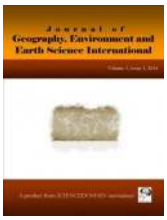


Journal of Geography, Environment and Earth Science International
6(2): 1-13, 2016; Article no.JGEESI.26361
ISSN: 2454-7352

SCIENCEDOMAIN *international*
www.sciencedomain.org

Distribution and Migration of Heavy Metals in Peenya Industrial Area, Bangalore, Karnataka, India- A Case Study

C. R. Ramakrishnaiah[1*] and N. Manasa[1]

[1]Department of Civil Engineering, BMS College of Engineering, Visvesvaraya Technological University, Bangalore, Karnataka, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author CRR designed the study, wrote the protocol and wrote the first draft of the manuscript. Author NM managed the literature searches; analyses of the study and performed the spectroscopy analysis. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2016/26361
Editor(s):
(1) Wen-Cheng Liu, Department of Civil and Disaster Prevention Engineering, National United University, Taiwan and Taiwan Typhoon and Flood Research Institute, National United University, Taipei, Taiwan.
Reviewers:
(1) Abida Begum, PESIT-BSC, Bangalore, India.
(2) Rosa Ana Rodriguez, Universidad Nacional de San Juan, San Juan, Argentina.
Complete Peer review History: http://sciencedomain.org/review-history/14656

Original Research Article

Received 13th April 2016
Accepted 4th May 2016
Published 16th May 2016

ABSTRACT

The present study is aimed to investigate the distribution and migration of the heavy metals in both ground water and soil profile in Peenya Industrial area. The Peenya Industrial area is considered to be one of the largest and oldest Industrial Area in the South-East Asia. Hence in this research work studies are carried out to know the level of heavy metals in ground-water, and soil profile, degree of pollution due to Industrial activities and water quality index of the study area. In this study a total number of 42 ground water samples were collected from different locations of Peenya Industrial Area and analyzed for various Physical and Chemical properties such as pH, Alkalinity, Chloride, Calcium, Magnesium, Total dissolved solids, Total hardness and Nitrate in the Laboratory using analytical methods. The concentration of heavy metals viz. Iron, Chromium, Nickel, Copper, Cadmium and Lead were analyzed using AAS (Atomic Absorption Spectrophotometer).Water quality of the study area is determined using a tool known as Water Quality Index (WQI). The WQI for the study area ranges from 35.29-7787.40. The high values of WQI is due to high values of Chromium, Nickel, Cadmium, Iron, Lead, TDS, TH, Calcium, Magnesium, Nitrate, Chloride, and

**Corresponding author: E-mail: crrkrishna.civ@bmsce.ac.in;*

Alkalinity. The total numbers of 24 Soil samples were collected to investigate both distribution and migration of heavy metals in soil profile. The concentration of heavy metals viz. Iron, Chromium, Nickel, Copper, Cadmium and Lead in soil were analyzed by Mehlich-I extraction method and determined using AAS. The present analysis reveals that ground-water and soil of the study area needs some degree of treatment and should be protected from future contamination.

Keywords: Heavy metals; distribution; migration; industrial area.

1. INTRODUCTION

Heavy metals contain various groups of elements which vary in their chemical & biological properties and functional HM is categorized as environmental pollutant due to their toxic effects on living beings and flora and fauna. Both natural and anthropogenic activities lead to heavy metal contamination in the environment. "Heavy metal is defined as a metal of relatively high density or high relative atomic weight" [1]. Industrial activity, agricultural activity, improper waste disposal practices and other human activities will often alter the physical, thermal, chemical and biological quality of the ground water, surface water and soil leading to its contamination [2] Toxic heavy metal has become one of the major causes of concern for human kind. Because it is non bio-degradable, stable and tend to accumulative plants and animals. Indiscriminate use of fertiliser, insecticide, pesticide and natural process such as weathering and erosion of crustal material increases the content of toxic metals in water and soil [3]. As the heavy metals are non bio-degradable, it will tend to bio-accumulate and enter to the food chain leading to health and environmental problems [4]. When heavy metals are discharged to environment it will ultimately sink to the soil. The distribution of heavy metals in the soil is mainly depends on the mobility of toxic metals, climatic conditions, soil parameters such as texture, mineralogy and classification of soil. Accumulation and availability of heavy metals in the soil environment are controlled by pH and organic carbon property of soil. In the monitoring of soil properties and interpretation of environmental data, statistical analysis is used as a powerful tool [5]. Introduction of waste leads to ecological imbalance in the soil [6].

1.1 Study Area

"Bangalore is located at a latitude 12°.58'N and longitude of 77°.35'E at an altitude of 921 m above mean sea level. Peenya industrial area is located on the north-western suburbs of Bangalore city between 13°1'42" and 77°30'45". Peenya industrial area, Bangalore India is considered to be one of the oldest and largest Industrial areas in Southeast Asia". Total extent area of Peenya Industrial Zone is 10 Sqkm. Red sandy soil and highly undulating terrain is most generally witnessed in this study area. This undulating terrain resulted in micro water sheds namely Shivapura micro water shed, Chokkasandra micro water shed and Luggeri micro water shed [1]. Peenya Industrial zone is mainly divided into two parts one is Peenya Industrial Area, which is identified as Phases and the other one is Peenya Industrial Estate, which is identified as Stages. In the late 1970's Peenya Industrial Estate was established by Karnataka Small Industrial Development Corporation as Stage-1, Stage-2 and Stage-3 and Peenya Industrial Phases are developed by Karnataka Industrial development Board as Phase-1, Phase-2, Phase-3 and Phase-4. Total number of operating Industries in the study area is 1690, Out of 1690 Industries more than 200 are Electroplating, Power coating, Heat Treatment and Spray Painting Industries. Ground water sampling and Soil sampling is carried out in Peenya Industrial area and Estate to know the distribution and migration of physicochemical parameters and heavy metals in both water and Soil. Study area is as shown in Fig. 1

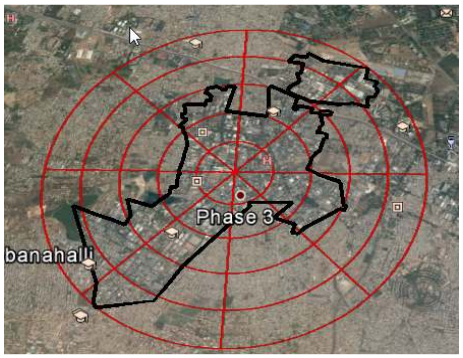


Fig. 1. Study area

2. METHODOLOGY

Ground water samples were collected by adopting Grab sampling method. 42 groundwater samples were collected in polythene containers of 1 liter capacity. These 42 groundwater samples were collected in the intervals of 2

Phases, out of which 20 groundwater samples were collected in the month of March-15 (1st Phase) and remaining 22 groundwater samples were collected in the month of April-15 (2nd Phase). The Samples were preserved in ice box and transported to laboratory for the analysis Physicochemical parameters such as pH, TDS, Total hardness, Chlorides, Alkalinity, Electrical conductivity, Calcium, Magnesium, Nitrate and determined by analytical methods & Heavy metals such as Iron, Copper, Nickel, Chromium, Lead, Cadmium by AAS. A total number of 24 soil samples were collected from the top surface and at a depth of 30and 60 for both distribution and migration study of heavy metals in soil. The collected soil samples were preserved in self-locking polythene bags for further analysis. The analysis of heavy metals in the collected soil samples is done by using Mehlich-I extraction method [7,8]. In this method Mehlich-I extraction solution (0.05N Hydrochloric acid + 0.025N Sulphuric acid) is prepared for further analysis. The collected soil samples are oven dried at a temperature of 101-105°C with the help of hot-air oven for 24 hours. The dried soil samples are grinded into fine powder by using mortar pestle and passed through 1 mm sieve. 5 grams of sieved soil sample is weighed in a conical flask. Adding 20 ml of Mehlich-I extraction solution into the conical flask, sample was kept in the Mechanical shaker for 10 minutes at 250 rpm. The contents of conical flask were filtered through whatman filter paper and taken into 50 ml volumetric flask and diluted up-to 50 ml with Mehlich-I extracting solution. The heavy metal concentration in the soil samples is analyzed using AAS. The spatial representation of Groundwater and Soil sampling is as shown in Figs. 2 & 3. The Quality of Groundwater is determined using a technique called water quality index [9,10].

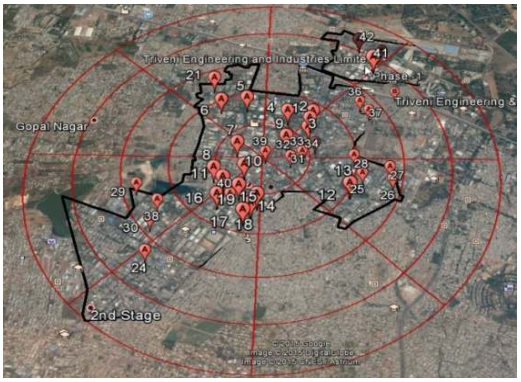


Fig. 2. Spatial representation of groundwater sampling points in Peenya industrial area

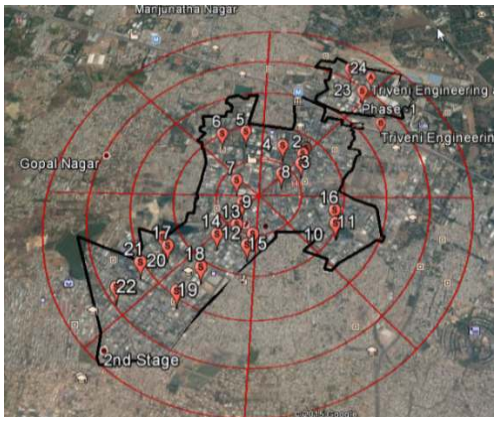


Fig. 3. Spatial representation of soil sampling points in Peenya industrial area

3. RESULTS AND DISCUSSION

Quality of groundwater samples in the study area were assessed by collecting 42 groundwater samples and analyzed for nine physicochemical parameters within 24 hours of sample collection by adopting standard methods and six Heavy Metals by AAS in the environmental Laboratory Department of Civil Engineering, BMS College of Engineering, Bangalore. The analysis results of all physicochemical parameters and heavy metals of 42 groundwater samples were shown in the Tables 1 and 2. The results shows that, PH ranges from 6.1-8.3, Conductivity 1005-5497 µs/cm , TDS 640-3298 mg/l, Total Hardness 131-1700 mg/l, Calcium 38-277.5 mg/l Magnesium 13.2-143.2 mg/l, Chloride 35-661 mg/l, Nitrate 2.90-368 mg/l, Alkalinity 86-506 mg/l. the concentration of chromium is too high than the standards prescribed by the WHO, which ranges from 0 -161 mg/l, the concentration of copper ranges from 0 – 1.530 mg/l, Nickel 0 -0.265 mg/l, Cadmium 0 – 0.330 mg/l, Lead 0 - 3.530 mg/l and Iron 0 – 19.590 mg/l.

In the present study nine physicochemical parameters and 6 Heavy metals are used to calculate water quality index. Viz., pH, TDS, conductivity, calcium, Magnesium, Total hardness, chloride, Nitrate and alkalinity. Heavy Metals Such as Cadmium, Chromium, Copper, Iron, Lead and Nickel. The water quality index of the study area ranges from 35.292 – 30541.51 Out of 42 sampling station only 11 sampling stations are suitable for drinking, viz., 13, 20, 21, 22, 28, 33, 34, 39, 41 & 42. In 12 sampling stations water quality is very poor, which are 5, 6, 9, 24, 27, 29, 31, 32, 35, 36 & 38. The remaining 19 sampling stations water are unsuitable for

drinking. The water quality index of these stations is more than 1000. The high value of water quality index is due to higher values of chromium, iron, nickel, lead, cadmium, TDS, total hardness, calcium and magnesium. Quality of water in the study area in percentage is shown in Table 3. The Variation of water quality Index is as shown in Fig. 4.

The Variation of Heavy Metals Concentration in Soil of Distribution Study is shown in Fig. 5. In the distribution study the concentration of heavy metal ranges from Copper – 0 to 0.560, Nickel- 0 to 1.410, Iron- 0.021 to 0.890, Chromium- 0 to 1.670, Cadmium- 0 to 0.033 and Lead- 0 to 0.067. The concentration of Copper, Nickel, Iron, Chromium, Cadmium and Lead is high at stations 1, 6, 7, 10, 13 and 15 respectively. The distribution of chromium is high and the distribution of Lead and Cadmium is very less in the study area. The variation of heavy metal concentration in soil is shown in Table 4. Spatial distribution of heavy metal concentration in soil is shown in Figs. 6-11. Heavy Metals Concentration in soil from 0 to 60 cm Depth for Migration Study as shown in Table 5.

The variation of Heavy Metals concentration (mg/kg) from 0-60 cm for sampling station 1-24 is as shown in Table 5. In most of the sampling station the concentration of Heavy metals is high at top soil and low at bottom soil in some of the sampling stations its vice verse i.e concentration of nickel at sampling station 9, 16, Copper at 2,20 and Chromium at 21. It might be due to runoff of topsoil.

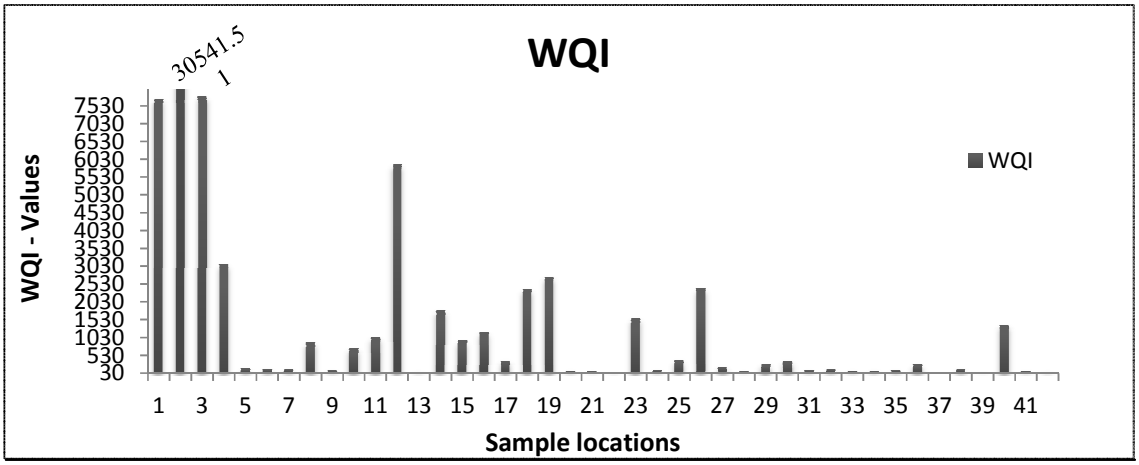


Fig. 4. Variation of water quality index in Peenya industrial area

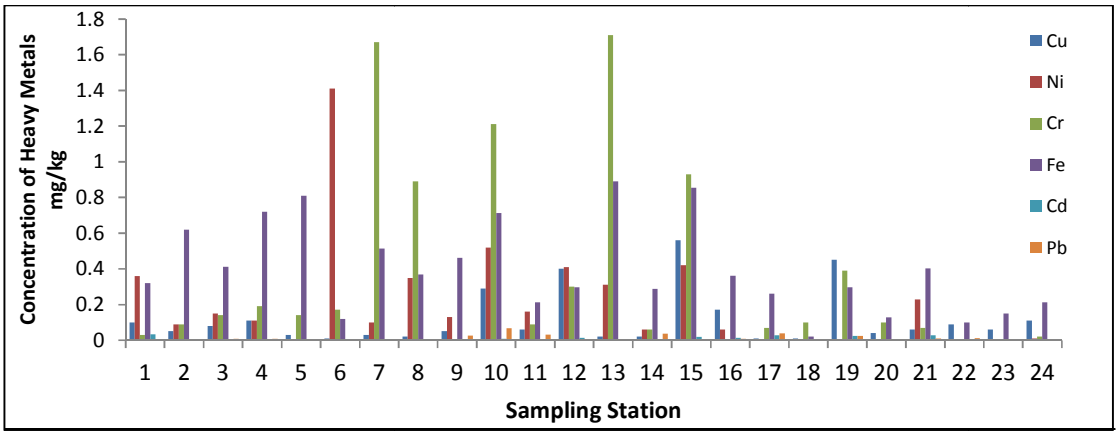


Fig. 5. The variation heavy metals concentration in soil of distribution study

Table 1. The results of physicochemical characteristics of groundwater in study area

Sl No	Lattitude	Longitude	PH	TDS (mg/L)	Conductivity (µs/cm)	Total Hardness (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Nitrate (mg/L)	Chloride (mg/L)	Alkalinity (mg/L)
			1	2	3	4	5	6	7	8	9
1	13°03'12.9"	77°51'96.5"	6.60	1072	1652	565	104.00	70	58.20	126	323
2	13°03'03.8"	77°51'93.5"	6.39	654	1005	404	74.00	5 9	176.00	151	180
3	13°02'91.5"	77°51'91.7"	6.56	1502	2310	703	80.00	122	55.70	320	292
4	13°03'13.8"	77°51'71.1"	6.10	947	1453	509	110.00	57	106.00	197	343
5	13°03'32.4"	77°51'28.9"	6.84	1448	1784	638	136.20	122	108.00	334	322
6	13°03'29.3"	77°51'02.7"	7.18	1606	2470	583	30.00	124	86.10	336	356
7	13°02'71.5"	77°51'21.9"	6.96	1505	2320	869	155.20	117	90.10	322	414
8	13°02'40.0"	77°51'01.0"	7.02	1148	2210	803	164.00	95	88.40	367	236.4
9	13°02'79.1"	77°51'70.0"	7.20	800	1228	486	116.00	47.7	81.40	232	235
10	13°02'43.0"	77°51'30.0"	7.00	1615	2490	968	195.0 0	117	69.70	416	475
11	13°02'27.9"	77°51'10.6"	6.95	1090	2080	600	154.0 0	52	65.70	281	197
12	13°02'20.5"	77°52'29.6"	6.70	1928	2980	1031	234. 00	108	73.80	471	335
13	13°02'20.5"	77°52'30.4"	6.80	746	1162	984	227.00	14	56.90	96	169
14	13°02'07.7"	77°51'43.3"	6.66	2000	3080	569	115.0 0	68	72.50	557	344
15	13°02'18.6"	77°51'26.0"	7.00	1491	2300	781	203.0 0	66	51.40	401	410
16	13°02'07.6"	77°51'06.5"	7.03	1038	1605	791	198.0 0	72	58.90	249	506
17	13°01'89.0"	77°51'31.3"	6.76	1445	2210	718	71.00	132	65.50	372	424
18	13°01'96.6"	77°51'38.3"	6.73	1821	2810	613	131.0 0	69.4	70.20	415	189
19	13°01'96.8"	77°51'37.3"	6.70	1640	2520	719	114.0 0	106	61.60	431	352
20	13°03'72.5"	77°51'05.8"	7.40	1256	2093	563	117.6 0	65.3	6.50	262	356
21	13°03'61.6"	77°50'93.4"	6.50	1676	2793	604	147.0 0	57	23.50	351	353
22	13°03'46.2"	77°50'84.2"	7.30	1176	1960	543	105.9 0	67.7	27.44	207	281
23	13°03'46.3"	77°50'86.0"	6.90	1098	1830	668	150.0 0	71	10.55	234	492
24	13°01'49.5"	77°50'46.6"	7.50	1384	2307	652	130.3 0	129	38.02	321	407
25	13°02'37.6"	77°52'42.9"	7.20	3298	5497	1700	249. 60	262	368.00	612	444
26	13°02'30.3"	77°52'71.6"	6.60	2030	3383	797	184.0 0	82	45.06	494	347
27	13°02'44.6"	77°52'69.9"	7.20	3298	5497	1700	48.0 0	123.5	368.00	252	466
28	13°02'58.3"	77°52'35.8"	7.30	1464	2440	740	59.00	144	2.37	448	120

Sl No	Lattitude	Longitude	PH	TDS (mg/L)	Conductivity (µs/cm)	Total Hardness (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Nitrate (mg/L)	Chloride (mg/L)	Alkalinity (mg/L)
			1	2	3	4	5	6	7	8	9
29	13°02'24.8"	77°50'28.7"	6.70	2436	4060	1148	277. 50	110.4	28.50	661	432
30	13°01'83.6"	77°50'47.2"	7.70	2204	3673	763	110.4 0	118.4	45.93	536	164
31	13°02'57.3"	77°51'74.4"	6.60	1274	2123	629	136.8 0	69.8	48.78	319	191
32	13°02'68.8"	77°51'84.1"	7.40	1670	2783	823	175.2 0	93.6	56.00	478	208
33	13°02'63.4"	77°51'85.8"	6.80	1126	1877	572	117.9 0	67.5	27.30	288	201
34	13°02'70.0"	77°51'88.0"	6.90	1434	2390	627	134.2 0	70.9	30.72	381	284
35	13°02'75.0"	77°51'98.2"	6.90	1416	2360	646	149.8 0	66	45.63	365	336
36	13°03'31.4"	77°52'45.4"	7.00	816	1360	419	89.40	47.5	62.15	142	248
37	13°03'17.9"	77°52'53.3"	6.90	988	1647	131	30.70	13.2	11.96	35	80
38	13°02'06.1"	77°50'50.8"	7.40	2458	4097	829	96.00	143.2	23.52	546	336
39	13°02'63.5"	77°51'49.6"	6.80	640	1067	375	38.00	68	8.92	134	330
40	13°02'12.2"	77°51'18.2"	7.00	1444	2407	684	75.00	148	2.90	434	86
41	13°22'04.8"	77°31'46.4"	8.13	780	1180	580	93.00	60	37.04	262.04	162
42	13°23'03.6"	77°31'29.2"	8.30	861	1318	517	106.00	61	37.30	306.00	234

Table 2. Heavy metals concentration* in groundwater in the study area

Sl No.	Latitude	Longitude	Chromium	Copper	Nickel	Cadmium	Lead	Iron
1	13°03'12.9"	77°51'96.5"	40.700	0.430	0.070	0.040	0.057	6.760
2	13°03'03.8"	77°51'93.5"	161.000	1.530	0.050	0.330	1.860	19.590
3	13°02'91.5"	77°51'91.7"	42.400	-	-	-	-	-
4	13°03'13.8"	77°51'71.1"	14.810	0.680	0.160	0.010	0.008	4.018
5	13°03'32.4"	77°51'28.9"	-	-	0.038	0.004	0.140	0.1 53
6	13°03'29.3"	77°51'02.7"	0.280	-	-	-	-	-
7	13°02'71.5"	77°51'21.9"	-	0.102	0.012	0.011	-	0.3 54
8	13°02'40.0"	77°51'01.0"	1.360	0.600	0.070	0.090	1 .280	6.780
9	13°02'79.1"	77°51'70.0"	-	0.112	0.023	0.002	-	0.1 32
10	13°02'43.0"	77°51'30.0"	3.370	-	-	-	-	-
11	13°02'27.9"	77°51'10.6"	3.650	0.450	0.060	0.110	0.019	5.310
12	13°02'20.5"	77°52'29.6"	25.740	0.560	0.110	0.190	3.530	6.400
13	13°02'20.5"	77°52'30.4"	-	-	-	-	-	0.454
14	13°02'07.7"	77°51'43.3"	0.375	3.540	0.090	0.290	3.370	2.370
15	13°02'18.6"	77°51'26.0"	0.880	0.730	0.030	0.220	1.440	6.020
16	13°02'07.6"	77°51'06.5"	4.810	0.420	0.010	0.010	0.270	6.600
17	13°01'89.0"	77°51'31.3"	1.540	0.010	0.010	-	-	0. 062
18	13°01'96.6"	77°51'38.3"	12.450	0.106	0.020	-	-	0 .642
19	13°01'96.8"	77°51'37.3"	6.320	7.614	0.080	-	-	2. 358
20	13°03'72.5"	77°51'05.8"	-	0.108	0.009	0.007	-	0. 322
21	13°03'61.6"	77°50'93.4"	-	-	-	0.005	-	-
22	13°03'46.2"	77°50'84.2"	-	-	-	0.002	-	0.203
23	13°03'46.3"	77°50'86.0"	2.450	0.750	0.190	0.160	2.870	6.960
24	13°01'49.5"	77°50'46.6"	0.161	0.007	-	-	-	0.052
25	13°02'37.6"	77°52'42.9"	0.032	0.008	0.142	0.021	0.092	0.102
26	13°02'30.3"	77°52'71.6"	8.040	0.620	0.120	0.120	2.400	6.960
27	13°02'44.6"	77°52'69.9"	-	0.001	0.013	0.011	-	-
28	13°02'58.3"	77°52'35.8"	-	-	-	-	0.015	-
29	13°02'24.8"	77°50'28.7"	-	0.019	0.126	0.017	0.12 7	0.170
30	13°01'83.6"	77°50'47.2"	-	0.164	0.265	0.001	-	0. 313
31	13°02'57.3"	77°51'74.4"	-	0.004	0.002	0.015	0.10 1	0.172
32	13°02'68.8"	77°51'84.1"	-	-	0.007	0.018	0.139	0. 452
33	13°02'63.4"	77°51'85.8"	-	-	0.004	0.013	0.096	0. 510
34	13°02'70.0"	77°51'88.0"	-	-	-	0.012	0.067	0.187
35	13°02'75.0"	77°51'98.2"	0.001	-	0.020	0.013	0.01 2	0.770
36	13°03'31.4"	77°52'45.4"	-	1.036	-	0.014	0.038	0. 136
37	13°03'17.9"	77°52'53.3"	-	-	-	-	-	0.603
38	13°02'06.1"	77°50'50.8"	-	0.068	0.041	-	-	0.026
39	13°02'63.5"	77°51'49.6"	-	-	-	0.010	-	0.466
40	13°02'12.2"	77°51'18.2"	7.150	-	0.010	-	-	0.010
41	13°22'04.8"	77°31'46.4"	-	0.107	-	0.001	0	0.166
42	13°23'03.6"	77°31'29.2"	0	0.03	0	0.002	0	0.133

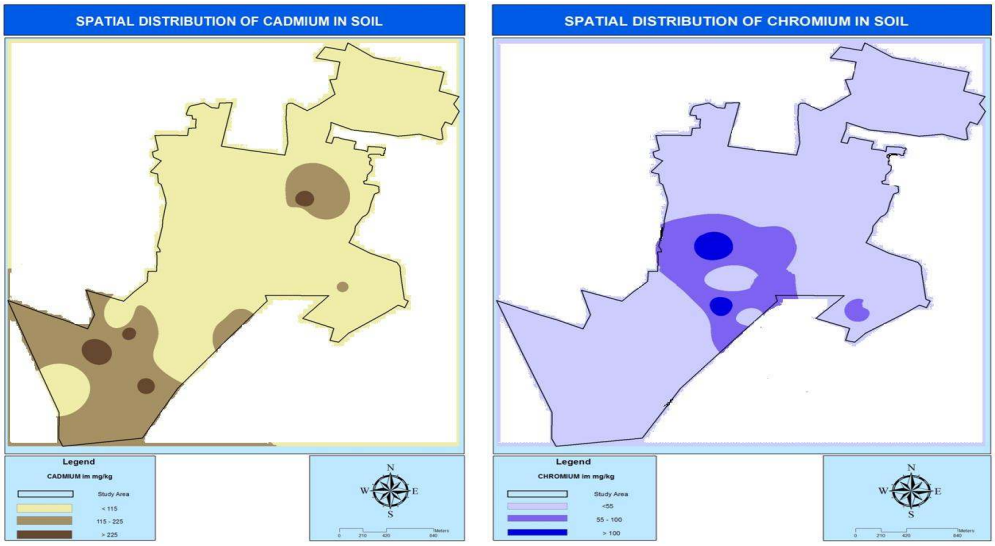
**Units are mg/l*

Table 3. Classification of water quality based on WQI value

WQI value	Quality of water	Percentage of water samples
<50	excellent water	2.38%
50-100	good water	23.12%
100-200	poor water	21.42%
200-300	very poor water	7.14%
>300	water unsuitable for drinking	45.23%

Table 4. Variation heavy metals concentration in soil of distribution study

SL NO	Latitude	Longitude	Copper (mg/Kg)	Nickel (mg/Kg)	Chromium (mg/Kg)	Iron (mg/Kg)	Cadmium (mg/Kg)	Lead (mg/Kg)
1	13°01'52.2"	77°31'10.6"	0.1	0.36	0.03	0.321	0.033 09	0.003
2	13°01'48.9"	77°31'09.8"	0.05	0.09	0.09	0.62	0.003 49	0.0052
3	13°01'44.5"	77°31'09.6"	0.08	0.15	0.14	0.412	0.00 726	0.0078
4	13°01'51.5"	77°31'05.3"	0.11	0.11	0.19	0.72	0.003 06	0.008
5	13°01'59.7"	77°30'46.4"	0.03	0	0.14	0.81	0.00272	0.0016
6	13°01'56.7"	77°30'38.2"	0.01	1.41	0.17	0.12	0.001 97	0.0011
7	13°01'38.9"	77°30'43.1"	0.03	0.1	1.67	0.513	0.002 65	0.0035
8	13°01'40.5"	77°30'52.8"	0.02	0.35	0.89	0.368	0.00 22	0.0016
9	13°01'28.6"	77°30'45.8"	0.05	0.13	0	0.461	0.00492	0.0248
10	13°01'19.8"	77°31'22.5"	0.29	0.52	1.21	0.712	0.0 0788	0.0672
11	13°01'36.9"	77°31'22.9"	0.06	0.16	0.09	0.212	0.0 0094	0.0315
12	13°01'14.8"	77°30'51.5"	0.4	0.41	0.3	0.298	0.013 86	0.0015
13	13°01'18.6"	77°30'45.0"	0.02	0.31	1.71	0.89	0.00 273	0.0045
14	13°01'13.4"	77°30'37.7"	0.02	0.06	0.06	0.289	0.0 006	0.0373
15	13°01'09.4"	77°30'50.6"	0.56	0.42	0.93	0.854	0.0 1901	0.0002
16	13°02'35.0"	77°52'28.4"	0.17	0.06	0	0.361	0.0127 4	0.0085
17	13°01'96.0"	77°50'56.0"	0.01	0	0.07	0.261	0.0270 2	0.0382
18	13°01'72.0"	77°50'93.0"	0.01	0	0.1	0.021	0.00278	0.0017
19	13°01'48.0"	77°50'71.0"	0.45	0	0.39	0.298	0.0239 6	0.0231
20	13°02'05.0"	77°50'50.6"	0.04	0	0.1	0.129	0.00319	0.0003
21	13°01'78.0"	77°50'31.0"	0.06	0.23	0.07	0.402	0.0 2815	0.0103
22	13°01'52.0"	77°50'10.0"	0.09	0	0	0.1	0.00561	0.0 115
23	13°22'04.8"	77°31'46.4"	0.06	0	0	0.15	0.00232	0. 0036
24	13°23'03.6"	77°31'29.2"	0.11	0.01	0.02	0.212	0.0 0182	0.001

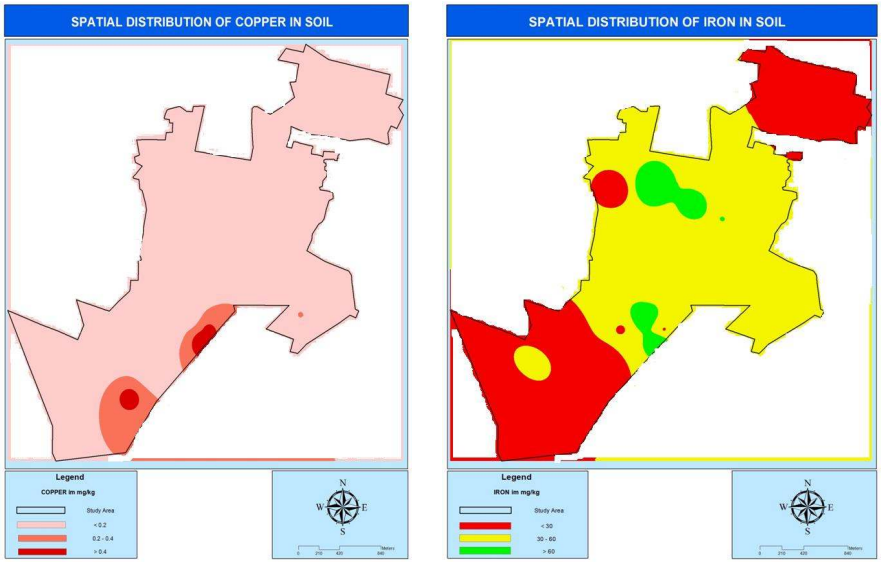


Figs. 6 and 7. Spatial distribution of cadmium and chromium (mg/kg) in soil in Peenya industrial area

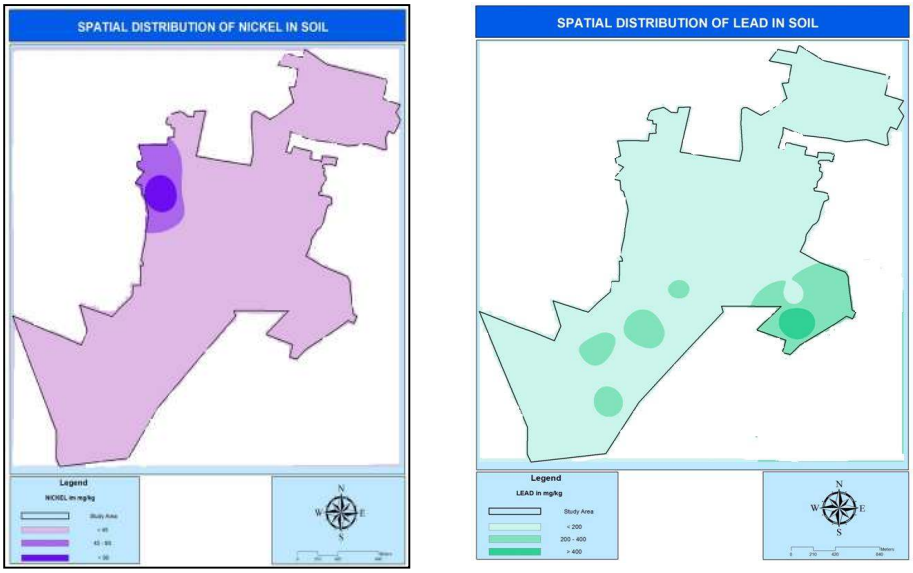
Table 5. Variation of heavy metals concentration in soil from 0 to 60 cm depth in study area

SL NO	Latitude	Longitude	Depth in Cm	Cu (Mg/Kg)	Nl (Mg/Kg)	Cr (Mg/Kg)	Fe (Mg/Kg)	Cd (Mg/Kg)	Pb (Mg/Kg)
1	13°01'52.2"	77°31'10.6"	0	0.1	0.36	0.03	0.321	0.0 3309	0.002966
			30	0.09	0.09	0	0.212	0.01102	0.002088
			60	0.02	0.02	0	0.2	0.01023	0.001079
2	13°01'48.9"	77°31'09.8"	0	0.05	0.09	0.09	0.62	0.0 0349	0.005199
			30	0.26	0	0.07	0.21	0.00301	0.005301
			60	0.84	0	0.13	0.05	0.01459	0.005542
3	13°01'44.5"	77°31'09.6"	0	0.08	0.15	0.14	0.412	0. 00726	0.007807
			30	0.08	0.1	0.1	0.38	0.006	0.007231
			60	0.06	0.09	0.05	0.21	0.00573	0.006905
4	13°01'51.5"	77°31'05.3"	0	0.11	0.11	0.19	0.72	0.0 0306	0.00804
			30	0.09	0.05	0.18	0.442	0.00509	0.010011
			60	0.05	0.05	0.09	0.212	0.01996	0.01574
5	13°01'59.7"	77°30'46.4"	0	0.03	0	0.14	0.81	0.0027 2	0.00163
			30	0.02	0	0.12	0.505	0.00209	0.000971
			60	0.01	0	0	0.313	0.00201	0.000702
6	13°01'56.7"	77°30'38.2"	0	0.01	1.41	0.17	0.12	0.0 0197	0.001059
			30	0	0.38	0	0.34	0.00109	0.001456
			60	0	0.3	0	0.52	0.00201	0.001568
7	13°01'38.9"	77°30'43.1"	0	0.03	0.1	1.67	0.513	0.0 0265	0.003473
			30	0.03	0.15	0.11	0.426	0.0011	0.00306
			60	0.01	0.05	0.04	0.249	0.00044	0.003011
8	13°01'40.5"	77°30'52.8"	0	0.02	0.35	0.89	0.368	0. 0022	0.001556
			30	0.02	0.19	0.07	0.247	0.00201	0.001391
			60	0.01	0.001	0.05	0.205	0.0011	0.001201
9	13°01'28.6"	77°30'45.8"	0	0.05	0.13	0	0.461	0.004 92	0.02478
			30	0.05	0.19	0.09	0.398	0.00289	0.01544
			60	0.04	0.25	0.12	0.364	0.00133	0.01012
10	13°01'19.8"	77°31'22.5"	0	0.29	0.52	1.21	0.712	0 .00788	0.06724
			30	0.06	0.34	0.22	0.699	0.0066	0.07055
			60	0.02	0.29	0.14	0.587	0.00603	0.07287
11	13°01'36.9"	77°31'22.9"	0	0.06	0.16	0.09	0.212	0 .00094	0.03145
			30	0.02	0.09	0.04	0.209	0.00291	0.00766
			60	0.01	0.01	0.02	0.18	0.0031	0.001828
12	13°01'14.8"	77°30'51.5"	0	0.4	0.41	0.3	0.298	0.0 1386	0.001536
			30	0.17	0.1	0.15	0.162	0.00267	0.00631
			60	0.13	0.09	0.09	0.102	0.00078	0.004203

SL NO	Latitude	Longitude	Depth in Cm	Cu (Mg/Kg)	Nl (Mg/Kg)	Cr (Mg/Kg)	Fe (Mg/Kg)	Cd (Mg/Kg)	Pb (Mg/Kg)
13	13°01'18.6"	77°30'45.0"	0	0.02	0.31	1.71	0.89	0. 00273	0.004521
			30	0.01	0.22	0.6	0.68	0.00311	0.003696
			60	0.03	0.06	0.19	0.542	0.0044	0.002181
14	13°01'13.4"	77°30'37.7"	0	0.02	0.06	0.06	0.289	0 .0006	0.0373
			30	0.02	0.03	0.02	0.232	0.00232	0.008181
			60	0	0	0.1	0.161	0.00605	0.002122
15	13°01'09.4"	77°30'50.6"	0	0.56	0.42	0.93	0.854	0 .01901	0.000229
			30	0.04	0.33	0.72	0.723	0.01067	0.010976
			60	0	0.13	0.3	0.512	0.09573	0.014741
16	13°02'35.0"	77°52'28.4"	0	0.17	0.06	0	0.361	0.01 274	0.008521
			30	0.13	0.18	0	0.211	0.00664	0.004254
			60	0.05	0.23	0.05	0.198	0.00536	0.001967
17	13°01'96.0"	77°50'56.0"	0	0.01	0	0.07	0.261	0.02 702	0.03819
			30	0.01	0	0	0.161	0.01237	0.004527
			60	0	0	0.08	0.148	0.01337	0.002802
18	13°01'72.0"	77°50'93.0"	0	0.01	0	0.1	0.021	0.002 78	0.001732
			30	0	0	0.06	0.019	0.0103	0.01405
			60	0	0	0.01	0	0.0313	0.01656
19	13°01'48.0"	77°50'71.0"	0	0.45	0	0.39	0.298	0.02 396	0.02312
			30	0.37	0	0.11	0.205	0.0155	0.1844
			60	0.19	0	0.02	0.178	0.00351	0.1006
20	13°02'05.0"	77°50'50.6"	0	0.04	0	0.1	0.129	0.003 19	0.000255
			30	0.05	0.05	0	0.102	0.00115	0.002568
			60	0.13	0	0.02	0.08	0.05122	0.0147
21	13°01'78.0"	77°50'31.0"	0	0.06	0.23	0.07	0.402	0 .02815	0.01029
			30	0.11	0	0.16	0.361	0.00867	0.02977
			60	0.02	0.11	0.18	0.212	0.00147	0.001877
22	13°01'52.0"	77°50'10.0"	0	0.09	0	0	0.1	0.00561	0 .01148
			30	0.04	0	0.13	0.1	0.0049	0.000696
			60	0.001	0	0.13	0	0.00401	0.00032
23	13°22'04.8"	77°31'46.4"	0	0.06	0	0	0.15	0.00232	0.003561
			30	0.01	0	0	0.121	0.00105	0.001981
			60	0	0	0	0.098	0.00062	0.000156
24	13°23'03.6"	77°31'29.2"	0	0.11	0.01	0.02	0.2124	0.00182	0.001005
			30	0.03	0	0.005	0.172	0.00092	0.000012
			60	0.005	0	0	0.1438	0.00032	0.000002



Figs. 8 and 9. Spatial distribution of copper and Iron (mg/kg) in Soil in Peenya industrial area



Figs. 10 and 11. Spatial distribution of nickel and lead (mg/kg) in soil in Peenya industrial area

4. CONCLUSIONS

The present work was carried out to know the Physico-Chemical Characteristics and Heavy metal concentration in Groundwater in Peenya Industrial Area. Distribution and migration of heavy metals in soil in Peenya Industrial Area, which is considered to be one of the oldest and largest Industrial Area in South East Asia.

The following are the main results obtained from the work carried out

- The present study reveals that pH, Chloride and Alkalinity of all the samples are well within the permissible limit,
- 64% (27 samples out of 42 samples) of the samples exceeding the permissible limit of conductivity, 16% (7 samples out of 42 samples) of samples exceeding the permissible limit of TDS i.e., 2000 mg/l. 64% (27 samples out of 42 samples) of the samples exceeding the permissible limit of TH, i.e., 600 mg/l. 12% (5 samples out of 42 samples) of samples exceeding the

permissible limit of Calcium i.e., 200 mg/l. 35% (15 samples out of 42 samples) of samples exceeding the permissible limit of Magnesium i.e., 100 mg/l. 12% (5 samples out of 42 samples) of samples exceeding the permissible limit of Nitrate i.e., 100 mg/l. Nitrate is high at stations 2, 25 & 27.

- Out of 42 bore-well samples, Chromium detected in 21 bore-wells, in which except 2 samples remaining all the samples are exceeding the limit of 0.05 mg/l, 45% of the samples exceeding the limit.
- Except one sample (Station 2), the concentration of Copper in remaining 25 samples is well within the permissible limit of 1.5 mg/l. Copper is not detected in 16 Ground water samples. Nickel is not detected in 14 Ground water samples. 28% (12 samples out of 42 samples) of the samples exceeding the permissible limit of 0.02 mg/l.
- Cadmium is not detected in 13 Ground water samples. 40% (17 samples out of 42 samples) of the samples exceeding the permissible limit of 0.01 mg/l. Lead is not detected in 21 Ground water samples. 38% (16 samples out of 42 samples) of the samples exceeding the permissible limit of 0.05 mg/l. Iron is not detected in 7 Ground water samples. 28% (12 samples out of 42 samples) of the samples exceeding the permissible limit of 1 mg/l.
- The Quality of Groundwater is determined using a technique called water quality index. The results obtained shows that 45% (19 samples out of 42 samples) of the Bore-well water are unsuitable for drinking. 28% of the samples are in very poor conditions, only 26% of the samples are suitable for drinking.
- The distribution study of Heavy metal concentration in soil reveals that, the distribution of Chromium concentration i.e.,(mg/kg) is very high at stations 7,10 & 13. The distribution of Lead and Cadmium concentration (mg/kg) is very low in the study area.
- The migration study of Heavy Metal concentration in soil reveals that, the concentration of the top soil is more (0 cm) as compare to bottom (60 cm) soil. In few of the sampling station which is visa-versa it might be due to runoff the top soil.

From the above obtained results, it can be concluded that, quality of ground-water in the study area is contaminated from Industrial discharge. Hence the periodical monitor of ground-water is required to prevent contamination. Hazardous waste dumping and effluent discharge on open land has lead to soil pollution i.e., increased level of heavy metal in soil damaging the soil quality for its best use.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Raja Rajeswari T, et al. National seminar on impact of toxic metals, minerals and solvents leading to environment pollution-2014. Journal of Chemical and Pharma-ceutical Sciences. ISSN. 2015;0974.
2. Ramesh A, Nagendra Prakash BS, Sivapullaiaih PV, Sadhashivaiah AS. Assessment of groundwater quality in designated Peenya Industrial Area and Estate, Bangalore, India – A case study. International Journal of Environmental Protection. 2012;2(6):21-25.
3. Shrivastava KBL, Mishra SP. Studies of various heavy metal in surface and ground water of Birsinghpur Town and its surrounding rural area District Satna (MP). Current world Environmental. 2011;6(2): 271-274.
4. Garba ST, Ahiahmed, Akan JC, Dauda BA. Distribution pattern of heavy metals: Pb, Zn, Cd and Cu in roadside soils of Maiduguri, Metropolis, Borno State Nigeria. International Research Journal of Pure and Applied Chemistry. 2014;4(5):486-493.
5. Ata Shakeri, Farid Moore, Soroush modabbere. Heavy metal contamination and distribution in the Shiraz industrial complex zone soil, South Shiraz, Iran. World Applied Science Journal. 2009;6(3): 413-425.
6. Rakesh Sharma MS, Raju NS. Correlation of heavy metal contamination with soil prosperities of industrial areas of Mysore, Karnataka, India by cluster analysis. International Research Journal of Environment Sciences. 2013;2(10):22-27.
7. Nelson WLA Mehlich, Winters E. The development, evaluation and use of soil tests for phosphorus availability. In Pierre WH, Norman AG, (eds). Soil and Fertilizer Phosphorus Vol. II. Agronomy A Series of Monograph. 1953;153-188.

8. Mehich A. Determination of P, Ca, Mg, K, Na and NH4. North Carolina Soil Test Division (Mimeo); 1953.
9. Ravikumar P, Mohammed Aneesul Mohmood, Somashekar RK. Water quality index to determine the surface water quality of Sankey tank and Mallthahalli Lake, Bangalore Urban District, Karnataka, India. Applied Water Science. 2013;3:247-261.
10. Ramakrishnaiah CR, sadashivaiah C, Ranganna G. Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. E-Journals of Chemistry. 2009;6(2):523-530.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/14656