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Spatial Distribution of Trace Metals in Groundwater: A Study Done in The Industrial Area of Visakhapatnam, Andhra Pradesh, India.

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ABSTRACT

Heavy metals though present at low level, are a matter of concern for determining the quality of the environment. The samples were analyzed by ICP – MS for the distribution of different heavy metals (Pb, As, Zn, Co. Ni ,Cu, As, Se, Rb, Cs, Ti, Cr & V) present in trace amount. Hg was analyzed by CVAAS. The Physico-chemical analysis with reference to selective parameters was carried out. The groundwater samples were collected from four different sites around the industrial areas of Visakhapatnam. 22 metals were detected in trace amounts in the groundwater samples. The suitability of water as per complied with BIS 10500:2012 was conformed. The concentration of mercury was analyzed in three forms. The total mercury (THg) was as observed in the range 0.76-3.54ng/L, organic mercury (OHg) in 0.13-1.03ng/L and dissolved mercury (DHg) in the range 0.02-2.35ng/L.

Keywords: Groundwater, Mercury, Heavy metals, CVAAS, ICP-MS

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INTRODUCTION

The source and the form of trace metals, occurring naturally or introduced anthropogenically in the environment, depends upon several factors [1, 2]. Urbanization is the most commonly identified reason leading to the contamination of air, water and soil [3]. Mercury is anthropogenally introduced element into atmosphere as by- products from various industries via fuel combustion [4-6]. Mercury exist in various chemical forms in the environment which are persistent and highly toxic. The different forms are elemental (Hg^0), oxidized inorganic (Hg^{2+}, Hg_2^{2+}) and organic form. Mercury compounds, directly or indirectly, when enter into ecosystem are retained for a long period [7-9]. Once entered into ecosystem especially hydrosphere, transformation of inorganic mercury in aquatic medium to methylated organic form takes place through abiotic and biotic mechanism [10]. Inorganic and organic mercury are fairly soluble in aqueous solution as compound to elemental mercury [11-14]. Organic form is the most toxic form [15]. Mostly Hg usually appears as inorganic form and forms sulfides with Zn, Fe and other metals in the environment [16]. The present work is aimed at assessing the impact of anthropogenic activity, were referred to the distribution of mercury and other metals, on groundwater in the industrial areas of Visakhapatnam.

MATERIALS AND METHODS

Study area

The study area (Fig.no.1) is located in the industrial area of Visakhapatnam lies between North Longitude 17° 42' 7.1892" N to East Latitude 83° 12' 55.5084" E of Visakhapatnam district, India. (Table.no.1). During the period of October 2014 to January 2015, a total of 61 groundwater samples were collected from hand pump. The details of the samples collected in the area covering around 5-10km from the industrial area (Table 1).

Table 1- Site description with periodic code and their geographical coordination

Sl.no	Sampling area code	Geographical Coordination	
1	W1	17° 42' 7.1892" N	83° 12' 55.5084" E
2	W2	17° 42' 4.2088" N	83° 12' 58.194" E
3	W3	17° 42' 8.676" N	83° 13' 1.7004" E
4	W4	17° 42' 10.0728" N	83° 12' 59.3028" E
5	W5	17° 37' 57.54" N	83° 11' 43.1376" E
6	W6	17° 37' 58.494" N	83° 11' 43.9908" E
7	W7	17° 41' 36.5172"N	83° 17' 27.6252" E
8	W8	17° 41' 35.412" N	83° 17' 27.9708" E
9	W9	17° 41' 33.6084" N	83° 17' 27.5856" E
10	W10	17° 41' 32.874" N	83° 17' 28.5504" E
11	W11	17° 41' 30.0048" N	83° 17' 27.2364" E
12	W12	17° 41' 29.9652" N	83° 17' 26.1168" E
13	W13	17° 43' 19.0596" N	83° 17' 10.1292" E
14	W14	17° 43' 15.6036" N	83° 17' 6.9972" E
15	W15	17° 43' 14.5344"N	83° 17' 5.1828" E
16	W16	17° 43' 10.5132" N	83° 17' 37.6368" E
17	W17	17° 43' 12.116" N	83° 17' 37.1636" E
18	W18	17° 38' 22.1172" N	83° 7' 24.0564" E
19	W19	17° 38' 17.1816" N	83° 6' 47.2752" E
20	W20	17° 38' 11.1264" N	83° 6' 40.0896" E
21	W21	17° 38' 1.2084" N	83° 6' 11.664" E
22	W22	17° 37' 21.0108" N	83° 5' 1.1364" E
23	W23	17° 37' 14.4588" N	83° 4' 52.176" E
24	W24	17° 36' 52.5708" N	83° 5' 17.5632" E
25	W25	17° 36' 49.9212" N	83° 5' 26.7444" E
26	W26	17° 34' 49.8432" N	83° 5' 26.9736" E

27	W27	17° 34' 49.5804" N	83° 5' 28.2624" E
28	W28	17° 34' 48.7164" N	83° 5' 27.2004" E
29	W29	17° 34' 49.2132" N	83° 5' 29.4108" E
30	W30	17° 35' 56.13" N	83° 6' 37.4364" E
31	W31	17° 35' 52.5228" N	83° 6' 47.6712" E
32	W32	17° 35' 59.8456" N	83° 6' 36.3244" E
33	W33	17° 36' 19.386" N	83° 7' 30.435" E
34	W34	17° 35' 57.9012" N	83° 6' 38.4876" E
35	W35	17° 36' 17.5708" N	83° 6' 45.09" E
36	W36	17° 36' 14.7276" N	83° 6' 47.1564" E
37	W37	17° 34' 50.0664" N	83° 5' 26.2392" E
38	W38	17° 33' 32.1208" N	83° 5' 4.0452" E
39	W39	17° 33' 47.0016" N	83° 5' 2.1516" E
40	W40	17° 33' 44.8308" N	83° 5' 1.9968" E
41	W41	17° 33' 42.3252" N	83° 5' 2.8104" E
42	W42	17° 33' 32.9004" N	83° 5' 50.1324" E
43	W43	17° 33' 30.8016" N	83° 5' 44.754" E
44	W44	17° 33' 31.7196" N	83° 5' 18.9924" E
45	W45	17° 33' 24.7968" N	83° 5' 46.6872" E
46	W46	17° 36' 19.1628" N	83° 9' 13.3668" E
47	W47	17° 36' 21.4272" N	83° 9' 7.9236" E
48	W48	17° 36' 21.6252 " N	83° 9' 7.8012" E
49	W49	17° 36' 22.6224" N	83° 9' 7.8552" E
50	W50	17° 36' 29.5812" N	83° 9' 3.0744" E
51	W51	17° 36' 30.888" N	83° 9' 3.1716" E
52	W52	17° 36' 29.6208" N	83° 8' 38.742" E
53	W53	17° 36' 14.1588" N	83° 8' 32.5608" E
54	W54	17° 36' 7.236" N	83° 8' 29.7816" E
55	W55	17° 35' 59.064" N	83° 8' 26.538" E
56	W56	17° 35' 55.3092" N	83° 8' 26.1492" E
57	W57	17° 35' 30.1992" N	83° 9' 0.756" E
58	W58	17° 35' 28.5072" N	83° 9' 4.0032" E
59	W59	17° 35' 24.3096" N	83° 9' 10.0188" E
60	W60	17° 35' 22.542" N	83° 9' 4.698" E
61	W61	17° 35' 16.944" N	83° 8' 57.2028" E

Figure 1: Map of study area with groundwater sampling points

Reagent

Analytical grade chemicals of Merck, India make were used. Ultra-pure water was used throughout the analysis. Glassware were thoroughly cleaned with 20% HNO_3 followed by ultrapure deionized water (DI). Selected phyisco-chemical parameters like pH & redox potential were measured using Elico CM 180, digital pH meter. Total alkalinity, sulfide, chloride and sulfate were determined according to standard methods of drinking water in APHA 2005 [17] . To determine the trace levels of metals inductively coupled plasma mass spectrometry (ICP-MS), Agilent technology, 7700 series was used. The concentration of mercury in water samples was determined using Cold vapour atomic absorption spectrometer (CVAAS) MA 5840, Electronics Corporation of India Ltd. (ECIL), Hyderabad, India. The reduction of Hg^{2+} ions in the sample test solution was done with stannous chloride to generate elemental mercury vapour (Hg^0) into the photo-absorption cell. The absorbance was recorded at 253.7 nm. Freshly prepared stannous (II) chloride (10 % w/v) in HCl was used as reducing agent. For stock solution of mercuric chloride (1000mg/l), mercuric chloride (0.1354gm) along with 1ml of $K_2Cr_2O_7$ (1% w/v)volumetric flask. It was made up to the mark with 2% HNO_3 in a 100ml.

Determination of dissolved mercury (DHg) in water samples

100ml of groundwater sample was measured into sample analyzer BOD bottle. 20ml of stannous chloride and 60ml of concentrated nitric acid was added to it. The inorganic form of mercury was reduced by adding stannous chloride. Elemental mercury thus formed was then drawn into the absorption cell and measured by a low pressure mercury lamp at 253.7nm using CVAAS.

Determination of organic mercury (OHg) in water samples

The method reported by Logar et al.,2001 [18] was used to extract OHg from the groundwater samples. A mix of 100ml of groundwater sample, 10.5ml of concentrated hydrochloric acid and 18ml of dichloromethane solvent was taken into a 250ml sample bottle which was shaken mechanically for 12h. The organic and aqueous were separated with the help of separating funnel and the aqueous layer was discarded. 30ml of Millipore water was added to the organic layer and it was heated over a water bath to evaporate the dichloromethane layer. The sample was cooled and the absorbance was measured in CVAAS as mentioned in the proceeding section.

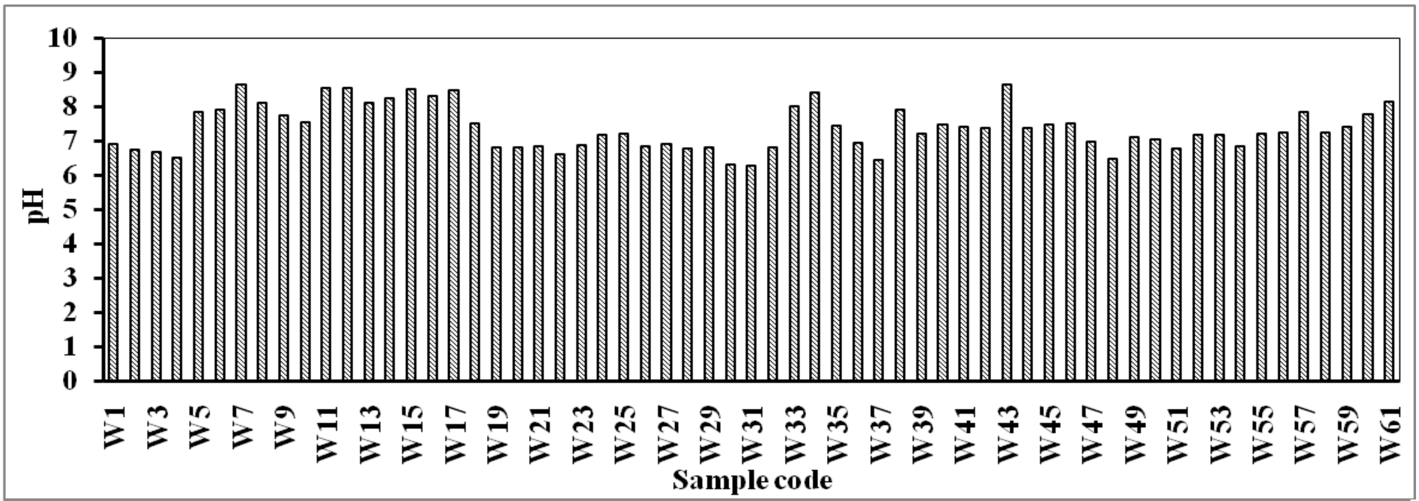
Determination of total mercury (THg) in water samples

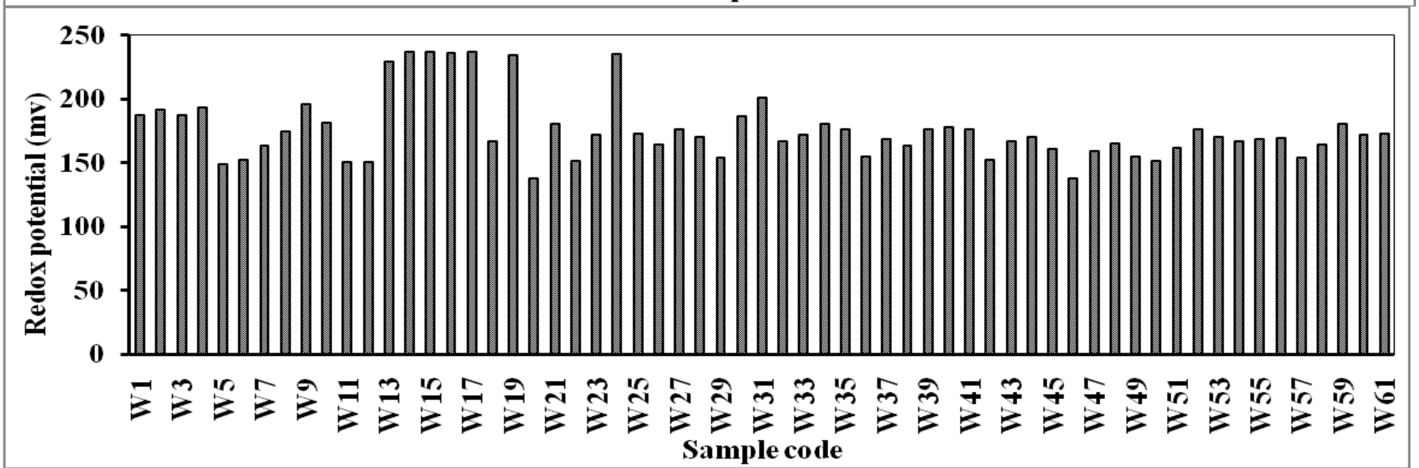
The method used by O'Dell et al., 1994 (EPA Method 2451) [19] was used for the digestion of THg.100ml of groundwater sample along with 5ml of sulfuric acid, 2.5ml of nitric acid, 15 ml of potassium permanganate solution and freshly prepared potassium persulfate were taken in a 300ml BOD bottle. It was then heated on a water bath for about 2hr at 95^{0}C. After cooling to the room temperature, the excess amount of potassium permanganate present in the sample was reduced by adding a few drops of hydroxylamine hydrochloride. The sample was then analyzed by CVAAS as described in the preceding section.

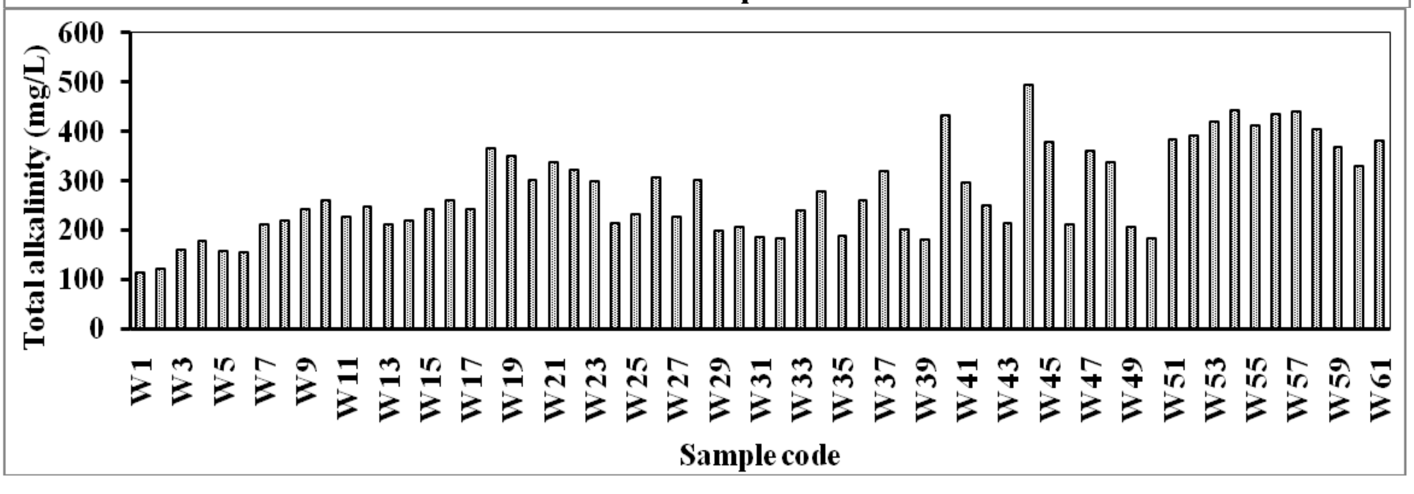
RESULTS AND DISCUSSION

Phyisco- chemical analysis of selected groundwater

The results of the physico chemical analysis of groundwater with reference to selected parameter like pH, redox potential, total alkalinity, chloride and sulfate are presented in the Table 2 and Figure 2. The pH of the sample ranged between pH 6.44 – pH 8.65 as shown in the Table 2.Redox potential and pH are reported to influence the mobility of Hg [20]. In the present study, the redox potential is reported in the range +137.81mv to +237.2mv. The maximum and minimum values of redox potential had been observed in the samples is +237.2 mv and +137.81mv, for the samples of W17 and W46 respectively. The average redox potential value was observed to be +176.41 mv. Fashola et al., 2013 [21] reported redox potential ranged between 124mv to 200 mv with a mean of 151 mv in groundwater in Old Port Harcourt, Niger. The concentration of total alkalinity of the groundwater samples had been observed in the range 116mg/L – 494mg/L. The maximum value found was 494mg/L in W44 sample. The average value of total alkalinity was 278.52mg/L. Kamaldeep et.al, 2011[22] investigated the quality of groundwater in Baddi-Barotiwala industrial belt area of Himachal Pradesh, India and reported that the total alkalinity of the sample between 110mg/L – 1123mg/L. The chloride concentration in groundwater samples ranged between 45mg/L – 745mg/L and the average values observed from the sample was 251.52mg/L. The maximum concentration of chloride was 745mg/L in W18 and minimum was 45mg/L in W44 water sample. Shankar et al., 2007 [23] studied the groundwater in Peenya industrial area, Bangalore, India and reported the concentration of chloride ranges between 40mg/L -2038mg/L with an average of 387mg/L. The concentration of sulfate in groundwater samples range was 2.366mg/L – 15.973mg/L. The maximum value of sulfate was found in W39, W42 and W52 (15.973mg/L) and the minimum value was found in W5 (2.366mg/L) water sample. The average value of sulfate was found to be 8.2mg/L. Dimitriou et al.,2008 [24] in their study on the groundwater quality, Greece and has reported the amount of Sulfate was between 4.17mg/L–728mg/L.







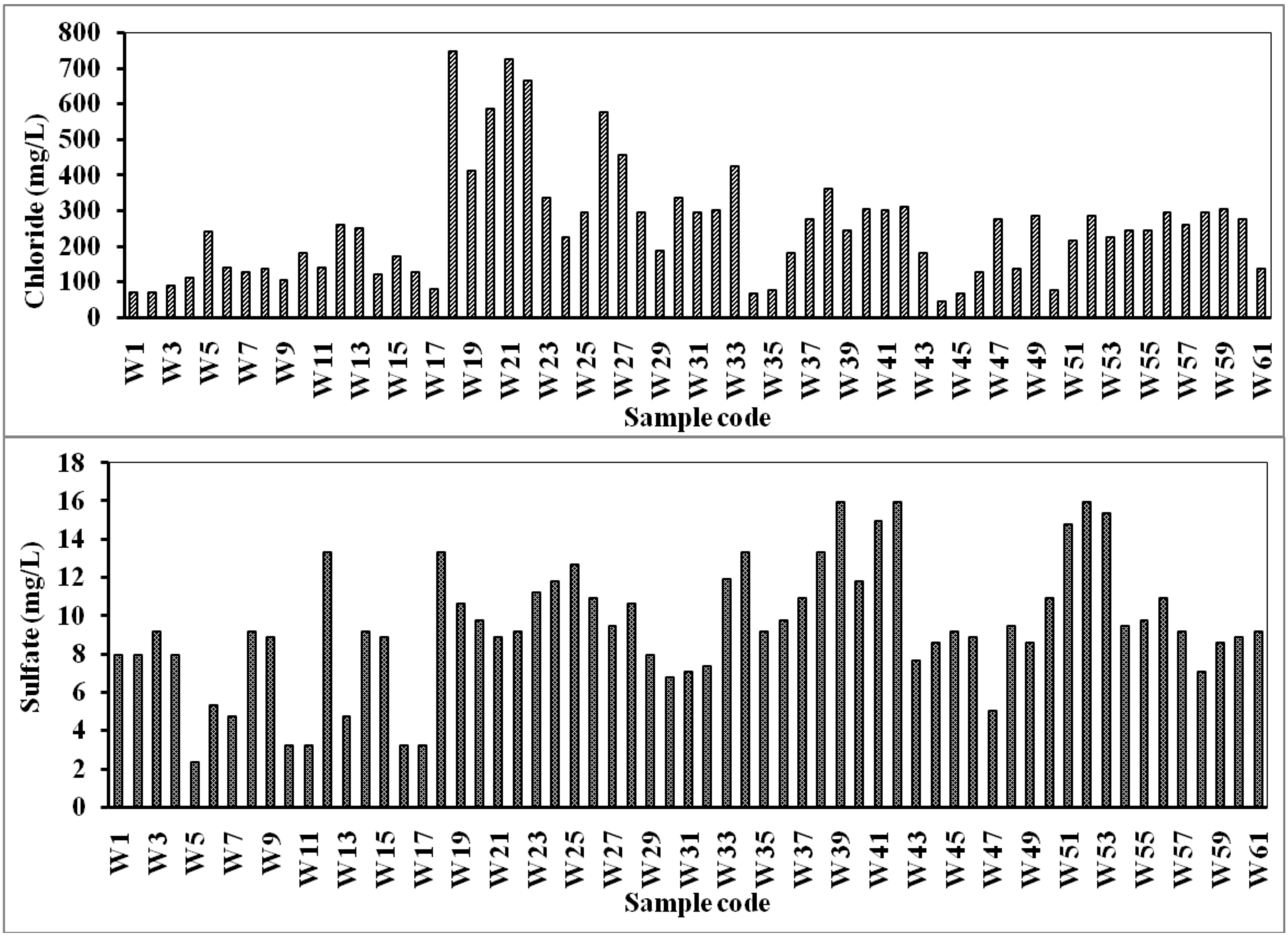


Figure 2: Bar graph physico-chemical parameters of groundwater samples near the industrial area, Visakhapatnam.

Table 2: Physico-chemical parameters of groundwater samples near the industrial area, Visakhapatnam

Sl.no.	Sample Code	pH	Redox potential (mv)	Total alkalinity (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
1	W1	6.89	187.6	116	70	7.98
2	W2	6.72	192	122	70	7.98
3	W3	6.66	187.6	160	90	9.16
4	W4	6.49	193.8	180	110	7.98
5	W5	7.85	149.53	158	240	2.36
6	W6	7.9	152.52	156	140	5.32
7	W7	8.62	163.36	213	125	4.73
8	W8	8.1	175.1	220	135	9.16
9	W9	7.75	195.75	242	105	8.87
10	W10	7.54	181.99	262	180	3.25
11	W11	8.53	150.53	227	140	3.25
12	W12	8.52	150.52	249	260	13.31
13	W13	8.1	229.6	213	250	4.73
14	W14	8.23	237	220	120	9.16
15	W15	8.5	236.8	242	171	8.87
16	W16	8.3	236	262	126	3.25

17	W17	8.46	237.2	242	79	3.25
18	W18	7.51	167.26	366	745	13.31
19	W19	6.79	235	350	410	10.64
20	W20	6.79	137.81	302	585	9.76
21	W21	6.82	181.05	338	725	8.87
22	W22	6.59	151.94	322	665	9.16
23	W23	6.88	172.23	300	335	11.24
24	W24	7.17	235.8	214	225	11.83
25	W25	7.2	173.21	232	295	12.71
26	W26	6.85	164.38	308	575	10.94
27	W27	6.9	176.13	228	455	9.46
28	W28	6.77	170.22	302	295	10.64
29	W29	6.81	154.53	200	185	7.98
30	W30	6.31	187.2	206	335	6.80
31	W31	6.27	201.4	188	295	7.09
32	W32	6.79	167.26	184	300	7.39
33	W33	8.01	172.23	240	425	11.94
34	W34	8.4	181.05	280	65	13.31
35	W35	7.43	176.13	190	75	9.16
36	W36	6.92	155.47	260	180	9.76
37	W37	6.44	169.25	320	275	10.94
38	W38	7.89	163.33	202	362	13.31
39	W39	7.19	176.13	182	245	15.97
40	W40	7.46	178.2	432	305	11.83
41	W41	7.39	176.13	298	300	14.97
42	W42	7.38	152.3	252	310	15.97
43	W43	8.65	167.26	214	180	7.69
44	W44	7.36	170.22	494	45	8.57
45	W45	7.46	161.4	380	65	9.16
46	W46	7.5	137.81	212	125	8.87
47	W47	6.97	159.47	362	275	5.02
48	W48	6.48	165.33	338	135	9.46
49	W49	7.11	155.47	208	285	8.57
50	W50	7.03	151.94	184	75	10.94
51	W51	6.77	162.42	384	215	14.79
52	W52	7.16	176.13	392	285	15.97
53	W53	7.16	170.22	420	225	15.38
54	W54	6.83	167.29	444	245	9.46
55	W55	7.21	169.25	412	245	9.76
56	W56	7.24	169.28	436	295	10.94
57	W57	7.85	154.53	442	260	9.16
58	W58	7.22	164.38	406	295	7.09
59	W59	7.41	181.05	370	305	8.57
60	W60	7.78	172.23	330	275	8.87
61	W61	8.13	173.21	382	135	9.16

Trace metals exist in colloidal, particulate and dissolved phases in water [25]. Selected water samples were analyzed for quantification of trace amount and presence of 22 metals had been observed. The detailed of the concentration of the different metals is mentioned as discussed here with Li (0.2 µg/L – 14.1 µg/L); V (0.2 µg/L – 11.5 µg/L); Co (0.01 µg/L – 1.0 µg/L); Be (0.05 µg/L – 0.1 µg/L); Cr (0.067 µg/L – 1.236 µg/L); Ni (0.091 µg/L – 4.773 µg/L); As (0.086 µg/L – 9.47 µg/L); Al (3.571 µg/L – 18.732 µg/L); Fe (8.845 µg/L – 22.068 µg/L); Cu (0.059 µg/L – 20.504 µg/L); Se (0.334 µg/L – 3.788 µg/L); Ba (311.17 µg/L – 16.590 µg/L). The concentration of other few trace metals in the water sample ranges was as follows Ga (1.788 µg/l – 28.123 µg/l), Rb (0.434 µg/l - 18.913µg/l), Cs (0.014µg/l) was observed in W7 sample, Sr (24.746 µg/l – 913.24 µg/l) and Ti was W18 (0.024µg/l), W19 (0.040 µg/l), W24 (0.02 µg/l), W25 (0.04µg/l), W28 (0.026 µg/l), W29

(0.01µg/l), W30 (0.01 µg/l) & W7(0.085 µg/l). The trace metal order was as follows: Zn> Mn> Sr> Ba> V> Ga> Fe> Cu> Rb> Al> Li> As> Ni> Se> Cr> Pb> Co> As> Be> Cd & Ti> Cs. All the water sample had complied with the permissible limits of metals as per BIS 10500: 2012 [26,27] (Table 3 & Figure 3).

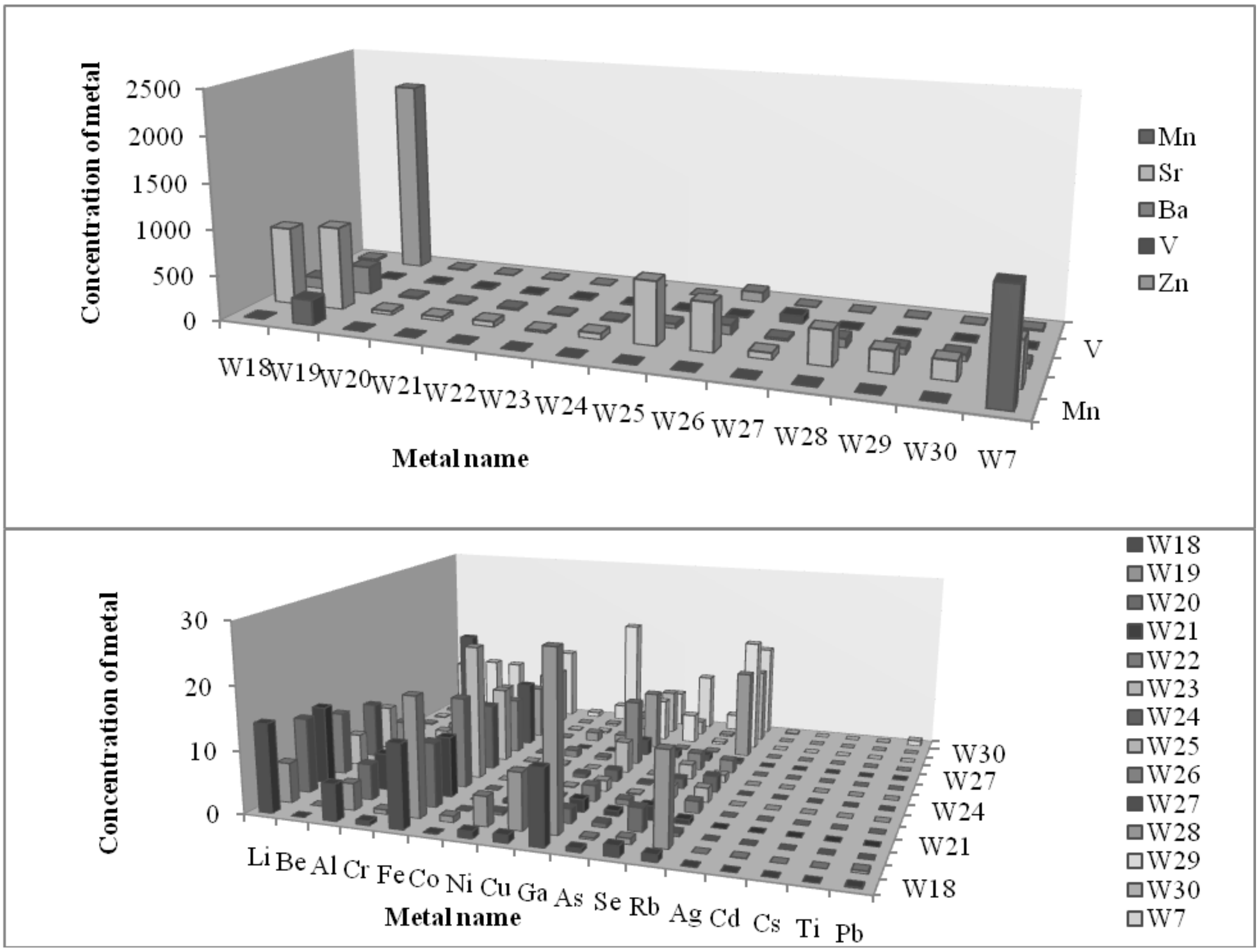


Figure 3: Concentration of trace metals in selected groundwater samples of industrial areas of Visakhapatnam.

Distribution of concentration of mercury

The mercury was analyzed in three forms – Total mercury (THg), Dissolved mercury (DHg) and organic mercury (OHg). The most existing and available form in environment is the elemental state [28].Due to biotic factor and the oxidation- reduction reaction, the inorganic form is converted to organic form [15]. To quantify the amount of Hg present, the groundwater samples were analyzed by CVAAS. The concentration of THg was observed in the range 0.76 ng/L – 3.54 ng/L. The maximum THg value was found in the water sample of W33 (3.54 ng/L) sample and the minimum THg value was found 0.76ng/L in W20& W24 sample. The average value was found to be 1.71ng/L. Kowalski et al.,2007 [29] investigated THg from groundwater in industrial area of Poznań, Poland and reported that the THg ranged from 0.8ng/L - 4.0ng/L, with average of 1.3 ± 0.7 ng/L. Tang et al.,2003 [30] evaluated THg in groundwater of Shanghai, China and reported that the THg concentration in the water sample from 0.04µg/L to 0.09µg/L. The concentration of OHg was found in the range 0.13 ng/L – 1.03ng/L.

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Table 3: Concentration of trace metals in selected groundwater samples reported by ICP-MS relating with WHO (2011) and BIS (2012) guidelines.

Sl. no .	Elements name	W18 (µg/l)	W19 (µg/l)	W20 (µg/l)	W21 (µg/l)	W22 (µg/l)	W23 (µg/l)	W24 (µg/l)	W25 (µg/l)	W26 (µg/l)	W27 (µg/l)	W28 (µg/l)	W29 (µg/l)	W30 (µg/l)	W7 (µg/l)	WHO guidelines (µg/l	BIS guidelines (µg/l)
1	Li	14.1	6.4	12.1	12.6	10.2	5.1	9.1	7.2	3.1	2.9	0.2	0.2	0.3	8.3	-	-
2	V	9.3	2.1	10.3	10.6	6.8	11.5	9.7	10.5	7.6	85.7	0.2	6.1	4.1	1.8	-	200
3	Co	0.09	1.0	0.05	0.06	0.01	0.02	0.02	0.1	0.1	0.03	0.1	0.1	0.08	0.7	80	-
4	Ga	11.9	28.1	2.3	2.0	2.6	1.7	1.9	5.1	10.7	2.6	9.6	7.0	7.3	5.9	-	-
5	Rb	1.1	14.7	0.6	0.7	1.9	2.3	2.6	1.2	2.2	0.4	14.5	18.9	12.4	15.6	-	-
6	Cs	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-
7	Be	-	-	-	0.05	0.05	-	0.05	0.05	0.05	0.05	0.05	0.1	0.1	0.1	12	-
8	Cr	0.7	0.7	0.5	0.6	0.06	0.07	0.5	0.6	0.2	0.3	0.4	0.6	1.2	0.9	50	50
9	Ni	1.1	4.7	0.5	0.5	0.7	0.05	0.8	0.2	1.1	0.09	1.5	0.3	0.3	2.6	70	20
10	As	0.6	0.3	0.7	0.8	0.9	0.1	0.2	0.08	0.1	1.2	0.1	4.8	2.2	9.4	10	10
11	Ag	0.04	0.004	-	-	-	-	0.002	-	-	-	-	-	-	0.2	-	-
12	Ti	0.02	0.04	-	-	-	-	0.002	0.004	-	-	0.02	0.01	0.001	0.08	-	-
13	Al	5.8	4.3	5.8	5.9	5.2	3.6	3.5	4.0	3.9	18.7	3.9	11.8	5.6	9.0	90	30
14	Fe	13.2	19.1	10.3	9.7	14.7	22.0	10.8	12.3	9.1	10.7	8.8	10.0	9.6	12.2	-	300
15	Cu	1.2	9.0	0.5	0.3	0.1	0.1	0.7	-	0.5	0.05	1.5	20.5	1.9	1.5	2000	50
16	Se	1.7	0.9	3.7	2.3	0.9	2.0	1.6	2.4	2.8	1.0	0.1	0.4	0.3	2.6	40	10
17	Cd	-	0.1	0.01	-	-	-	-	-	0.08	-	-	-	0.007	-	3	3
18	Pb	0.1	0.4	-	-	-	-	0.03	-	-	0.08	-	-	-	0.9	10	50
19	Sr	852.7	913.2	42.1	43.6	59.7	24.7	66.7	690.7	531.0	73.4	378.4	236.7	210.0	498.0	-	-
20	Zn	24.6	2150.3	14.0	8.9	10.4	5.9	5.0	4.3	111.5	6.5	4.5	7.5	6.0	19.3	3000	15000
21	Mn	3.6	280.5	5.2	-	-	-	-	-	5.0	-	6.8	1.3	-	1206.5	-	100
22	Ba	123.2	311.1	22.5	18.6	22.4	16.5	19.2	52.7	106.0	25.6	98.0	68.4	72.4	57.6	700	700

The maximum OHg value was found in W46 & W33 (1.03ng/L) sample and the minimum OHg value was found at 0.13ng/L (W41). The average value was found to be 0.39ng/L. Karunasagar et al.,2006 [31] determined Hg pollution in Kodai Lake, which suffered Hg contamination due to emissions and waste from thermometer factory. The concentration of THg was 356 ng/L–465 ng/L and 50 ng/L of Hg in OHg (in MeHg form) were found in the Kodai waters. In our studies, the concentration of DHg range was found to be 0.02ng/L – 2.35ng/L, the maximum value was at W32 (2.35ng/L) and the minimum value was found to be 0.02ng/L (W11 & W12). The average value was found to be 1.13ng/L. Li et al.,2008 [32] determined THg and DHg in the water as 95 to 278 ng/L and 87 to 117 ng/L, respectivity in Zinc smeltering area of Guizhou, China

Table 4: Concentration of mercury in different forms analyzed in groundwater samples

	Sample Code	Total mercury (ng/L)	Dissolved mercury (ng/L)	Organic mercury (ng/L)
1	W1	2.08	1.52	0.54
2	W2	1.87	1.26	0.56
3	W3	1.69	1.16	0.51
4	W4	1.64	1.1	0.48
5	W5	2.03	1.56	0.46
6	W6	1.59	1.2	0.38
7	W7	2.18	0.36	0.36
8	W8	2.08	0.24	0.24
9	W9	1.9	0.26	0.26
10	W10	1.9	0.33	0.33
11	W11	1.08	0.02	0.02
12	W12	1.25	0.02	0.41
13	W13	1.84	1.32	0.41
14	W14	0.81	0.52	0.26
15	W15	1.15	0.86	0.26
16	W16	1.69	1.2	0.37
17	W17	1.69	1.18	0.34
18	W18	1.3	0.76	0.38
19	W19	1.15	0.56	0.31
20	W20	0.76	1.52	0.18
21	W21	1.64	1.04	0.67
22	W22	1.35	1.69	0.26
23	W23	1.9	0.56	0.23
24	W24	0.76	1.52	0.18
25	W25	2.08	1.28	0.38
26	W26	1.76	1.09	0.38
27	W27	1.61	1.09	0.52
28	W28	1.3	1.04	0.18
29	W29	1.35	0.81	0.26
30	W30	1.25	1.09	0.41
31	W31	1.35	0.96	0.18
32	W32	1.74	2.35	0.57
33	W33	3.54	1.25	1.03
34	W34	2.08	0.64	0.72
35	W35	0.98	0.52	0.32
36	W36	0.82	1.28	0.33
37	W37	1.76	1.62	0.38
38	W38	2.13	1.48	0.38
39	W39	2.23	1.65	0.53
40	W40	2.18	1.68	0.38
41	W41	2.08	1.48	0.13
42	W42	2.23	1.52	0.58

43	W43	1.54	1.18	0.31
44	W44	1.3	0.82	0.38
45	W45	1.25	0.81	0.41
46	W46	3.54	2.35	1.03
47	W47	1.2	0.8	0.34
48	W48	1.64	1.19	0.35
49	W49	1.69	1.25	0.27
50	W50	2.23	1.48	0.58
51	W51	1.9	1.69	0.23
52	W52	1.35	1.04	0.26
53	W53	1.74	0.96	0.57
54	W54	1.79	0.92	0.67
55	W55	2.61	1.54	0.7
56	W56	1.64	1.35	0.2
57	W57	1.76	1.28	0.38
58	W58	2.03	1.25	0.72
59	W59	2.08	1.89	0.13
60	W60	2.18	1.65	0.38
61	W61	1.35	1.09	0.18

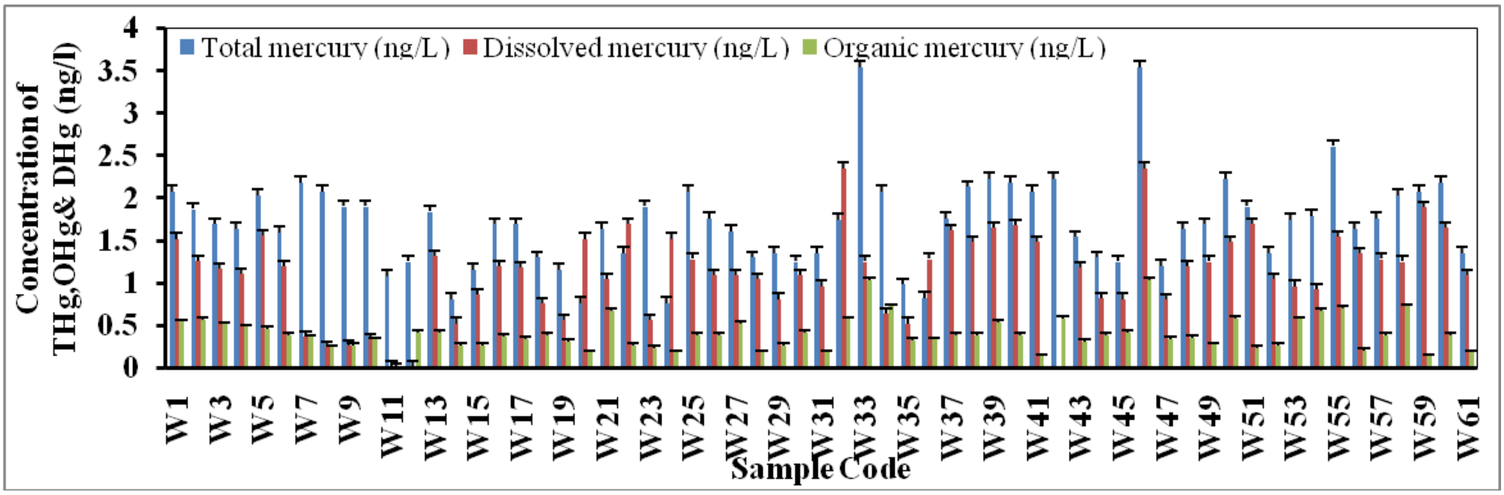

Figure 4: Concentration of THg, OHg & DHg in ground water samples presented in bar graph.

CONCLUSION

All the groundwater samples analyzed for the selected physico-chemical parameters, trace metals and mercury conformed to the permissible limits prescribed by the guidelines of WHO and BIS (10500:2012) for drinking water samples. The order of concentration of trace metals in the samples analyzed was as follows Zn> Mn> Sr> Ba> V> Ga> Fe> Cu> Rb> Al> Li> As> Ni> Se> Cr> Pb> Co> As> Be> Cd & Ti> Cs. All the metals analyzed were observed to be with in the permissible limit given by WHO and BIS.

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