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Quantification of Ground Water Pollutants in Semi-Arid Region of Zahirabad, Telangana State India.

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Abstract

The major issue in today world is the ground water pollution and due to increase in the industrialization at the same rate, the ground water pollution is increased. The primary objective this study is to determine the ground water pollution in terms of heavy metals(toxic elements) using Heavy metal pollution Index (HPI) method and Contamination Index (CI) method is used to calculate degree of contamination and this study is carried to know the groundwater is suitable for domestic purposes. An Atomic Absorption Spectrometer (AAS) was used to calculate the quantity of seven heavy metals are present in the ground water and these are Arsenic, Cadmium, Copper, Iron, Manganese Lead and Zinc. The present study area is near Zahirabad Mandal, Sangareddy District, Telangana state, India. In the study area, total thirty nine (39) groundwater samples were collected and analyzed and the individual heavy metals concentration showed in each spatial distribution maps to find out the anomaly and extent of distribution of heavy metals and also demarcate the pollutant to non-pollutant of the basin and delineate the sources. These data were analyzed and used to generate the Heavy metal Pollution Index (HPI), Heavy metal Evaluation Index (HEI), and Contamination Index (CI). For both Pre- and Post-Monsoon seasons, the areas mean HPI value ranges between 422 and 345, the mean HPI value is greater than the critical pollution index value 100, and the mean value of HEI is between 3.4 and 3.1. The testing of HPI, HEI and CI evaluate a region based contamination levels such as low, medium, and high. Many agencies have unique water quality standards (WHO, 2012) that consider various factors in groundwater quality valuation and pollution management. Several pollution index approaches were used for each region. Over all, the scenario of anomaly evolution of the basin indicates that the basin slightly affected by the anthropogenic and geogenic influence. The major area of the basin is unaffected by the anthropogenic and geogenic influence, expect few locations.

Keywords: Heavy metals, Spatial Distribution maps, Contamination Degree (CD), HPI and HEI.

Introduction

Urbanization and the continuous growth of the global population have resulted in the acute scarcity of Water resources in many parts of the world, leading to a huge increase in potable water demand. As a result, groundwater has emerged as a major source of drinking water because water pollution decreases water quality and its influence on public health, economic growth, and social wealth. The term heavy metals have been widely used, it is often used as a group name for metals that have been associated with contamination and potential toxicity or eco-toxicity (Duffs, 2002). The heavy metals are based upon the density of the elements from the metal, and classifies those heavy metals as those metals with elemental densities above 7 g/cm3. However, the compounds have highly toxic or eco-toxic properties. This usage implies that the pure metal and all its compounds have the same physicochemical, biological and toxicological (Sakram et al., 2022a) properties.

Contamination of groundwater is a serious environmental issue these days due to numerous pollutants (Pathogens, Organic materials, inorganic compounds and macroscopic pollutants). Groundwater quality is being degraded due to over-exploitation and untreated waste-water discharge. Heavy metals enter into groundwater through both natural (geogenic) and anthropogenic (Sakram et al., 2022b) causes. These heavy metals create an alarming situation when entering groundwater due to their extreme toxicity, even in low quantities. Minerals, geological formations and soils present in natural ecosystems produce low-concentration metals.

The varied heavy metal contamination produced by anthropogenic activity such as mining, dumping of unprocessed (untreated effluents) and partially treated effluents and metals of various industries, and the widespread utilization of fertilizer and (Sakram et al.,2022a) pesticides. Metals like Copper and Zinc are necessary micronutrients for animals and plants to metabolism, but metals like Cadmium and Lead have no known physiological action (Kar et al., 2008; Suthar and Singh et al., 2008; Aktar et al., 2010, Ostad Ali-Askari Kaveh et al., 2017). Arsenic is a toxic metal that contaminates water and aggravates the situation. Metals cumulate in the human body because they are non-degradable, causing harm to the brain and internal organs. (Lee et al., 2007; Lohani et al., 2008). Selenium (Se) supplementation efficiently facilitated the phytoextraction of combined Cu-Cd-Cr contaminated soil, and B.proteolyticus SES inoculation shoed the synergistical enhancement effect in the presence of Se (Min Nie, 2023). Heavy metal contamination in soil has become a global key ecological environmental problem, due to anthropogenic activities associated with agriculture, industry and mining (Chaoua et al., 2019; Hu et al., 2014a). Heavy metals are a great threat to human health and ecological environment because of their toxic and non-biodegradable properties (Sun et al., 2020). Copper (Cu), Cadmium (Cd) and Chromium (Cr) are the three common heavy metals with potential risk in soil (Wang et al., 2019; Xia et al., 2019).

As a result, the vast majority of the population relies on groundwater as their primary source of drinking water (Riemann and Banks et al., 2004, Ostad Ali-Askari Kaveh et al., 2021). Water quality indicators are among the most effective tools for determining the nature of water. The HPI is a technique in that proportion is combined with the influences of individual heavy metals on the overall quality of water. It is useful in evaluating the combined influence of all metals on total pollution. The HEI gives rise to the overall water quality in terms of heavy metals, comparable to

HPI (Edet and Offiong et al., 2002), and it is used for easy understanding of pollution levels (Ostad Ali-Askari Kaveh et al., 2019, Prasanna et al., 2012). The contamination index for this method quantifies quality by estimating the degree of pollution.

In terms of metal contamination, the suitability of groundwater for human consumption is calculated by using HPI and HEI, which are powerful tools for ranking the integrated effect of different toxic metals pollution on the total quality of water (Reza et al., 2010) and also the possible preservative effect of toxic metals on human health that aid in assessing the quality of portable water. There is a need to monitor the quality of water regularly to see if heavy metal concentrations in water are increasing and causing harm to human health on life. Furthermore, there are numerous methodologies in the literature for generating and utilizing pollution index methods to assess water quality. Several studies, however, have been done and discovered heavy metal contamination in groundwater (Muhammad et al., 2010). In the present study determines the concentration of heavy metals in subsurface water. The heavy metal pollution index (HPI), heavy metal evaluation index (HEI) and Contamination Degree (CD) tools are used to assess the level of pollution index also to portray the geographical distribution of heavy metal concentration.

Material and Methods

Study Area

The present study area situated around Zahirabad Mandal, Sangareddy District and Telangana State and the extent of area is bounded by the coordinates E77° 25'-E77° 55' and N17° 28' -N17° 55' (See Fig.1). Geologically the study area covered by Basalts with Intertrappean of Cretaceous age and Laterite rocks of Cenozoic (Fig. 2). The Subsurface water is available in an underwater-table and under semiconfined conditions.

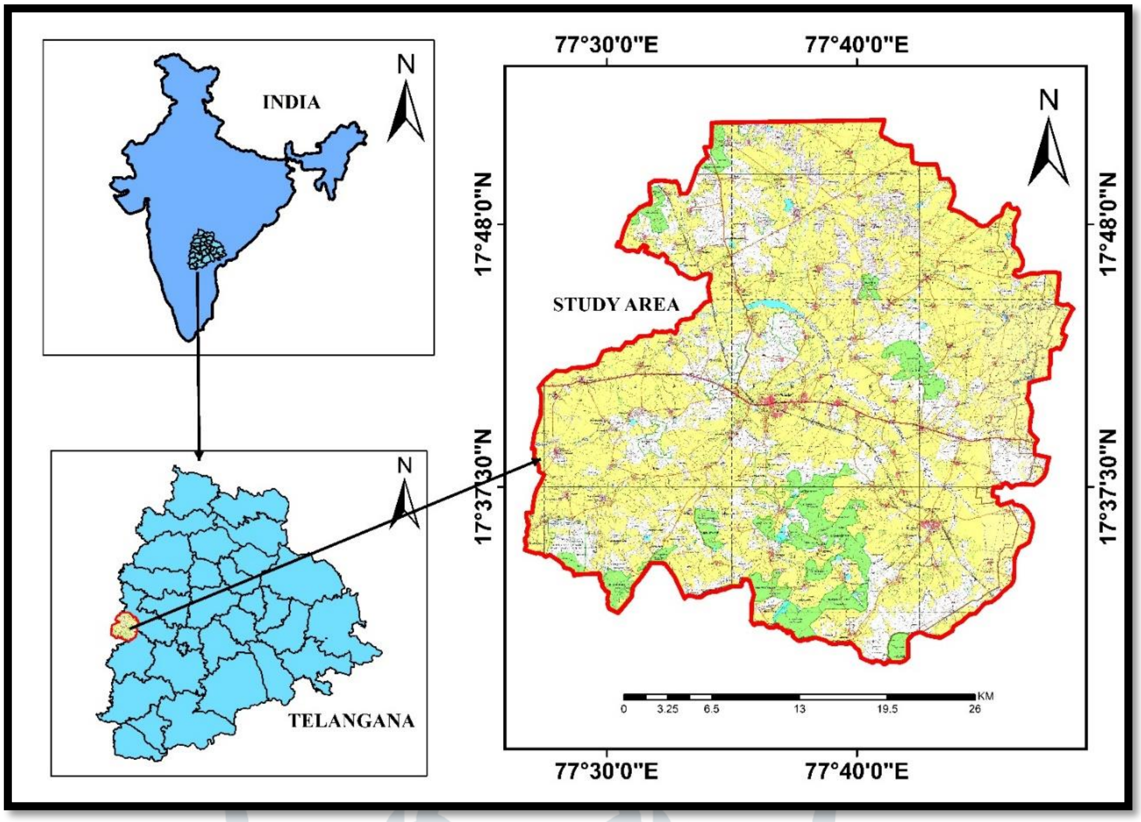

Fig 1. Location map of the study area

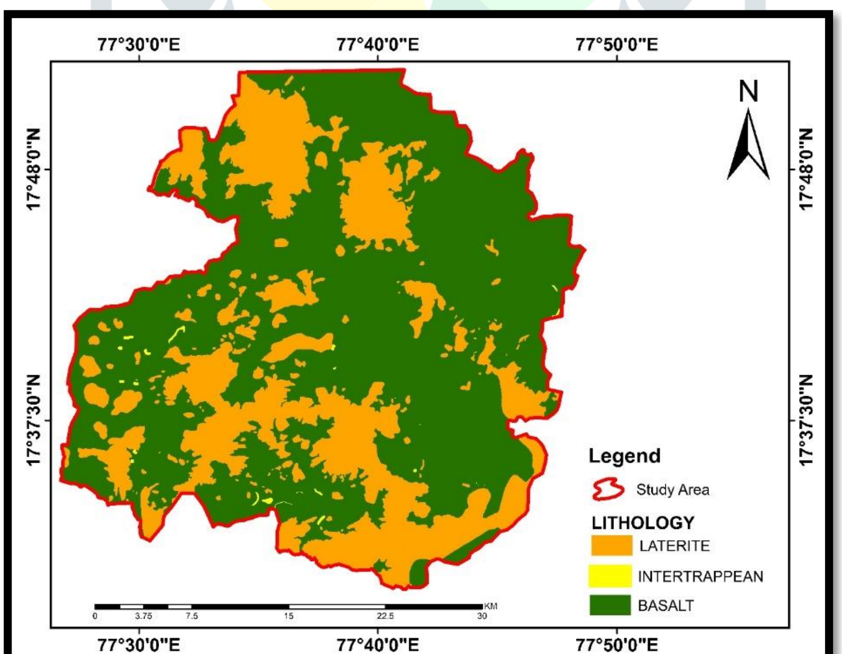

Fig 2. Geology map of the study area

Sampling

To analyze the pollutant concentration, total thirty nine (39) ground water samples collected from the bore wells (Fig. 3), which cleaned and rinsed with acetone. These samples are taken into the 1 liter polythene bottles and added l ml of nitric acid to it. The water samples collected after pumping out water for about 5 min to remove stagnant water from the wells and different locations, standard methods of grid pattern of the study area for both pre-monsoon (May-June) and post-monsoon (October-November) analysis was carried out (APHA, 1995). The methods of collections of samples play an important role in maintaining high degree of accuracy of analytical data. Were drawn from the agricultural zones. In site measurements, physical parameters such as Potential Hydrogen (pH), specific Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were made. Samples were collected using standard procedures and Methods, as described by Gale and robins (1989).

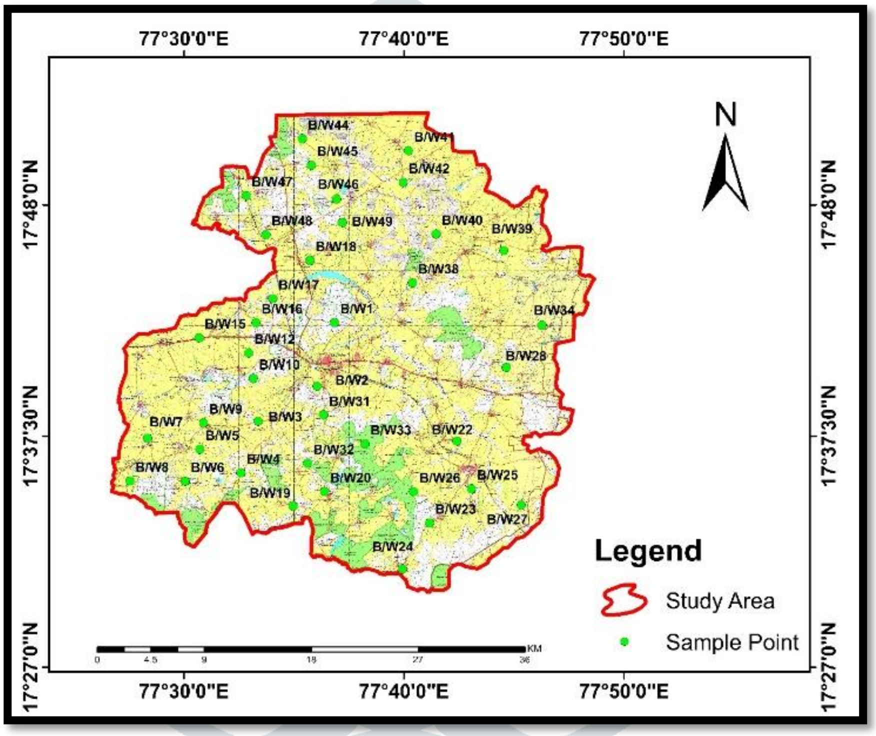

Fig 3. Sample location map of the study area.

Methodology

The heavy metal pollution index (HPI), Heavy metal evaluation index (HEI), and contamination Degree (CD) are used to determine the appropriateness of drinking water by comparing heavy metal concentrations to WHO Standards 2011. The HPI and HEI readings provide an overall picture of heavy metal content in water and CD has the combined effect of several harmful quality attributes in potable water. These three indexes are extremely helpful in identifying and quantifying trends in water quality.

Heavy Metals

Arsenic (As)

Drinking water can be contaminated by arsenical insecticides, natural mineral deposits, or incorrect disposal of arsenic compounds. Heavy metals are causing concern for the eco-system and individual health aspects (Hughes et al., 1988). The pre-and post-monsoon concentration of arsenic geographical distribution maps are prepared (Fig. 4a & 4b). Areas of excessive concentration of arsenic are shown. Desirable limits of Arsenic concentration as per WHO standards is 10 ppb. In the pre monsoon period total 75% of the samples under desirable limits and remaining 25% of the samples are above WHO standard limits and in the post monsoon period the results are same as above.

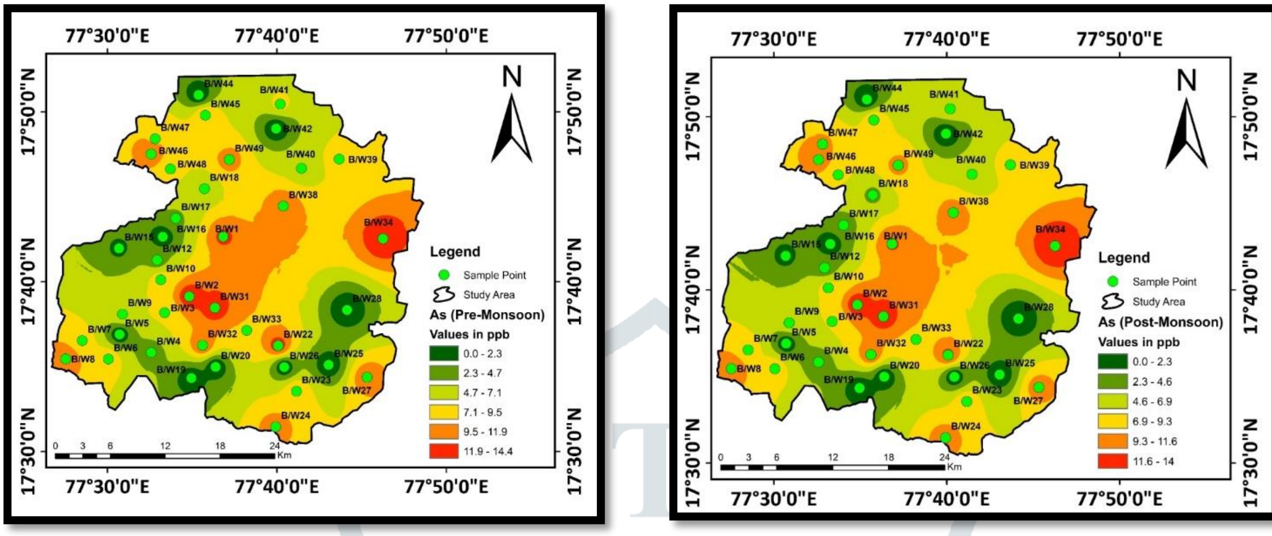

Fig 4a & 4b. Arsenic spatial distribution maps for both pre and post-monsoon

Cadmium (Cd)

Cadmium discharged into the environment through wastewater, while fertilizer contamination causes diffuse pollution. In addition, galvanized pipes and solders can contaminate potable water. Geographical distribution maps are prepared for both seasons (Fig. 5a & 5b). In both seasons, 92.4 percent of the Cd samples found to be above the permitted limit. Areas of excessive concentration of Cadmium were identified. Widespread distribution of Cadmium in the environment by this atmospheric emission, waste-water reuse or agricultural activities can serve as diffuse sources (ATSDR, 2012; Knappe et al., 2008; Schuetze et al., 2003; Sprynskyy et al., 2011; UNEP, 2010). Desirable limits of Cadmium concentration as per WHO 2011 standards is 3 ppb. In the pre monsoon period total 92.4% of the samples above desirable limits and remaing 7.6% of the sample are below and in the post monsoon period the results are same as above.

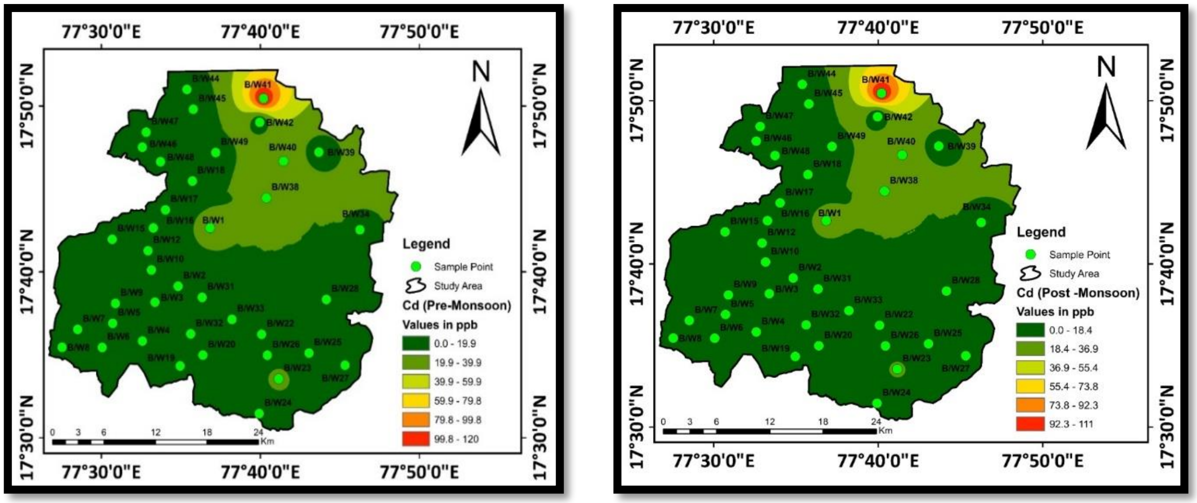

Fig 5a & 5b. Cadmium spatial distribution maps for both pre-and post-monsoon.

Copper (Cu)

Like brass and bronze medals, copper is a malleable metallic element frequently used as a good electrical conductor Steel, plastic, and blast furnace sectors contribute to Cu build-up in water. Cu is mostly found in agrochemicals and garbage dumps (G Sakram et.al. 2019). Cu concentrations in drinking water are normally modest, but they can be elevated by copper plumbing and extended water stagnation in pipes. Geographical distribution maps are prepared for both seasons (Fig. 6a & 6b). Areas of excessive concentration of copper are identified. In the pre monsoon and post monsoon period, 100% samples are under desirable limits as per WHO standard limit (<2000).

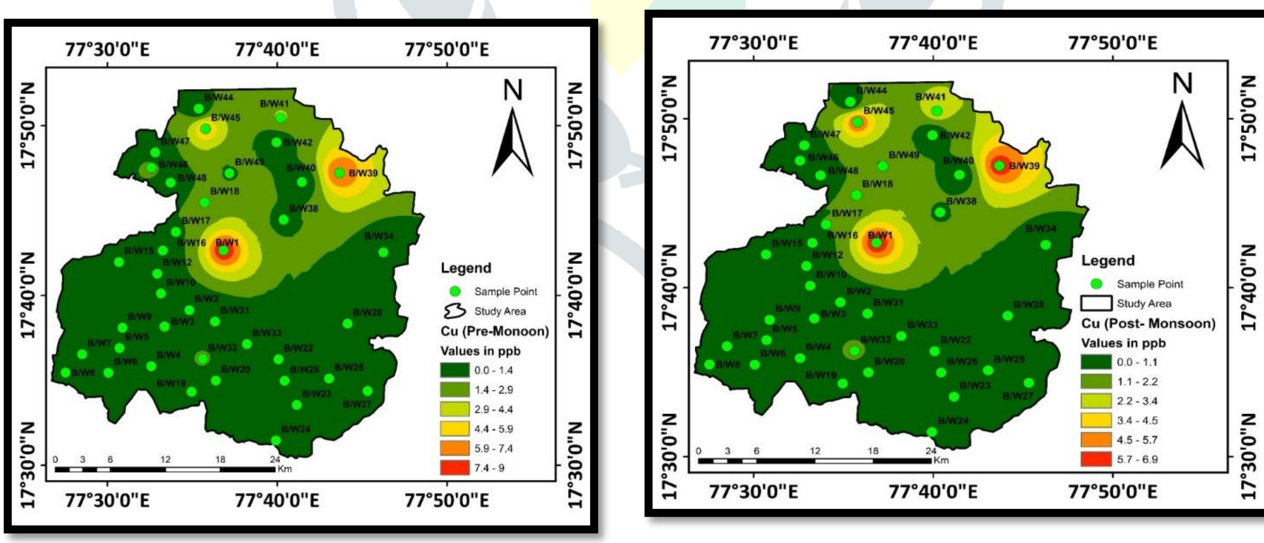

Fig 6a & 6b. Copper spatial distribution maps for both pre-and post-monsoon

Iron (Fe)

Iron is essential for the development and survival of all living things (Valko et al., 2005). Dissolved iron concentrations in fresh water are very low, with a detection level of 5 mg/L, whereas they are quite high in groundwater, with a concentration of 20 mg/L. Geographical distribution maps are prepared for pre-and post-monsoon (Fig. 7a &

7b). Areas of excessive concentration of iron are identified. In the pre monsoon and post monsoon period, 100% samples are under desirable limits as per WHO standard limit (<1000).

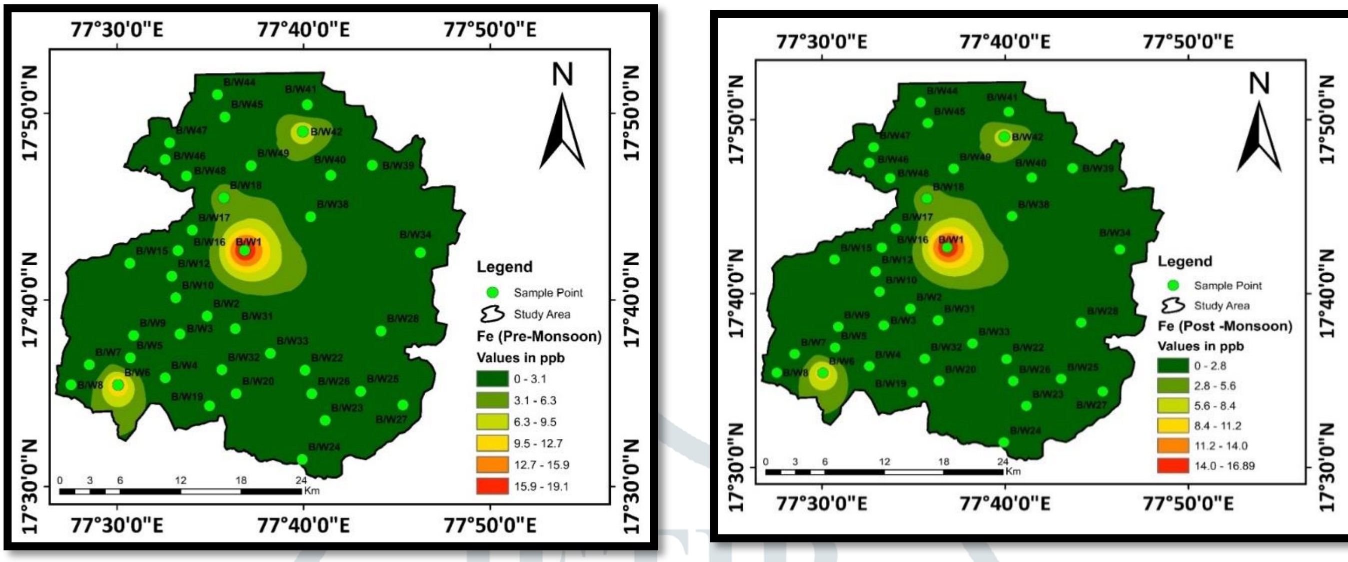

Fig 7a & 7b. Iron spatial distribution maps for both pre-and post-monsoon.

Lead (Pb)

Lead is emitted as a by-product of vehicle exhaust, Industrial effluents and lead pipe corrosion (Machender G et al., 2014, Gowd and Govil et al., 2008). It is commonly found in portable water through lead pipes, faucets, and. Pipes that transfer drinking water from a water source to a residence and residential plumbing systems containing pipes, solder, and fitting may contain lead. Geographical distribution maps are prepared for pre-and post-monsoon (Fig. 8a & 8b). Areas of excessive concentration of lead are identified. In the pre monsoon and post monsoon period, 100% samples are under desirable limits as per WHO standard limit(<10).

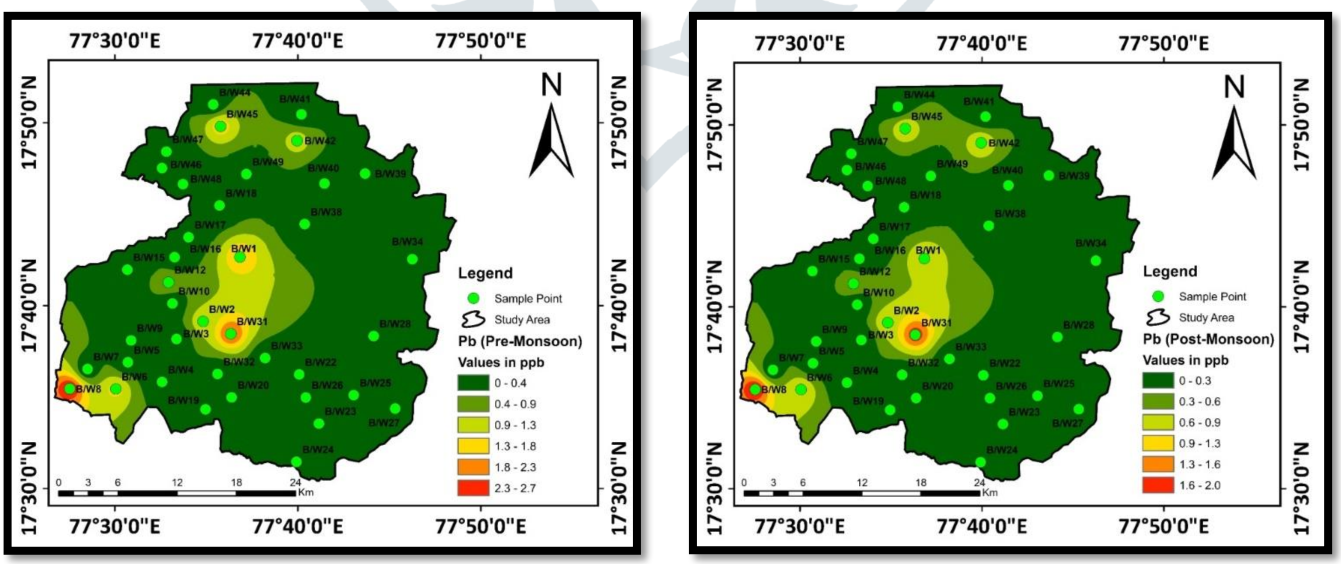

Fig 8a & 8b. Lead spatial distribution maps for both pre-and post-monsoon.

Zinc (Zn)

Zinc is a trace element found in salts or chemical complexes in food and water. Nevertheless, the usage of zinc pipes raises the amounts in tap water. Zinc levels in drinking water beyond 3 mg/L, on the other hand, may not be acceptable to consumers. Geographical distribution maps are constructed for both seasons (Fig. 9a & 9b). Areas of excessive concentration of Zinc are identified (G Sakram et.al., 2014). In the pre monsoon and post monsoon period, 100% samples are under desirable limits as per WHO standard limit(<3000-5000).

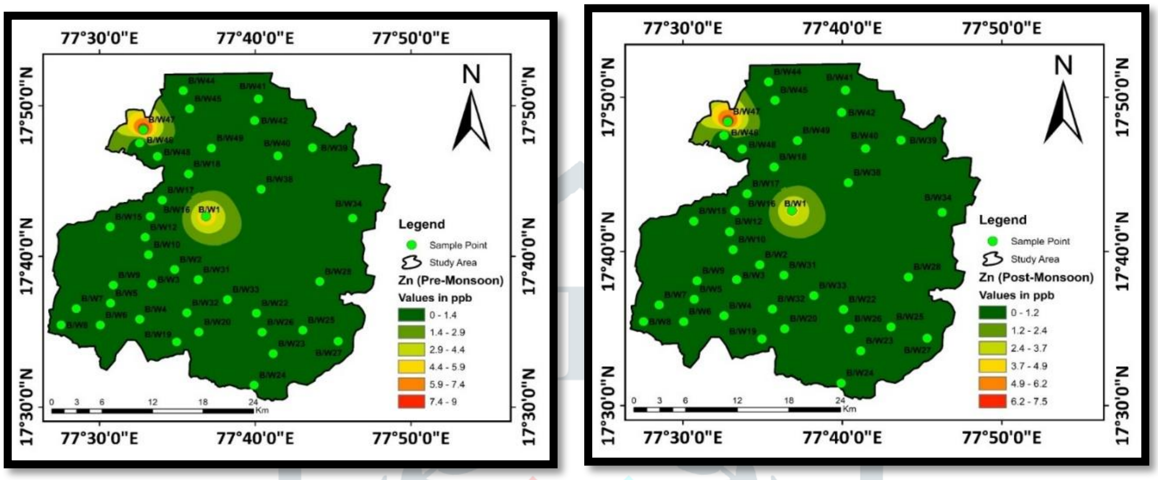

Fig 9a & 9b. Zinc spatial distribution maps for both pre-and post-monsoon

Heavy Metal Pollution Index (HPI)

The heavy metal contamination index is used to evaluate the water purity (quality) and suitability for human consumption. HPI is a method for determining heavy metal content. It is divided into two parts and is based on the weighted arithmetic quality mean method. In step one, a rating with weightage is recognized for each selected parameter, and in step two, the pollutants on which the index is dependent are picked.

The rating method measures as an assignment of arbitrary values between 0 and 1 depending on the importance of each parameter's contribution to overall quality; it is evaluated by assigning values that are inversely proportional to the recommended level of relevant pollutant. A unit weight (Wi) is defined as a value that is inversely proportional to the suggested standard (Si) of the relevant parameter in line with India's drinking water regulations for this evaluation (BIS, 2012). The HPI model can be determined by the following equation (1).

$$\boldsymbol{HPI} = \frac{\sum_{i=1}^{n}(wi * Qi)}{\sum_{i=1}^{n} wi}$$

Where Wi is the i^{th} parameter's unit weight, n is the number of parameters evaluated for the model, and Qi is the parameter's sub-index as calculated by Eq (2).

$$\boldsymbol{Qi} = \sum_{i=1}^{n} \frac{(Mi - Ii)}{(Si - Ii)} * 100$$

Where,

Mi is the monitored heavy metal value for the i^{th} Parameter (i.e., analytical data),

It is the ideal value for the i^{th} parameter and

Si is the expected value for the i^{th} parameter.

In this equation, the (-) sign represents a numerical difference between values and has no algebraic (sign) significance. The HPI model employed for the study is designed to assess the appropriateness of drinking water, with the critical pollution index of the HPI value set at 100.

Heavy metal Evaluation Index (HEI)

The HEI measures the total water quality in terms of toxic metals, similar to HPI, and the same is utilized to understand pollution levels. It is calculated by:

$$\boldsymbol{HEI} = \sum_{i=1}^{n} \frac{Mi}{Si}$$

Where, Mi and Si denote the i^{th} parameters monitored, and standard permitted concentrations,

Contamination Index (CI)

This method uses a degree of contamination (CD) to calculate water quality (CI). It is calculated as follows.

$$\boldsymbol{CD} = \sum_{i=1}^{n} Cfi$$

Where,

$$\boldsymbol{Cfi} = \frac{CAi}{CNi} - 1$$

The contamination factor (CF) (Machender G et al., 2011), analytical value, and maximum allowed concentration of the i^{th} component are denoted by Cfi, CAi, and CNi. N represents the "normative value'. Whereas CNi represents the Standard Permissible Concentration (SPC). Parameters with analytical values less than the SPC are not considered.

Results and Discussion

The pollution indicators such as HPI, HEI and CD were estimated using WHO standards 2011. The metals such as Arsenic, Cadmium, Cobalt, Iron, Manganese, Lead and Zinc parameters are shown in Tables 1 and 2, reflecting the World Health Organization's (WHO, 2011) recommended values and the MCL (Maximum Concentration Limit). In the present study the 12 samples out of 39 samples showed the Arsenic concentration is greater than WHO standard limit i.e.10 ppb in pre -monsoon and post- monsoon period and Cadmium, which has 92.4 per cent samples in both seasons, all pre-and post-monsoon metals values are greater than permissible levels. The reason is the use of phosphate fertilizers, which contain Cadmium as an impurity, is the cause of elevated cadmium concentrations in subsurface water.

The pre-monsoon HPI ranges from -381.73 to 5415.91, with a mean of 422.47, and the post-monsoon HPI ranges from -383.33 to 4980.08 with an average of 345.72. Pre-monsoon period HPI data values are greater than post-monsoon period. Samples indices (52 percent pre-monsoon and 62 percent post-monsoon) are less than the World Health Organization's critical guidelines of 100 for potable water.

The Pre-monsoon ranges from 0.07 to 24.16, with an average of 3.45, and post-monsoon values range from 0.06 to 22.3, with a mean of 3.13. Based on HEI, for both Seasons, 87 per cent of the samples collected for HEI analysis had the threshold value of 1 (HEI >1) and were ruled unfit for domestic use.

Metal pollution is estimated using the contamination index (CD). The measurements in the Pre-monsoon range from -12.79 to 67.33 with a mean of -1.21 and from -12.82 to 61.3 with a mean of -2.4 in the post-monsoon. CD is divided into three divisions for determining the appropriateness of water samples for drinking water: low (CD=1), medium (1 CD >3), and high (CD>3) (Backman et al., 1997). According to the Contamination Degree, 87.3 percent of pre-monsoon samples have low metal concentrations, 2.5 percent have medium Metal concentrations, and 10.2 percent have high metal concentrations. Metal concentrations in post-monsoon samples range from low to high, with 89.7 percent in the low range and 10.3 percent in the high range.

According to (Machender G et al., 2012, Prasad et al., 2001) levels of heavy metal pollution index, heavy metal evaluation Index, and Contamination Degree that fall below their respective average values and associated negative percent deviations should be regarded for better water quality. Pollution indices are split into three categories, as illustrated in Table3: low (55), medium (55-100), and high (>100). As a result, according to HPI, 51.3 and 46.1 percent of samples are in a low category, 10.3 and 7.8 percent fall into a medium category, and 38.4 and 46.1 percent fall into a high category for the pre-and post-monsoon. According to the heavy metal evaluation Index, 97.4 percent of the samples are in the low category for both seasons, whereas 2.6 percent fall into the high category. Contamination Degree (CD), 89.8 and 89.7 % samples fall in low class, in medium class at 5.1 and 7.7 % and high class at 5.1 and 2.6 % for the pre-and post-monsoon.

Conclusion

The findings of this study area indicate that the metals such as Arsenic, Copper, Iron, Lead, Manganese, and Zinc were found to be within limits for both seasons, except for Cadmium, which is found to be beyond the World Health Organization’s (2011) recommended range for drinking water. It's because of the concentration of various agricultural and human activities and the nearby wells. Creating awareness around the importance and an urgent need to take steps for groundwater prevention pollution will also help in combating the issue. Groundwater is a commodity used by everyone. So the onus to protect it from contaminants and its scarcity for the present & future generations lie on each and every individual on the face of the earth. Each individual can play a role by taking small but effective steps like not wasting water in the house or workplace, using fewer plastics, and proper disposal methods.

Acknowledgment

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Table 1: Pollution Indices and heavy metal analysis for pre-monsoon Season.

Well	As (ppb)	Cd (ppb)	Cu (ppb)	Fe (ppb)	Mn (ppb)	Pb (ppb)	Zn (ppb)	HPI	mean deviation	deviation %	HEI	mean deviation	deviation %	CD	mean deviation	deviation %
B/W1	12.72	34.48	8.99	19.06	7.75	1.89	5.60	1323.28	900.81	213.23	7.32	3.86	1.12	13.54	14.76	-1215.43
B/W2	14.38	10.26	0.00	0.00	0.00	1.27	0.00	139.78	-282.69	-66.91	2.35	-1.11	-0.32	-3.90	-2.69	221.32
B/W3	7.42	10.15	1.74	0.00	1.00	0.00	1.43	116.57	-305.90	-72.41	2.19	-1.27	-0.37	-5.89	-4.68	385.37
B/W4	3.30	11.52	1.32	0.00	0.49	0.00	0.00	172.85	-249.62	-59.09	2.38	-1.08	-0.31	-5.16	-3.95	325.39
B/W5	0.00	7.04	0.00	0.00	0.71	0.00	0.00	-51.57	-474.04	-112.21	1.42	-2.04	-0.59	-8.28	-7.06	581.85
B/W6	9.30	9.62	0.00	13.21	1.01	1.59	0.00	109.84	-312.63	-74.00	2.18	-1.28	-0.37	-3.92	-2.70	222.60
B/W7	8.20	7.95	0.00	0.00	0.53	0.00	0.00	11.91	-410.56	-97.18	1.76	-1.70	-0.49	-7.35	-6.14	505.74
B/W8	12.24	7.56	0.00	0.00	0.44	2.80	0.00	6.31	-416.16	-98.51	1.79	-1.67	-0.48	-3.71	-2.50	205.65
B/W9	7.56	4.01	0.00	0.00	0.58	0.00	0.00	-179.31	-601.78	-142.44	0.96	-2.50	-0.72	-10.00	-8.78	723.54
B/W10	8.72	8.57	0.00	0.00	0.52	0.00	0.00	43.29	-379.18	-89.75	1.89	-1.56	-0.45	-6.92	-5.70	469.80
B/W12	3.39	0.00	1.48	0.00	0.00	0.97	0.00	-381.73	-804.20	-190.36	0.08	-3.38	-0.98	-11.57	-10.36	853.19
B/W15	1.80	6.61	0.00	0.00	0.47	0.00	0.00	-67.82	-490.29	-116.05	1.36	-2.09	-0.61	-8.50	-7.29	600.21
B/W16	0.00	8.52	0.00	0.00	0.66	0.00	0.00	19.61	-402.86	-95.36	1.71	-1.75	-0.51	-7.30	-6.08	501.02
B/W17	4.48	0.00	1.36	0.00	0.66	0.00	0.00	-380.32	-802.79	-190.02	0.10	-3.36	-0.97	-12.79	-11.58	953.63
B/W18	4.97	4.04	1.88	4.20	0.60	0.00	0.00	-180.27	-602.74	-142.67	0.93	-2.53	-0.73	-10.04	-8.83	727.04
B/W19	0.00	8.59	0.00	0.00	0.90	0.00	0.00	23.08	-399.39	-94.54	1.73	-1.73	-0.50	-7.24	-6.02	496.23
B/W20	0.00	10.96	0.00	0.00	0.52	0.00	0.00	137.77	-284.70	-67.39	2.20	-1.26	-0.36	-5.67	-4.46	367.06
B/W22	13.77	9.01	0.00	0.00	0.51	0.00	0.00	76.90	-345.57	-81.80	2.08	-1.37	-0.40	-6.42	-5.21	428.80
B/W23	9.61	23.17	0.80	0.00	0.69	0.00	0.00	749.78	327.31	77.47	4.83	1.37	0.40	2.86	4.07	-335.28
B/W24	11.06	11.37	0.00	0.00	0.76	0.00	0.00	184.13	-238.34	-56.42	2.50	-0.95	-0.28	-4.95	-3.73	307.38
B/W25	0.00	7.96	0.00	0.00	0.00	0.00	0.00	-7.15	-429.62	-101.69	1.59	-1.87	-0.54	-7.70	-6.48	533.84
B/W26	0.00	18.54	0.00	0.00	0.19	0.00	0.00	503.22	80.75	19.11	3.71	0.25	0.07	-0.64	0.58	-47.63
B/W27	11.68	16.26	0.00	0.00	0.46	0.00	0.00	421.46	-1.01	-0.24	3.49	0.03	0.01	-1.68	-0.46	38.02
B/W28	0.00	9.74	0.00	0.00	0.51	0.00	0.00	78.57	-343.90	-81.40	1.95	-1.51	-0.44	-6.49	-5.27	434.47
B/W31	14.03	7.31	0.00	0.00	0.97	2.48	0.00	-2.34	-424.81	-100.55	1.78	-1.68	-0.49	-4.22	-3.01	247.63
B/W32	12.54	13.15	1.93	0.00	1.41	0.00	0.00	273.45	-149.02	-35.27	2.90	-0.56	-0.16	-3.67	-2.46	202.50

B/W33	9.40	15.46	0.54	0.00	0.83	0.00	0.00	377.32	-45.15	-10.69	3.29	-0.17	-0.05	-2.28	-1.07	88.18
B/W34	14.11	18.58	0.00	0.00	0.52	0.00	0.00	539.26	116.79	27.64	4.00	0.54	0.16	-0.03	1.18	-97.55
B/W38	11.67	32.66	1.04	0.00	0.65	0.00	0.00	1212.81	790.34	187.07	6.77	3.31	0.96	9.27	10.48	-863.20
B/W39	8.01	13.70	7.74	0.00	19.80	0.00	0.00	285.15	-137.32	-32.50	3.11	-0.35	-0.10	-2.74	-1.53	125.77
B/W40	5.40	29.98	0.00	0.00	0.68	0.00	0.00	1068.34	645.87	152.88	6.11	2.65	0.77	7.23	8.44	-695.42
B/W41	7.88	119.95	3.17	0.00	1.18	0.00	0.00	5415.91	4993.44	1181.96	24.16	20.70	5.99	67.34	68.55	-5646.08
B/W42	0.00	8.75	0.00	8.61	0.00	1.21	0.00	40.67	-381.80	-90.37	1.79	-1.67	-0.48	-5.47	-4.26	350.69
B/W44	0.00	12.83	0.00	0.00	0.64	0.00	0.00	228.02	-194.45	-46.03	2.57	-0.88	-0.26	-4.42	-3.20	263.95
B/W45	9.66	8.08	6.06	0.00	0.31	1.66	0.00	24.27	-398.20	-94.25	1.83	-1.62	-0.47	-4.99	-3.77	310.79
B/W46	12.04	8.03	1.99	0.00	0.29	0.00	0.00	25.35	-397.12	-94.00	1.85	-1.61	-0.46	-7.15	-5.94	489.11
B/W47	9.30	0.00	0.00	0.00	0.45	0.00	9.04	-368.34	-790.81	-187.19	0.19	-3.27	-0.94	-12.61	-11.39	938.50
B/W48	7.73	8.23	0.00	0.00	1.99	0.00	0.00	24.00	-398.47	-94.32	1.82	-1.64	-0.47	-7.13	-5.91	487.03
B/W49	10.92	13.22	1.36	0.00	0.52	0.00	0.00	273.06	-149.41	-35.36	2.87	-0.59	-0.17	-3.73	-2.51	207.03
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-381.73			0.07899			-12.792		
Max	14.38	119.95	8.99	19.06	19.80	2.80	9.04	5415.91			24.1624			67.3351		
AVG	7.11	16.48	1.23	1.56	1.71	0.41	0.61	422.47			3.45818			-1.2141		
WHO Standards	10	3	2000	1000		10	3000-5000									

Table 2: Pollution Indices and heavy metal analysis for post-monsoon Season.

well	As (ppb)	Cd (ppb)	Cu (ppb)	Fe (ppb)	Mn (ppb)	Pb (ppb)	Zn (ppb)	HPI	mean deviation	deviation %	HEI	mean deviation	deviation %	CD	mean deviation	deviation %
B/W1	12.05	26.86	6.85	16.85	7.02	1.04	4.22	950.63	604.90	174.97	5.76	2.62	83.80	7.24	9.66	-398.47
B/W2	13.98	9.68	0.00	0.00	0.00	0.98	0.00	110.77	-234.96	-67.96	2.23	-0.91	-28.96	-4.68	-2.26	93.01
B/W3	7.02	9.75	1.18	0.00	0.96	0.00	1.02	96.24	-249.49	-72.17	2.10	-1.03	-32.92	-6.18	-3.75	154.75
B/W4	2.86	10.12	1.05	0.00	0.22	0.00	0.00	104.17	-241.56	-69.87	2.08	-1.05	-33.46	-6.13	-3.70	152.68
B/W5	0.00	6.96	0.00	0.00	0.36	0.00	0.00	-55.35	-401.08	-116.01	1.40	-1.74	-55.45	-8.35	-5.92	244.12
B/W6	8.95	9.12	0.00	10.38	0.86	1.08	0.00	81.53	-264.20	-76.42	2.06	-1.08	-34.33	-4.98	-2.56	105.50
B/W7	8.02	7.02	0.00	0.00	0.36	0.00	0.00	-33.10	-378.83	-109.58	1.57	-1.56	-49.94	-7.98	-5.56	229.24
B/W8	11.96	7.01	0.00	0.00	0.28	2.02	0.00	-21.90	-367.63	-106.34	1.66	-1.47	-46.87	-5.14	-2.72	112.10
B/W9	7.02	3.98	0.00	0.00	0.38	0.00	0.00	-182.21	-527.94	-152.71	0.94	-2.19	-69.99	-10.05	-7.63	314.42
B/W10	8.02	7.12	0.00	0.00	0.41	0.00	0.00	-28.29	-374.02	-108.19	1.59	-1.54	-49.29	-7.92	-5.49	226.41
B/W12	2.89	0.00	1.05	0.00	0.00	0.65	0.00	-383.33	-729.06	-210.88	0.07	-3.07	-97.91	-12.02	-9.59	395.44
B/W15	1.56	6.03	0.00	0.00	0.26	0.00	0.00	-96.44	-442.17	-127.90	1.24	-1.89	-60.42	-8.91	-6.48	267.27
B/W16	0.00	7.56	0.00	0.00	0.48	0.00	0.00	-26.43	-372.16	-107.65	1.52	-1.62	-51.58	-7.94	-5.52	227.43
B/W17	3.85	0.00	1.18	0.00	0.52	0.00	0.00	-381.82	-727.55	-210.45	0.08	-3.05	-97.34	-12.82	-10.40	428.72
B/W18	3.96	3.56	1.32	3.75	0.51	0.00	0.00	-206.14	-551.87	-159.63	0.81	-2.32	-74.14	-10.41	-7.98	329.14
B/W19	0.00	7.48	0.00	0.00	0.76	0.00	0.00	-30.35	-376.08	-108.78	1.50	-1.63	-52.00	-7.98	-5.56	229.16
B/W20	0.00	9.92	0.00	0.00	0.43	0.00	0.00	87.46	-258.27	-74.70	1.99	-1.14	-36.53	-6.37	-3.94	162.64
B/W22	12.65	7.68	0.00	0.00	0.38	0.00	0.00	9.91	-335.82	-97.14	1.79	-1.34	-42.77	-7.36	-4.93	203.43
B/W23	9.02	20.18	0.42	0.00	0.48	0.00	0.00	604.33	258.61	74.80	4.22	1.09	34.77	0.83	3.26	-134.38
B/W24	10.78	9.38	0.00	0.00	0.56	0.00	0.00	87.38	-258.35	-74.73	2.10	-1.04	-33.05	-6.29	-3.87	159.49
B/W25	0.00	6.85	0.00	0.00	0.00	0.00	0.00	-60.57	-406.30	-117.52	1.37	-1.76	-56.26	-8.43	-6.01	247.74
B/W26	0.00	16.58	0.00	0.00	0.02	0.00	0.00	408.93	63.20	18.28	3.32	0.18	5.86	-1.95	0.48	-19.76
B/W27	10.65	16.02	0.00	0.00	0.28	0.00	0.00	407.54	61.81	17.88	3.42	0.29	9.17	-1.88	0.54	-22.36
B/W28	0.00	7.18	0.00	0.00	0.38	0.00	0.00	-44.74	-390.47	-112.94	1.44	-1.69	-54.04	-8.20	-5.77	238.04
B/W31	13.65	7.01	0.00	0.00	0.78	1.85	0.00	-18.12	-363.85	-105.24	1.70	-1.43	-45.69	-5.28	-2.86	117.83

B/W32	12.02	12.58	1.65	0.00	1.02	0.00	0.00	244.84	-100.89	-29.18	2.77	-0.36	-11.63	-4.09	-1.66	68.59
B/W33	9.04	14.98	0.38	0.00	0.68	0.00	0.00	353.41	7.68	2.22	3.18	0.05	1.64	-2.62	-0.20	8.20
B/W34	13.96	16.68	0.00	0.00	0.38	0.00	0.00	447.35	101.62	29.39	3.62	0.49	15.53	-1.31	1.12	-46.12
B/W38	10.62	30.56	0.96	0.00	0.62	0.00	0.00	1109.08	763.36	220.80	6.33	3.20	102.12	7.82	10.25	-422.62
B/W39	7.85	12.68	6.52	0.00	15.68	0.00	0.00	236.56	-109.16	-31.58	2.86	-0.28	-8.82	-3.59	-1.17	48.14
B/W40	5.02	26.98	0.00	0.00	0.38	0.00	0.00	922.79	577.06	166.91	5.50	2.37	75.58	5.20	7.63	-314.50
B/W41	7.22	110.95	2.98	0.00	0.98	0.00	0.00	4980.08	4634.35	1340.49	22.35	19.21	613.40	61.30	63.73	-2627.54
B/W42	0.00	5.68	0.00	6.98	0.00	0.98	0.00	-109.24	-454.97	-131.60	1.17	-1.96	-62.68	-7.84	-5.41	223.14
B/W44	0.00	12.02	0.00	0.00	0.51	0.00	0.00	188.78	-156.95	-45.40	2.41	-0.72	-23.09	-4.97	-2.54	104.78
B/W45	9.03	7.88	5.85	0.00	0.28	1.02	0.00	12.54	-333.19	-96.38	1.78	-1.36	-43.32	-6.00	-3.58	147.51
B/W46	11.68	6.87	1.08	0.00	0.18	0.00	0.00	-31.36	-377.09	-109.07	1.61	-1.52	-48.59	-7.94	-5.52	227.54
B/W47	9.65	0.00	0.00	0.00	0.28	0.00	7.52	-367.53	-713.26	-206.31	0.20	-2.94	-93.70	-12.60	-10.18	419.59
B/W48	7.12	6.95	0.00	0.00	1.02	0.00	0.00	-38.81	-384.54	-111.23	1.54	-1.59	-50.75	-8.04	-5.62	231.56
B/W49	10.33	12.76	1.10	0.00	0.38	0.00	0.00	249.55	-96.18	-27.82	2.76	-0.37	-11.78	-4.06	-1.64	67.53
WHO Standards	10	3	2000	1000		10	3000-5000									
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-383.33			0.06535			-12.822		
Max	13.98	110.95	6.85	16.85	15.68	2.02	7.52	4980.08			22.3472			61.3006		
AVG	6.74	14.92	0.99	1.34	1.34	0.28	0.49	345.729			3.13256			-2.4253		

Table 3: Classification of water quality based on modified categories of pollution indices

Indices	Pre-monsoon Season				Post-monsoon Season			
Method	Category	Class	No. of Samples	% samples	Category	Class	No. of Samples	% samples
HPI	<55	low	20	51.3%	<55	low	18	46.1%
	55-100	Medium	04	10.3%	55-100	Medium	03	07.8%
	>100	High	15	38.4%	>100	High	18	46.1%
HEI	<8	low	38	97.4%	<8	low	38	97.4%
	08-15	Medium	00	0.0%	08-15	Medium	00	00.0%
	>15	High	01	02.6%	>15	High	01	02.6%
CD	<5	low	35	89.7%	<5	low	35	89.8%
	5-10	Medium	03	07.7%	5-10	Medium	02	05.1%
	>10	High	01	02.6%	>10	High	02	05.1%

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