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Physico-chemical Characterization of Ground Water with Reference to Water Quality Index and Their Seasonal Variation in Vicinity of Thermal Power Plant at Yamuna Nagar, Haryana

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Abstract

In coal based thermal power plants, the effluents like fly ash ,either in dry or slurry form is the major source of contamination of ground water with the toxic elements present in fly ash. This problem is having potential significance in India, as coal used in these power plants has high ash content. In the present research paper, an effort has been made to study the physico-chemical characterization of ground water with reference to water quality index (WQI) in villages around thermal power plant, Yamuna Nagar, Haryana .Water samples from the tube well of 4 villages and a thermal colony surrounding the thermal power plant in Yamuna Nagar, Haryana, were collected for analysis in December 2017 and June 2018. For characterization, various standard methods like inductively coupled plasma emission spectrophotometry (ICPE) and atomic absorption spectrophotometry (AAS), etc have been employed and water quality index is calculated using Tiwari & Mishra method. The standards values of parameters used are incorporated from World Health Organisation (WHO) and Bureau of Indian Standards (BIS). Different Physico- chemical parameters for determining the ground water quality in the vicinity of thermal power plant, Yamuna Nagar are much higher than the standard given by WHO (2017) and BIS (10500:2012) and thus water quality index values calculated from these parameters indicates very poor quality of water and water is not fit for drinking purposes.

Keywords: *AAS; ICPE; Physico-chemical; WQI; Yamuna Nagar*

1. Introduction

Throughout the ages, water has been considered pure medium carrying nutritional elements for survival of every form of life on the earth. Water covers about 71% of earth surface. From biological direction, water possesses a lot of different characteristics that are critical for propagation of life. However, in the last few decades, due to accelerated pace of industrialisation and urbanisation, there has been a tremendous decline in the drinking water quality due to its overexploitation and inappropriate disposal of industrial effluents disposal, particularly in urban areas [1]. The quality of drinking water is governed by appropriate values of physico chemical parameters like Electrical conductivity(EC), pH, turbidity, total dissolved solids etc and certain permissible limits of elemental concentration of toxic trace elements [2]. These has to be in a strict limits, which are governed by certain water standards regulatory authorities like Bureau of Indian standards(BIS),United State environmental protection agency(USEPA), Indian council of medical research (ICMR), World health organization (WHO) etc [3]. These agencies strictly and regularly monitor the water standards. Inspite of adhering to the various guidelines issued by these authorities regarding the safe and appropriate disposal of the effluents, most of the industries at state or even central level are not taking proper care for the management of safe disposal of effluents, e.g., fly ash as a by-product produced in tons during coal combustion in the thermal power plants [4-5]. The Coal fired thermal power plants are producing not only tons of fly ash, but also SO_x, N_2, some hydrocarbons etc [6]. Fly ash produced from thermal power plants has SiO_2, Fe_3O_4, Fe_2O_3, TiO_2 etc as chief constituents. Moreover partially burnt carbon particles and a small fraction of Na, K, Mg, Zn, Pb, Cr, Cd, Ni, Fe, As, and Co in trace quantities are also available in it. These toxic trace elements acts as main source of pollution for soil, water (both surface and ground). Ground water is susceptible to metal contamination due to waste disposal of fly ash and leachate infiltration. The collection of huge quantity of coal fly ash in dumping location causes leakage of perilous substances and seepage through layers of soil and finally pollutes the ground water [7].

It thus becomes essential to recurrently keep an eye on the groundwater quality and to find out the ways to shield it from contamination. One very important and effective tool to get information of water quality is water quality index(WQI). First and foremost, the water quality index was introduced by Horton in U.S by choosing 10 most generally used parameters of quality of water like DO, pH, TDS, EC, etc [8]. Afterwards a number of methods has been proposed like weighted arithmetic water quality index, NSFWQI, CCMEWQI, etc. have been applied to estimate quality of water. Kaushik *et.al* (2002) [9] employed a total of nine parameters like electrical conductivity, pH etc. for determining water quality index for ground water of Hisar and Panipat using weighted arithmetic water quality index method and found that the WQI is less than 50 in Panipat region, which indicates that water is not fit for consumption whereas, it ranged between 50 and 100 for Hisar indicating poor water quality. Sunita *et.al* (2014) [10] employed weighted arithmetic water quality index method for estimating the ground water quality of Samalkha, Panipat using ten parameters and reported that WQI lies in the range of 89.09 to 146.67 thus indicating poor water quality and not fit for drinking purposes. Khawaja *et .al*. (2016) [11] estimated water quality index for ground water samples of Aligarh, UP by incorporating Tiwari and Mishra method [12] using 14 parameters and found that WQI for this region ranged from 18.91 to 74.66 pre-monsoon and 16.81 to 70.35 during post-monsoon. The study revealed that half of the area chosen for research was moderately polluted. In the light of study of literature, it is obvious that several studies has been conducted to characterise physico-chemical parameters of ground water samples and estimate water quality index so far. However no study has been performed in Yamuna Nagar, Haryana, to characterise physico-chemical parameters and estimate the water quality in this region so far. Yamuna Nagar district is core industrial hub and is densely populated due to increasing number of immigrants from other states for exploring employment. The city has Sugar industry like sugar Mill and heavy machinery production like ISGEC and paper and pulp industry like Ballarpur paper and pulp industry and in the centre of the city, Deenbandhu thermal power plant. Thus from environmental pollution prone area point of view, Yamuna Nagar is best suited for our study.

2. Study Area

In our study, various samples of ground water were collected from tube wells situated in four villages and one residential colony surrounding the thermal power plant, Yamuna Nagar. Table 1 shows the location of sampling areas and Fig. 1 shows the geographical map of the sampling locations.

Table 1: Sampling locations surrounding thermal power plant Yamuna Nagar

Sr. No.	Sampling Code	Sampling Location	Source of ground water	Distance from Thermal Plant
1	TPYN-1	Rattan Pura	Tubewell	1 Km.
2	TPYN-2	Ram Pur	Tubewell	1.5 Km
3	TPYN-3	IshharPur	Tubewell	2 Km
4	TPYN-4	Bhadimajra	Tubewell	4 Km
5	TPYN-5	Power Plant Colony, Yamuna Nagar	Tubewell	0.5 Km

Fig.1: Geographical map of sampling site locations in the vicinity of thermal power plant Yamuna Nagar

3. Materials and Methods

The water samples from sampling locations of Yamuna Nagar were collected in sterilised plastic bottles. Temperature measurement was done in-situ using mercury thermometer and rest parameters are measured in the laboratory by adopting standard instruments and methods for examination of water and waste water according to American Public Health

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Association manual (APHA 2005) and are given in table 2.

All the instruments stated in table 2 are calibrated against the standards. Table 3 shows the standard values of different parameters measured for characterization of water quality and have been taken from standards manuals of BIS and WHO.

Table 2: Details of Instruments used to measure various parameters

Sr. No.	Parameter	Instrument
1	pH	Eutech pH 510
2	Electrical Conductivity	Eutech CON 700
3	Total Dissolved Solids (TDS)	Cyberscan CON 1500
4	Total hardness	EDTA Titration
5	Turbidity	Eutech TN 100
6	Zn, Fe, Cu, Mn, Pb, Cd, Cr, Ni, As, Co, Ca, Mg	ICPE 9000, Shimadzu
7	Na, K	AAS, ZEEnit 700p, Analytic Zena

Table 3: Standard values of parameters of drinking water quality

Measured parameter	Standard value as per WHO(2017)	Standard value as per BIS(10500:2012)
pH	No guideline available in WHO manual	6.5- 8.5
Electrical Conductivity	<2500 µS cm	No guideline
Total Dissolved Solids	No guideline	500-2000 ppm
Total hardness	No guideline	200-600 ppm
Turbidity	No guideline	1-5
Zn	3 ppm	5-15 ppm
Fe	No guideline	<0.3 ppm
Cu	<2 ppm	0.05-1.5 ppm
Mn	0.5 ppm	0.1-0.3 ppm
Pb	<0.01 ppm	<0.01 ppm
Cd	<0.003 ppm	<0.003 ppm
Cr	<0.05 ppm	<0.05 ppm
Ni	<0.02 ppm	<0.02 ppm
As	<0.01 ppm	<0.01ppm
Co	No guideline	No guideline
Na	200 ppm	No guideline
K	No guideline	No guideline
Ca	No guideline	75-200 ppm
Mg	No guideline	30-100 ppm

These standard values of different parameters are widely used during the calculations of WQI. A number of methods have been devised for the WQI calculations after Horton method (1970). One such method is Tiwari and Mishra method, used in the present work for the calculation of WQI.

3.1 Tiwari & Mishra Water Quality Index

In this method, WQI is computed by the following equation:

$$\mathrm{WQI} = \mathrm{Antilog}\left[\sum w_i \log_{10} q_i\right]$$

where $w_i = \frac{K}{v_s}$

and K = constant = $\frac{1}{\left(1/v_{s1} + 1/v_{s2} + \cdots + 1/v_{sn}\right)}$

where

v_s = standard value of ith parameter q_i is calculated using the following equation:

$$q_i = \frac{(v_0 - v_i)}{(v_s - v_i)} \times 100$$

where

v_0 = observed value of ith parameter

v_i = ideal value of parameters (for pH, v_i = 7 and for all other parameters, $v_i = 0$)

v_s = standard value of ith parameter

As per Tiwari & Mishra method the rating scales for the quality of water are shown in Table 4.

Table 4. Rating Scales for Water Quality index as per Tiwari & Mishra method

WQI	Rank
0-25	Excellent quality
26-50	Good quality
51-75	Poor quality
76-100	Very Poor quality
Above 100	Unfit for drinking purposes

4. Results and Discussions

Physico-chemical parameters like, Electrical conductivity (EC) , pH TDS, Total hardness (TH), Turbidity, temperature and metal contents like Zn, Fe, Cu, Mn, Toxic trace elements Pb, Cd, Ni, Cr, As, Co and alkali contaminants Na, K, Ca and Mg are measured and compared with WHO guidelines (2017) [14] and BIS guidelines (10500: 2012) [15] standards. Table 5 and 6 shows the measured values in Dec 2017 (winter) and June 2018 (summer).

Table 5: Measured values of different parameters in vicinity of TPP Yamuna Nagar in Dec 2017

Measured parameter	Unit	Results (mean±s.d.)				
		TPYN-1	TPYN-2	TPYN-3	TPYN-4	TPYN-5
pH	-----	7.315±0.046	7.38±0.018	7.66±0.057	7.58±0.13	7.54±0.23
Electrical Conductivity	µS cm	1194.5±4.2	1249.7±30.6	1220.7±9.5	857± 16.0	1256.5±38
Total Dissolved Solids	ppm	832±11.13	861.2 ±13.14	831.5±11.5	573±10.7	855.2±19.7
Total hardness	ppm	353.75±19.5	326.75±11.7	328.25±16.9	284±8.0	362±15.0
Turbidity	NTU	5.63±0.10	5.47±0.08	5.10±0.09	4.74±0.17	5.62±0.10

Temperature	ºC	13.75±0.5	12.75±0.95	13±0.81	13±0.81	13.5±0.57
Zn	ppm	5.82±0.44	6.03±0.048	6.13±0.106	4.15±0.13	10.11±0.08
Fe	ppm	0.38±0.05	0.34±0.02	0.43±0.008	0.28±0.006	0.83±0.06
Cu	ppm	0.079±0.001	0.092±0.006	0.089±0.004	0.046±0.002	0.094±0.003
Mn	ppm	0.112±0.01	0.182±0.007	0.202±0.006	0.096±0.002	0.26±0.008
Pb	ppm	0.021±0.009	0.016±0.007	0.017±0.006	0.008±0.0006	0.033±0.005
Cd	ppm	0.005±0.0006	0.005±0.0008	0.005±0.0008	0.0018±0.0005	0.0038±0.0005
Cr	ppm	0.055±.003	0.053±0.003	0.055±0.003	0.038±0.008	0.055±0.002
Ni	ppm	0.025±0.002	0.024±0.003	0.022±0.002	0.018±0.0008	0.024±0.002
As	ppm	0.014±0.003	0.014±0.002	0.014±0.003	0.008±0.001	0.013±0.002
Co	ppm	0.0038±0.0005	0.0028±0.001	0.0038±0.001	0.0013±0.0005	0.002±0.0005
Na	ppm	119.6±8.34	120.55±5.50	112.35±2.40	138.22±6.69	170.67±13.12
K	ppm	11.65±0.91	12.08±0.39	11.23±0.81	12.53±0.49	15.81±1.01
Ca	ppm	82.45±2.89	73.87±2.26	76.2±4.14	72.75±1.98	84.75±2.51
Mg	ppm	35.1±3.22	34.02±3.16	32.62±2.24	26.75±0.85	35.7±2.53

Table 6: Measured values of different parameters in vicinity of TPP Yamuna Nagar in June 2018

Measured parameter	Unit	Results (mean±s.d.)				
		TPYN-1	TPYN-2	TPYN-3	TPYN-4	TPYN-5
pH	-----	7.89±0.11	7.67±0.09	7.78±0.087	8.34±0.13	8.22±0.29
Electrical Conductivity	μS cm	1207±20.11	1242.75±15.4	1235.25±30	867±12.8	1282.25±11.2
Total Dissolved Solids	ppm	843±8.04	867±3.55	827.75±12.5	577.5±5.8	860.25±12.09
Total hardness	ppm	356±13.2	337±2.94	334±5.77	299.75±4.34	382.25±9.28
Turbidity	NTU	5.71±0.06	5.28±0.08	5.83±0.10	4.05±0.03	5.07±0.07
Temperature	ºC	36.75±0.95	35.75±0.95	35.75±0.95	35.75±0.95	34.75±0.5
Zn	ppm	6.20±0.06	6.105±0.10	6.17±0.10	4.53±0.33	10.42±0.32
Fe	ppm	0.41±0.03	0.37±0.04	0.47±0.02	0.27±0.01	0.79±0.01
Cu	ppm	0.08±0.006	0.090±0.004	0.091±0.005	0.043±0.003	0.097±0.001
Mn	ppm	0.118±0.006	0.18±0.005	0.21±0.005	0.094±0.003	0.27±0.01
Pb	ppm	0.024±0.008	0.018±0.003	0.020±0.006	0.007±0.001	0.032±0.002
Cd	ppm	0.005±0.0005	0.005±0.0008	0.004±0.001	0.002±0.0008	0.003±0.0005
Cr	ppm	0.053±0.001	0.054±0.003	0.053±0.002	0.041±0.009	0.054±0.001
Ni	ppm	0.026±0.002	0.026±0.001	0.024±0.001	0.017±0.001	0.024±0.0008
As	ppm	0.015±0.001	0.016±0.001	0.015±0.001	0.008±0.0008	0.015±0.001
Co	ppm	0.003±0.0005	0.003±0.0008	0.004±0.0008	0.001±0.0006	0.003±0.0006
Na	ppm	122.3±8.77	122.0±3.11	116.0±1.32	139.0±3.84	171.5±10.5
K	ppm	11.53±0.67	11.66±0.27	11.14±0.40	12.07±0.08	15.43±0.57
Ca	ppm	82.0±3.8	78.8±0.83	75.95±1.13	72.6±0.94	85.97±1.44
Mg	ppm	35.8±1.11	33.1±1.17	33.9±0.76	28.0±0.88	37±0.90

There is a significant difference between the values of pH during two seasons i.e summer and winter, the observed values lies in the interval 7.31 (TPYN-1) to 7.66 (TPYN-3) for the winter, i.e., Dec 2017 samples and between 7.67(TPYN-2) to 8.34(TPYN-4) for the summer, i.e., June 2018 samples. In the summer season, pH values are higher than those in winter season which reveals the dependence of pH on temperature. W. F. Langelier (1946) [16] and Castells C.B. et.al. (2003) [17] suggests a possible reason for this temperature dependence. As the temperature rises, molecular vibrations increase which results in the ability of water to ionise and form more hydrogen ions. As a result, the pH will drop**.** However in our study pH has higher values in summer. One of the possible cause for this anomaly is measurement of pH in laboratory environment whereas it must be done in-situ so that temperature of environment does not affect the measurement of pH. The values of electrical conductivity lies in range 857 μS cm (TPYN-4) to 1256.5 μS cm (TPYN-5) in winter and 867 μS cm (TPYN-4) to 1282.25 μS cm (TPYN-5) in summer. Electrical conductivity does not show any variation with temperature. The presence of large amount of inorganic elements dissolved in water is obvious from the values of electrical conductivity [18]. These lie well in the range of normal electrical conductivity values as prescribed by WHO. The values of total dissolved solids are in the range 573 ppm (TPYN-4) to 861.2 ppm (TPYN-2) in winter season and 577.5 ppm to 867 ppm in the summer season. The hardness of water do not alter significantly with season [19]. Its value measured in winter season varies from 284 ppm to 353.75 ppm and 299.75 ppm to 382.25 ppm in the summer season and lie well in the range prescribed for normal value of hardness by BIS. As far as turbidity is concerned, there is very small deviation in the values from winter to summer. Concentration of various toxic pollutants like Pb, Cd, Cr, Ni, As, Co are having deviations from their standard values which indicates the pollution in ground water in the surrounding areas of thermal power plant [20].

The possible reason behind this contamination may be effluents discharges from thermal power plant [21-22].

Table 7 shows the values of water quality index (WQI) measured for the samples collected in summer and winter season both for different sampling locations. In total 20 parameters are used to calculate WQI values using Tiwari & Mishra method.

Table 7: WQI values for samples collected in Dec 2017 (winter) and June 2018 (summer)

Sampling location Code	WQI value for samples collected in Dec 2017 (winter)	Water quality	WQI value for samples collected in June 2018 (summer)	Water quality
TPYN-1	271.64	Not fit	238.39	Not fit
TPYN-2	222.33	Not fit	236.10	Not fit
TPYN-3	268.53	Not fit	269.33	Not fit
TPYN-4	102.04	Not fit	87.94	Very poor
TPYN-5	246.55	Not fit	224.38	Not fit

The values of water quality index as shown in table 7 for sampling location TPYN-1 to TPYN-3 and TPYN-5 are very much above the quality rating for “not fit” water category. Moreover for these three sampling locations WQI values are not much altered by seasonal variation. For sampling location TPYN-4, i.e., Bhaadhimajra, WQI are 102.4 in winter and is 87.94 in summer. The big difference in WQI at this location from all other location is probably due to more distance between the thermal power plant and the village Bhaadhimajra and thus less prone to pollution [23-24].

5. Conclusions

The physico-chemical parameters for deciding the quality of ground water in the vicinity of thermal power plant, Yamuna Nagar are much higher than the standard values decided by WHO (2017) and BIS (10500:2012), and thus the water quality index values are much higher than that of normal water fit for drinking purposes. This is affecting not only the present human population of surrounding areas but may cause serious implications for the survival of floura and fauna in next few years. Moreover the values of various parameters measured in Dec 2017 i.e., winter and June 2018 i.e., summer undergoes mild seasonal variation.

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