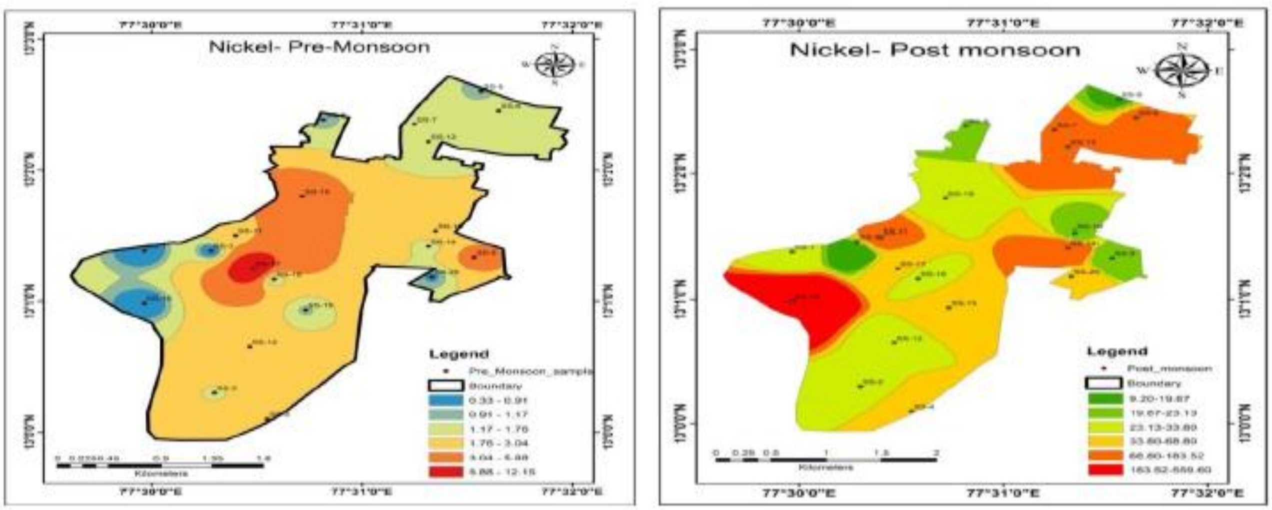

Fig. 15: Spatial distribution of Nickel in soil of Peenya industrial area during Pre-monsoon and Post monsoon seasons

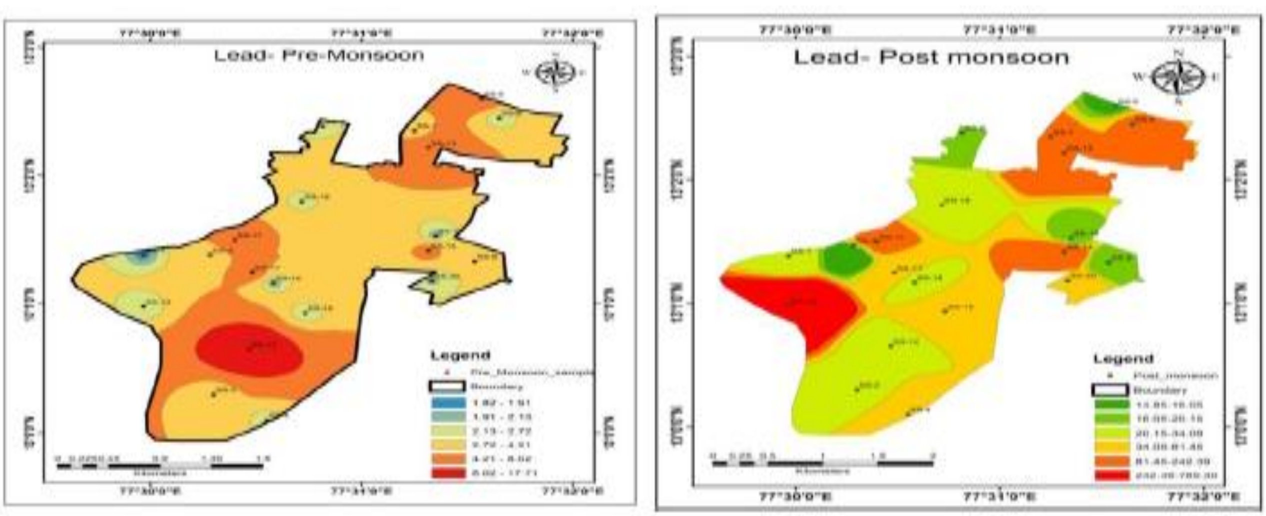

Fig. 16: Spatial distribution of Lead in soil of Peenya industrial area during Pre-monsoon and Post monsoon seasons

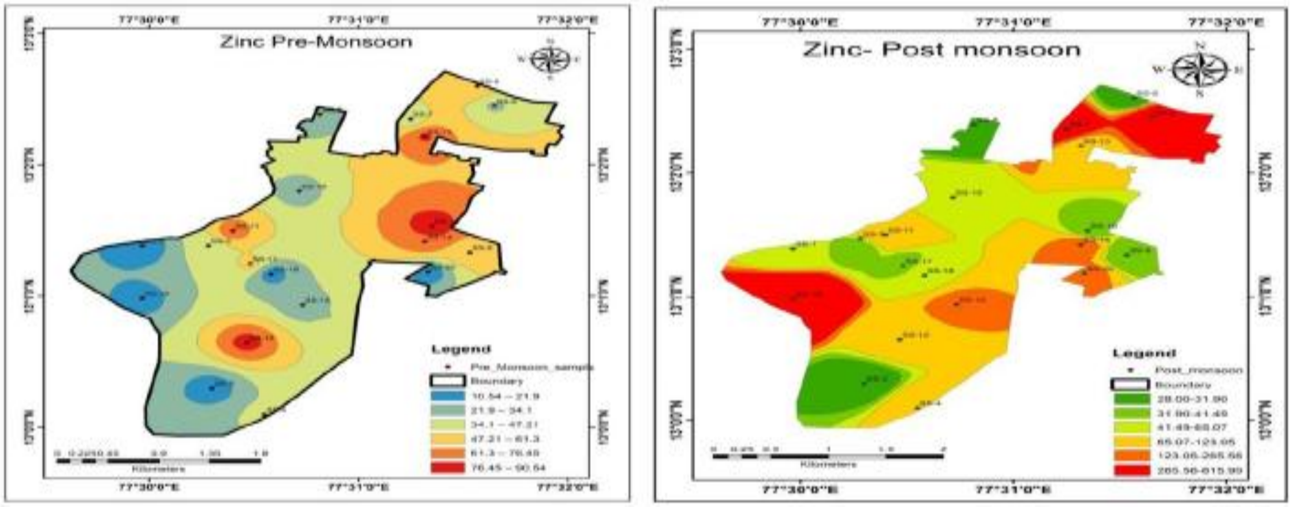

Fig. 17: Spatial distribution of zinc in soil of Peenya industrial area during Pre-monsoon and Post monsoon seasons

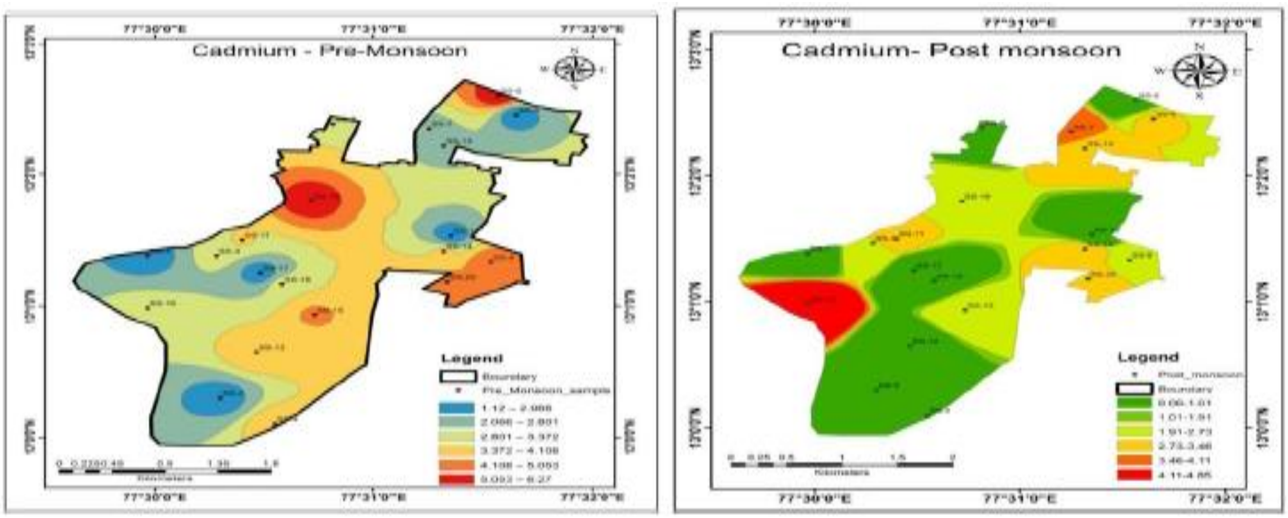

Fig. 18: Spatial distribution of cadmium in soil of Peenya industrial area during pre-monsoon and post monsoon seasons

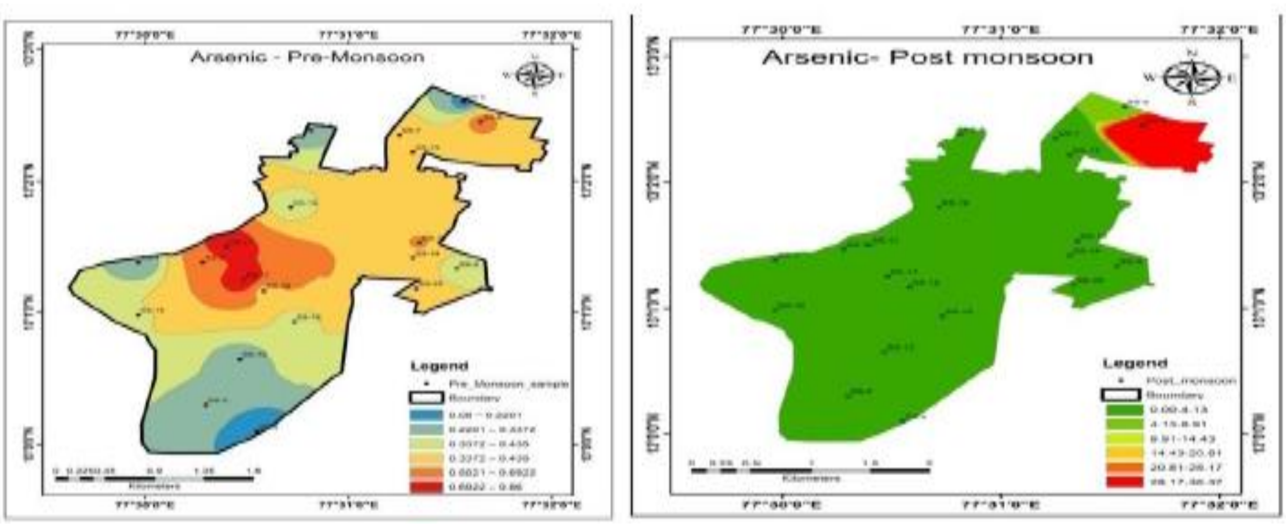

Fig. 19: Spatial distribution of arsenic in soil of Peenya industrial area during pre-monsoon season and post monsoon season

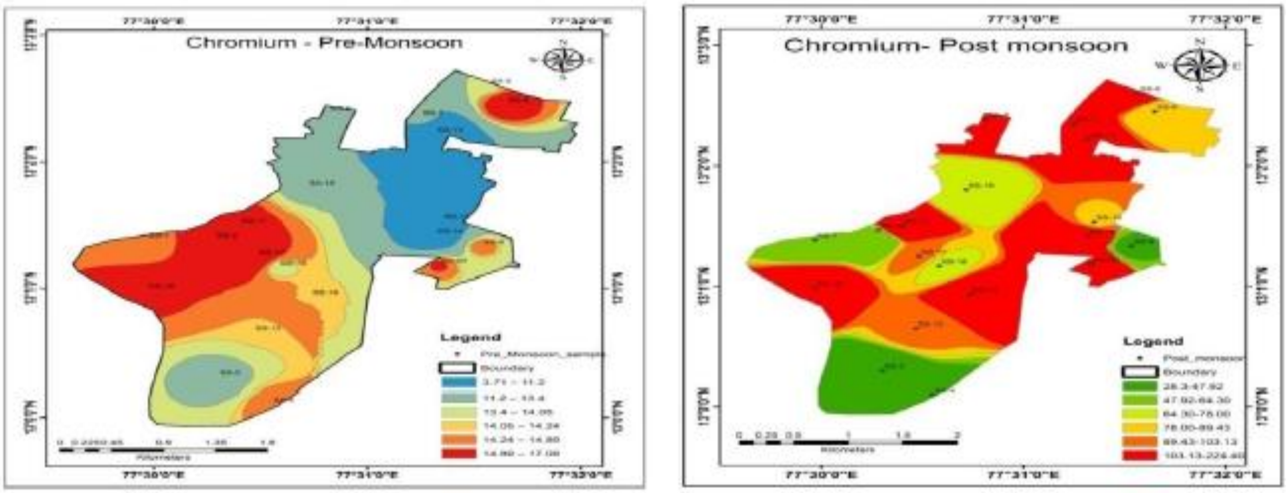

Fig. 20: Spatial distribution of chromium in soil of Peenya industrial area during pre-monsoon season and post monsoon season

3.1. Soil Quality Index (SQI)

SQI is an important tool to evaluate the quality of soil. It provides information regarding the overall quality of soil. Soil quality parameters like pH, EC, iron, copper, nickel, lead, zinc, cadmium, were considered to evaluate the SQI of the soil samples collected from the study area during pre and post-monsoon seasons of 2013. The SQI was computed using the following equation [6-8].

$$SQI = \frac{DpH+DEC+DFe+DCu+DNi+DPb+DZn+DCd}{8}$$

Where, DpH =1, if pH= 4-5.5 and 7.2-8.5 and 0 otherwise; DEC=1, if EC< 2mMhos/cm and 0 otherwise, DFe = 1, if Fe > 0.1mg/kg and 0 otherwise, DCu = 1, if Cu is 0.1-1mg/kg and 0 otherwise, DNi = 1, if Ni < 5mg/kg and 0 otherwise, DPb = 1, if Pb < 1mg/kg and 0 otherwise, DZn = 1, if Zn is 1-10 mg/kg and 0 otherwise, DCd = 1, if Cd < 0.5 mg/kg and 0 otherwise.

The soil quality index (SQI) was calculated for all soil samples collected from the study area during the pre and post-monsoon seasons of 2013, and are presented in Table 1 and 2 respectively. SQI is bounded between digits (D) 0 to 1, and higher the SQI, better is the quality of soil. Based on the obtained SQI values, the soil quality scale was rated as very good (>0.7), good (0.6-0.7), average (0.5-0.6) and poor (0.4-0.5).

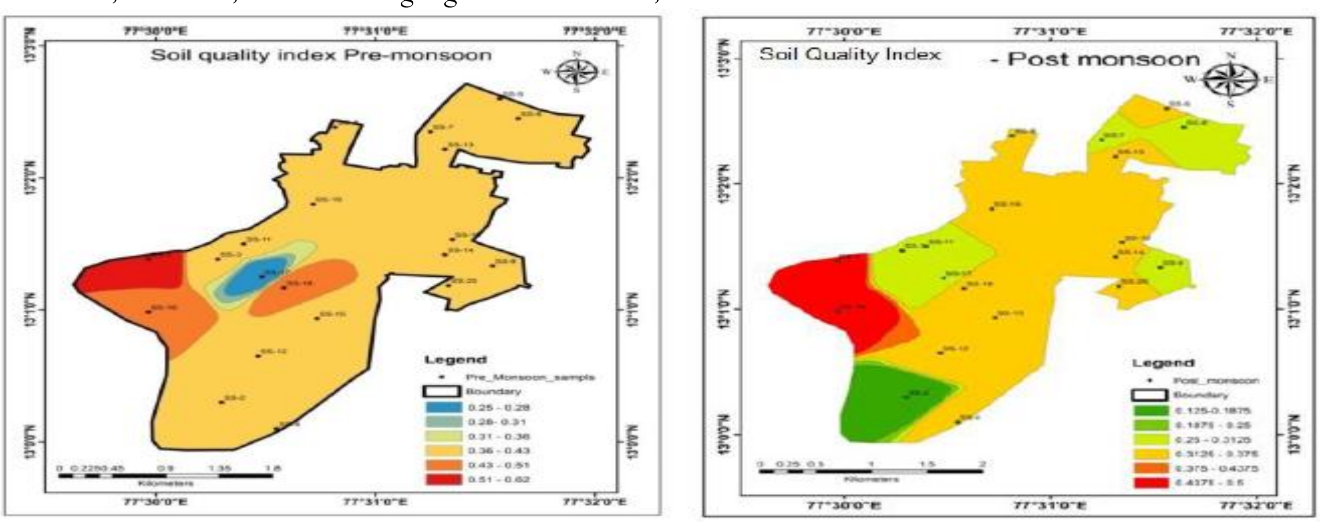

Fig. 21: Soil Quality index map for the pre-monsoon and post-monsoon season

Based on the soil quality index (SQI) calculated, it is observed that during pre-monsoon season, in sampling station SS-1 the soil quality was good, in sampling stations SS-16, SS-18 soils were of average quality and soils from rest of the sampling stations were of poor quality. During post monsoon season the soil from sampling stations SS-1, SS-16 was of average quality and soil from rest of the sampling stations was of poor quality.

Soil Quality Index (SQI) maps for the pre-monsoon and post monsoon seasons are as shown in Fig. 21.

4. CONCLUSION

In most of the soil samples of the study area, concentration of heavy metals such as iron, nickel, lead, zinc, chromium increased during the post monsoon season compared to pre-monsoon season. The reason for this may be percolation of metal ions into soil during monsoon season. In most of the soil samples, copper concentration was not altered much between pre and post-monsoon seasons.

For the soil samples collected, SQI values were computed to know the soil quality in the study area. Based on the values of SQI of soil samples obtained, soils can be classified as very good, good, average and poor.

5. SUGGESTIONS

The following suggestions are made in order to overcome the groundwater pollution and soil pollution identified in the study area:

1. Proper disposal of waste water generated from the residential areas, i.e., providing underground drainage system.
2. Proper maintenance of open drains, i.e., checking the lining of sewers at short intervals and undertaking repair works.
3. Proper solid waste management system must be provided in the area.
4. Government should take up lake rejuvenation programme to avoid surface water pollution.
5. Divert the drains joining the water bodies towards open drains leading to treatment plants.
6. Educating the public regarding ill-effects of using contaminated water and precautions to be taken to overcome the ill-effects. Educating the private sector as well to know the ill effects of the untreated industrial water disposal to the nearby water bodies. It also affects their production if the workers are from the same region and affecting their work-life balance.
7. To avoid soil pollution, identify the industries disposing of the industrial wastes onto the land and directing them to dispose of the waste in scientific manner (after treatment).
8. Government Bodies like Pollution Control Board must frame stringent rules regarding the industrial waste disposal measures.
9. Water supply authorities like BWSSB must provide treated water or water from the sources of the unaffected area to public to safe guard them from diseases caused by consumption of contaminated water.
10. A rainwater harvesting plan to be designed providing one recharge bore for every 3000sq.m of land area.
11. Using bio-remediation methods to overcome the soil pollution problems.
12. Non-governmental organizations should organize awareness programs for public to participate in lake conservation progammes.
13. Encouragement of public participation in the pollution control and pollution remedial programmes taken up by government organizations or non-government organisations.
14. Punishing or fining the persons or the industries dumping of the wastes in haphazard manner.

6. REFERENCES

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