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Preliminary Assessment of Ground Water Quality using Water Quality Index near Landfill Site: A Case Study of Ghazipur, Delhi

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***Abstract*:** *The aim of this study is to assess the groundwater quality with the help of water quality index (WQI) and its suitability for human consumption in the residential neighborhood adjacent to Ghazipur landfill site. For the purpose of study, twenty ground water samples were collected within 2 km radius of landfill-site (from the periphery of landfill) during post monsoon (November 2016) and pre monsoon season (June 2017). Each of the samples were analyzed and compared with Bureau of Indian Standards (BIS) drinking water standards. Mainly 8 parameters viz. pH, total dissolved soild, total hardness; total alkalinity, fluoride, nitrate, chloride and iron were selected to determine the WQI. The WQI of pre monsoon groundwater samples ranged from 49.30 (GW2) to 244.83 (GW10) whereas the WQI of post monsoon groundwater samples ranged from 36.06 (GW17) to 239.40 (GW10). It has been found that about 65 percent of sampling locations represents poor quality of groundwater, whereas 20 percent of sampling locations had very poor quality of groundwater. The higher WQI value has been found due to increased concentration of iron, nitrate, total dissolved solids, hardness, fluorides, in the groundwater. The results indicate that there are significant seasonal variations during Pre and Post Monsoon season and contamination level was very high in most of the ground water samples. The results of the present study clearly indicate that the groundwater near landfill site requires adequate treatment before its utilization for human consumption.*

Keywords: *Groundwater pollution, Landfill site, Municipal solid waste, Water Quality Index (WQI).*

1. Introduction

India is a rapidly growing developing country resulting into the heaps of municipal solid waste (MSW). According to census of India (2011), Delhi is a second most populated city of India with the population of 1.67 crore and expected to generate about 7000 metric tonnes of waste daily. The per capita generation of solid waste is ranging from 200 gms to 600 gms per day depending upon the economic status of the community. It is mainly produced from residential, commercial, and agricultural sources as direct consequences of human activities. Unfortunately, landfill has been used most consistently and the ultimate destiny of MSW disposal without following proper scientific methods (Bhide et al., 1998; Longe et al., 2010). Though landfills emerge as the cost effective and easy way to dispose the MSW, it has been also identified as one of the major threats to the contamination of groundwater resources.

Lack of proper waste management practices and its implementation is the major problem behind MSW disposal. After disposal, it goes through various physico-chemical and biological changes. The combination of degraded organic fraction of the wastes and percolating rainwater lead to the generation of a highly concentrated complex liquid called leachate (Kurniawan et al., 2006). Leachate percolates through soil and gradually accumulates at the bottom of landfill, and finally joins the aquifer (Mor et al., 2006). Areas near by landfill have greater possibility of groundwater contamination due to leachate percolation. Such contaminated groundwater and its frequent use in several domestic purposes possess substantial risk to human health and natural environment (Jha et al., 2003; Taylor et al., 2006). It has been confirmed under various research studies that there is strong relation between landfill leachate and groundwater and surface water contamination (Abu-Rukah et al., 2001; Mor et al., 2006). According to WHO (World Health Organization), about 80% of disease is mainly caused due to use of contaminated water. Once the groundwater is contaminated, it is very difficult to restore its quality. Therefore, it is required to strictly monitor the quality of groundwater regularly and to find the ways to protect from further contamination. Water Quality Index (WQI) is the most effective tool to communicate the water quality information in a simpler way to the concern people and policy makers too (Sharma et al., 2011; Sebastian et al., 2013). Thus, WQI is calculated to know the suitability of groundwater for human consumption.

The objective of the study was to assess the groundwater quality and its suitability for human consumption in the residential neighborhood adjacent to landfill site with the help of WQI.

1.1. Study Area

The study area is Ghazipur Landfill site, which is situated in East Delhi, India. It is located at the latitude of 28°37'28"N to 77°19'41"E longitude with an area of approximately (3 x 105 m2) 29.62 hectares (situated near National Highway 24). It is operational since the year 1984. The landfill receives on an average of 2200-2500 MT of waste daily from the entire East Delhi. The average height of waste is approximately 25 m. However at some places, it has crossed the height of 50 m. The study area is characterized by alluvial formation and quartzite hard rock at greater depth of approximately 100 m below ground level (bgl). The nearby residential area within the radius of 1 km is densely populated.

Fig.1: Ghazipur Landfill Site in Delhi (Source: Babbar P., 2015)

2. Hydrogeological Frame-Work of Ghazipur Landfill Site

Occurrence and movement of groundwater is majorly affected by hydrogeology of the site. Therefore, detailed hydrogeology of landfill site is required to be explained to understand the movement of leachate into the groundwater and further its contamination. At Ghazipur landfill site, the leachate has been infiltrating into the sub-soil strata since long. Uncontaminated aquifers may exist around the landfill site due to presence of thick clay layer or occurrence of confined sources.

The strata below the landfill site are mainly consisting of about 134 m thick quaternary alluvium, weathered and fractured quartzite thereafter. To study the nature of aquifer material and its characters, Central Ground Water Board (CGWB) has constructed a number of shallow and deep piezometers as well as exploratory tube wells in the region of the Ghazipur SLF. Lithological details of piezometers at shallow (15 m) and deeper depth (134 m) constructed by CGWB have been summarized in Table1 and 2.

TABLE I: Detail of Aquifer Material (15m shallow piezometer of SLF)

Sl. No	Location	Granual zones encountered (m bgl)	Lithology
1	SLF Office-50 m north of SLF site office	7 - 12 12 - 15	Sand Sand with Kankars
2	Poultry Farm-50 m	4 - 15	Silty clay with kankars
3	Bio-gas plant-50 m west to landfill border	4.5 - 12 12 - 15	Sand with silt Clay and kankars

TABLE II: Lithological Data of Fish Market, Ghazipur (134 m depth)

Depth range in m bgl	Thickness (m)	Lithological detail
0.00-14.45	14.45	Light yellow clay with minor coarse to gravel size kankar
14.45-21.35	6.90	Sand with clay silt admixed with fine sand and kankars
21.35-24.13	2.78	Gravel and kankar with minor silt and fine Sand
24.13-34.10	9.97	Silty clay with traces of kankar
34.10-41.89	7.79	Gravel with minor silt and fine sand
41.89-51.46	9.57	Sand fine-grained along with tracers of gravel
51.46-65.10	13.64	Clay with silt
65.10-131.55	66.45	Sticky clay
131.55-134.55	3.00	Gravel with fine sand

The above observations and inferences obtained from the details of lithology data are represented through the sub-surface geological cross section (Figure 2). It shows that the area consists of a mixture of fine and medium sand with coarse hard kankar up to a depth of 50 m bgl. Hence, it may be inferred as single aquifer system of 50 m depth. However at some places, thin layers of clay silt are also present within the sand horizon. Clay was mainly found below the depth of 50 m. Three aquifers were identified in the depth range of 0.00 to 12.00 m, 15.00 to 30.00 m and 41.00 to 47.00 m bgl, due to presence of clay silt horizons. A mixture of silt with minor clay and kankar separates these aquifers from each other.

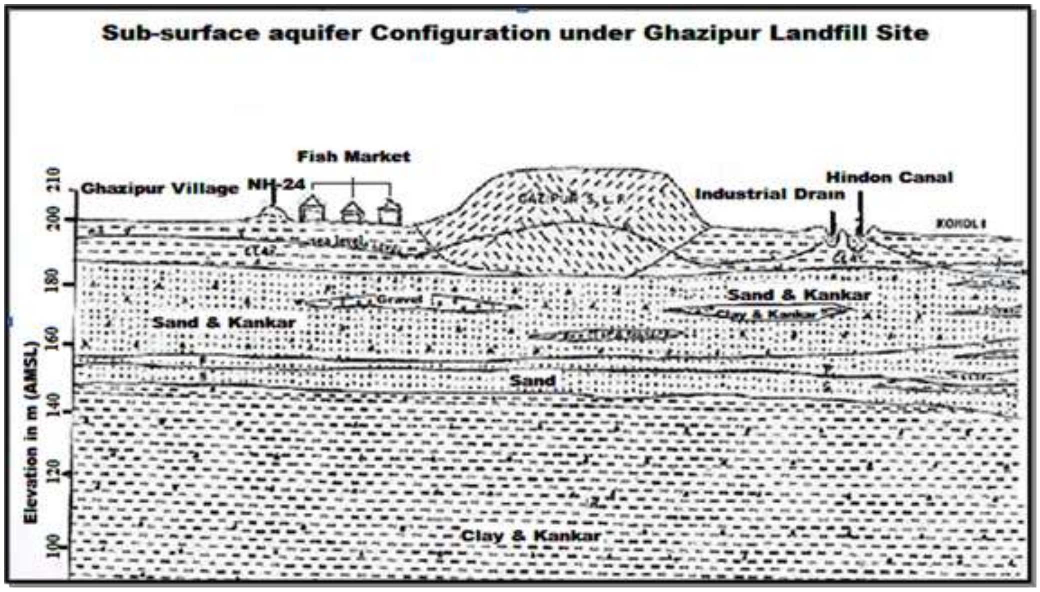

Fig. 2: Sub-surface geological cross section of Ghazipur landfill (Source: Babbar P., 2015)

3. Materials and Methods

To assess the groundwater quality, 20 groundwater sampling stations were selected within the area of approximately 2 km2 at a distance of 0.5 km, 1 km, 1.5 km and 2 km respectively. The samples were collected during post (Nov. 2016) and pre-monsoon (June 2017).

Fig. 3: Groundwater (GW) sampling lo0063ations around Ghazipur landfill site

Physico-chemical analysis of samples for the parameters like pH, Total Dissolved Solids (TDS), chloride, total hardness, total alkalinity, phosphate, fluoride, nitrate and iron were determined as per the Standard Methods

(APHA, 1998). The two parameters i.e. pH and TDS were measured on the site only. Sampling locations and landfill site are illustrated in Figure 3. The results were used for the calculation of WQI, which finally necessitate evaluating suitability for drinking and human consumption purposes during both the season.

TABLE III: Details of Ground Water (GW) sampling location, near Ghazipur landfill, New Delhi

Sampling location	**Radial distance from site (km)**	**GW location**	**Coordinates**	
			Latitude	**Longitude**
0-0.5 Km Buffer Area				
SLF* site	0.07	20	28°37'35.10"	77°19'35.30"
WtE$ Site	0.09	19	28°37'20.60"	77°19'27.14"
Radhakrishn Mandir	0.23	18	28°37'23.24"	77°19'21.19"
C-27, Mulla Colony	0.28	4	28°37'13.79"	77°19'46.09"
C Block, Dairy Farm	0.35	1	28°37'31.68"	77°19'18.85"
0.5-1 Km Buffer Area				
MCD Area, Near Delhi Transco	0.66	12	28°37'00.48"	77°19'22.88"
96 A, Sapera Colony	0.69	5	28°37'13.21"	77°20'04.81"
Dhobi Ghat, Kicharipur	0.76	16	28°37'02.34"	77°19'13.39"
Rajbir colony	0.95	15	28°36'50.92"	77°19'50.32"
Block No. 8, Khicharipur	1.08	17	28°37'10.54"	77°18'53.25"
1-1.5 Km Buffer Area				
GD Colony, Gharoli Extension	1.11	13	28°36'45.77"	77°19'50.47"
Shani Bazar, Near Subhash Park	1.25	7	28°37'39.10"	77°20'31.90"
Khora Colony	1.31	6	28°37'13.17"	77°20'31.04"
Block 16, Kalyanpuri Park	1.40	3	28°36'55.46"	77°18'48.78"
Sec- 62A, Makanpur Colony	1.68	8	28°37'54.32"	77°20'42.56"
1.5-2 Km Buffer Area				
Anand Vihar, Kaushambi	1.92	10	28°38'36.10"	77°19'28.77"
New Kondli village	1.98	14	28°36'18.49"	77°19'58.00"
Sec-5, Vaishali	2.03	9	28°38'38.34"	77°20'30.50"
Shani Mandir, I.P Extension	2.09	11	28°38'08.69"	77°18'31.50"
B Block, Mayur Vihar Phase II	2.13	2	28°37'12.09"	77°18'11.84"

$Waste to Energy
*Sanitary Landfill site

3.1. Water Quality Index (WQI):

Water Quality Index has emerged as a standard tool to assess the water quality of ground and surface water (Yadav et al., 2015 and Krishnan et al., 2016). The main purpose of WQI is to convert a complex set of water quality data into logical and easily usable information, so that even common man can easily understand the water quality (Akoteyon et al., 2011; Balan et al., 2012). Following steps are followed for the calculation of WQI (Ramakrishnaiah et al., 2009; Vasanthavigar et al., 2010):

In the first step, each parameter has been assigned a weight (wi) according to its relative importance in the overall water quality for drinking purposes as compared with values of Bureau of Indian Standards (BIS 10500:1991). The relative weight of each chemical parameter is shown in table 4.

In the second step, following equation is used to calculate the relative weight (Wi):

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

where, wi = weight of each parameter, Wi = relative weight, n = number of parameters

In the third step, to derive the quality rating scale (q_i), concentration of each chemical parameter in each water sample has been divided by its respective standard according to the BIS 10500 (1991) guidelines and finally the outcome is multiplied by 100:

$q_i = (C_i/S_i) \times 100$

where, q_i = quality rating,

C_i = concentration of each chemical parameter in each water sample (mg/l)

S_i = Indian drinking water standard for each chemical parameter (mg/l)

Now, the SI (Sub-Index) is determined for each chemical parameter and finally used to calculate the WQI as per the below equation:

$SI_i = W_i \times q_i$

$WQI = \sum SI_i$

Where, SI_i = sub-index of ith parameter, q_i = rating based on concentration of ith parameter,
n = number of parameters

TABLE IV: Relative Weight of Chemical Parameters of Ground Water

Chemical parameters (mg/l)	S_i (BIS Standard 10500)	Weight (w_i)	Relative weight (W_i)
pH	6.5-8.5	4	0.1429
Total dissolved solids (TDS)	500	4	0.1429
Total hardness (TH)	300	2	0.0714
Total Alkalinity (TA)	300	2	0.0714
Chloride (as Cl)	250	3	0.1071
Fluoride (as F)	1	4	0.1429
Nitrate (as NO_3)	45	5	0.1786
Total Iron	0.1	4	0.1429
		$\sum w_i = 28$	$\sum W_i = 1.000$

4. Results and Discussion

WQI has been estimated from the analysis of various water quality parameters. The statistical summary of the various groundwater samples collected from the surrounding area of Ghazipur landfill site during pre and post monsoon season has been illustrated in Table 5 as follow.

TABLE V: WQI estimates of Ground Water quality near Ghazipur landfill site, New Delhi.

GW Samples	WQI - Post Monsoon	WQI- Pre Monsoon	Average WQI	Water Quality
GW1	164.95	139.89	152.42	Poor
GW2	101.29	86.86	94.07	Good
GW3	107.43	102.01	104.72	Poor
GW4	107.32	104.59	105.95	Poor
GW5	75.53	106.73	91.13	Good
GW6	143.19	150.60	146.90	Poor
GW7	141.11	169.56	155.33	Poor
GW8	239.31	245.07	242.19	Very poor
GW9	238.77	238.59	238.68	Very poor
GW10	281.07	282.30	281.68	Very poor
GW11	340.78	345.45	343.11	Very poor
GW12	158.23	174.84	166.54	Poor
GW13	113.11	138.01	125.56	Poor
GW14	95.49	145.74	120.61	Poor
GW15	72.58	114.44	93.51	Good
GW16	123.74	123.86	123.80	Poor
GW17	50.47	90.34	70.41	Good
GW18	92.47	116.55	104.51	Poor
GW19	119.92	132.94	126.43	Poor
GW20	135.42	134.28	134.85	Poor

The Table 5 shows that the WQI of 20 groundwater samples during pre monsoon ranged from 49.30 (GW2) to 244.83 (GW10) whereas the WQI for post monsoon groundwater samples ranged from 36.06 (GW17) to 239.40 (GW10). The average WQI value in the study area ranged from 46.54 to 242.12. The Table 6 illustrates the water quality classification, based on WQI value (table 5). Water quality can be categorized into five different classes which can vary from "excellent water quality" to "water unsuitable for drinking". It also shows the percentage of water samples that falls under different quality.

TABLE VI: Classification of Water Quality Based on WQI Value (Ramakrishnaiah et al., 2009, Vasanthavigar et al., 2010)

WQI Value	Water Quality	Percentage of GW samples
<50	Excellent water quality	00
50-100	Good water quality	20
100-200	Poor water quality	60
200-300	Very poor water quality	20
>300	Water unsuitable for drinking	00

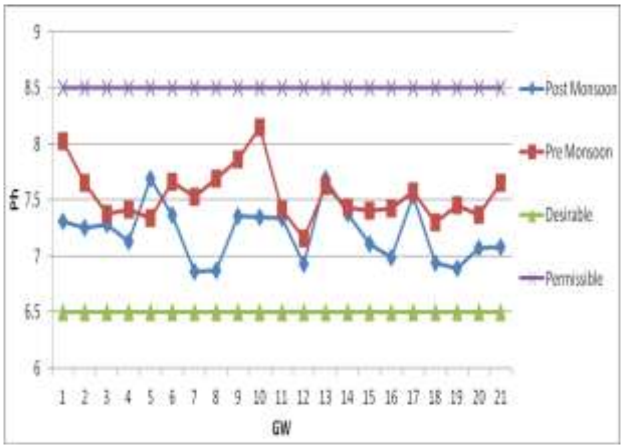

Fig. 4 (a)

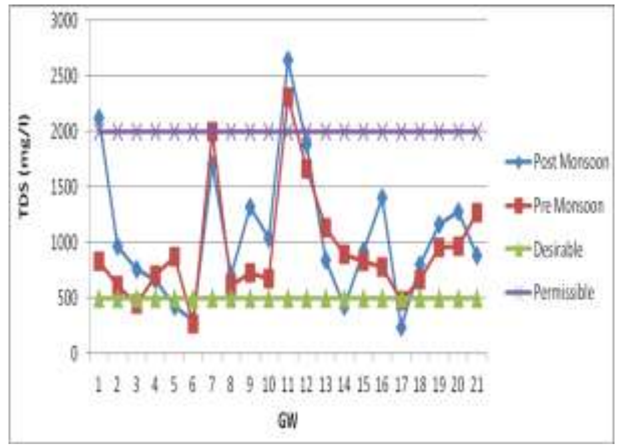

Fig. 4 (b)

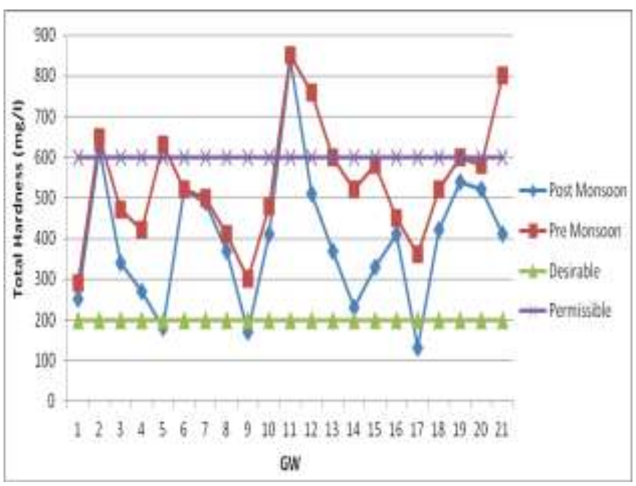

Fig. 4 (c)

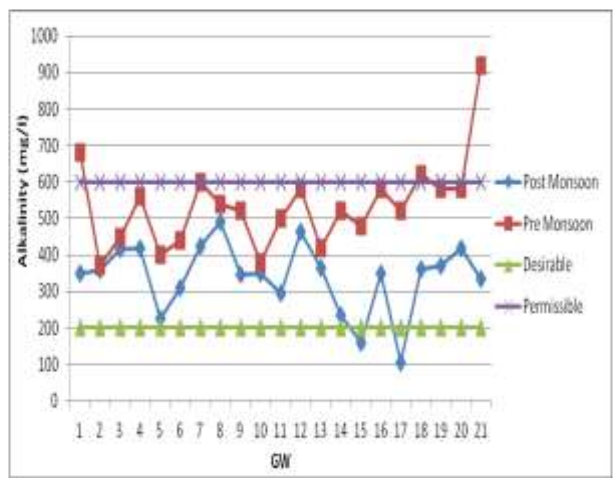

Fig. 4 (d)

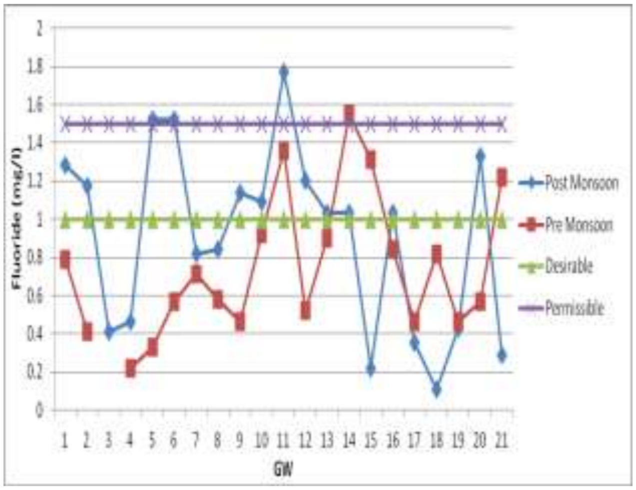

Fig. 4 (e)

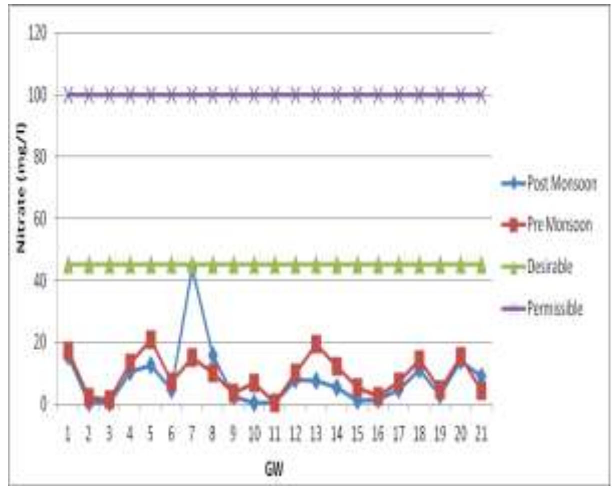

Fig. 4 (f)

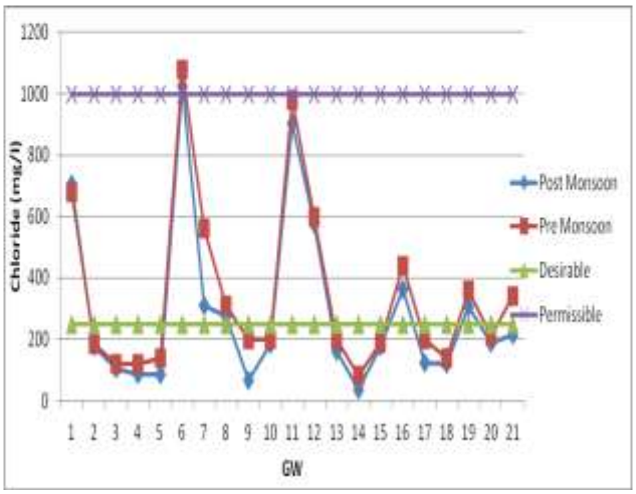

Fig. 4 (g)

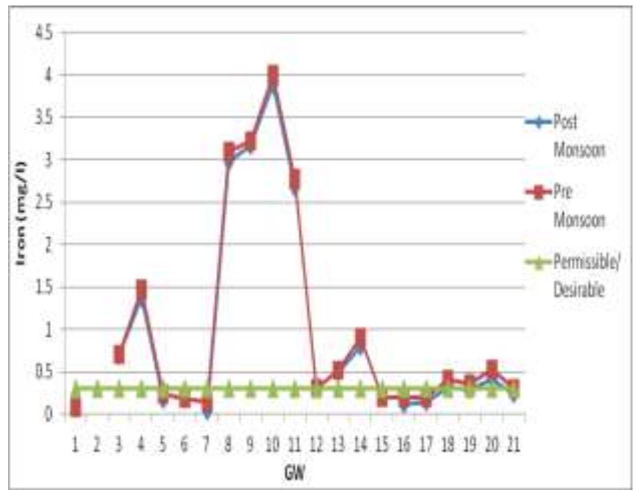

Fig. 4 (h)

Fig. 4: Figures of different parameters representing, a) pH, b) TDS, c) Hardness, d) Alkalinity, e) Fluoride, f) Nitrate, g) Chloride, h) Iron vis-a-vis BIS standards

The pH value represents the extent of acidity or alkalinity of a given water sample. The min. and max pH values of samples for pre monsoon season were 7.16 and 8.15 respectively and 6.86 and 7.69 for post monsoon season. The average pH values for pre & post monsoon were within the BIS prescribed limits i.e. 6.5 – 8.5. The pH values for most of the groundwater samples were in the range of 7 to 8, which shows that the groundwater in the study area is slightly alkaline in nature.

Measurement of TDS is a direct representation of the total dissolved solid particles present in a sample. The concentration of TDS ranged from 266mg/l to 2310 mg/l during pre monsoon and from 240 to 2640 mg/l during post monsoon, which was mostly exceeding the BIS desirable limit of 500 mg/l. The highest concentration of TDS during post monsoon was found to be 2120 mg/l at GW1, a sampling location nearest to landfill site while for the pre monsoon season, the highest concentration of TDS (2310 mg/l) was found at GW11. This indicates that there is a presence of inorganic material in the groundwater. Olaniya (Olaniya et al., 1977) also found the indications of groundwater pollution in the vicinity of landfill sites due to a higher concentration of TDS in the groundwater samples collected. Groundwater with high TDS is usually not hazardous to human health however the high concentration of TDS may be harmful to persons already affected with kidney and heart diseases (Gupta et al., 2004) and the same may also cause laxative or constipation effects to human beings (Kumaraswamy, 1999).

Hardness mainly caused due to the presence of cations of calcium and magnesium. The concentration of total hardness ranges from 290mg/l to 850mg/l in pre monsoon and 130mg/l to 840mg/l in the post monsoon season respectively. The hardness values of most of the ground water samples for pre-monsoon season were found to be higher than the standard desirable limit i.e. 200mg/l. At some of the sampling locations viz. GW2, GW5, GW11, GW12, GW13 and GW19, the hardness values were exceeding the permissible limit (600mg/l) of BIS standards as well. During post monsoon season, the hardness values were found to be higher than desirable limit except for three locations i.e. at GW5, GW9, and GW17. According to Vasanthavigar (Vasanthavigar et al., 2010) high values of hardness in post-monsoon were contributed by dissolution of salts and minerals through infiltration of rainwater into the groundwater system. During post monsoon season, the maximum value of hardness i.e. 840mg/l was found at GW11 as against the permissible limit of 600mg/l. It may be inferred from the figure 4 (c) that most of the groundwater samples in the study area are hard in nature. The alkalinity of groundwater in the study area was ranging from 370mg/l to 680mg/l and 105mg/l to 490mg/l during pre and post monsoon seasons respectively. All the sites have alkalinity above the BIS standards of desirable limit (200mg/l) and alkalinity at GW1 has the maximum value of 680mg/l in pre monsoon which exceeded the permissible limit of BIS as well.

The fluoride concentration was ranging from 0.22mg/l to 1.55 mg/l during pre monsoon and 0.11mg/l to 1.77mg/l during post monsoon season respectively. The maximum level of fluoride i.e. 1.55mg/l during pre monsoon was observed at GW14 which exceeded the standard permissible limit of 1.5mg/l. During post monsoon season, 45% of groundwater samples were found to have fluoride concentration beyond the desirable limit of 1mg/l. Such samples are of GW1, GW2, GW9, GW10, GW12, GW13, GW14, GW16, and GW20. Around 15% of groundwater samples exceeded the permissible limit of fluoride (1.5mg/l) and such samples are of GW5, GW6 and GW11.

The nitrate concentration varied from 0.52mg/l to 20.86 mg/l during the pre monsoon season and 0.25mg/l to 43.97mg/l during post monsoon season. The nitrate value for the study area was within the BIS standard permissible limit i.e. 45 mg/l for all groundwater samples. The highest value of nitrate was observed at GW7 location during the post monsoon season.

A high concentration of Chloride in groundwater may be indicating its pollution and contamination (Loizidou et al., 1993). Chloride is the most commonly found element in rocks in different forms. It has high affinity towards sodium and its concentration is high in groundwater, where the temperature is high and rainfall is less. Soil porosity and permeability also play major role in increasing the chlorides concentration (Chadha, 1999). The chloride concentrations in groundwater samples varied from 80mg/l to 1080 mg/l during pre monsoon and 35 to 1025 mg/l during post monsoon. The chloride concentration in the study area was found within the standard permissible level (1000 mg/l), except at GW6 where it was 1080mg/l for pre monsoon and 1025mg/l for post monsoon season. Increased Chloride level in groundwater may be harmful for persons suffering from diseases related to kidney and heart (WHO, 1997).

The iron concentration in pre monsoon was varying from 0.08mg/l to 4 mg/l and 0.04mg/l to 3.89mg/l in post monsoon. During pre monsoon, 12 groundwater samples (60% of the total samples) were having iron concentration beyond the desirable limit. During post monsoon season, iron was not traceable at some locations i.e. at GW1, GW2, GW6, GW12 and GW15, however at 9 locations (45% of sample size), it exceeded the standard desirable limit (0.3mg/l). This may be an indication of presence of iron and steel scrap in the garbage being dumped at site or may be its direct dumping at the landfill site of Ghazipur.

5. Conclusions

The high concentration of TDS, hardness, alkalinity, chloride, fluoride and iron in groundwater in close proximity to landfill site has polluted the groundwater and deteriorated its quality for drinking and other domestic purposes. WQI is a standard tool for assessment and management of water quality. According to WQI values, approximately 60 percent of groundwater samples had poor quality of water, whereas 20 percent falls under the category very poor quality water. Only 20 percent of groundwater samples in the study area had good quality of water. High values of hardness, magnesium and chloride indicate leaching and infiltrations from upper soil layers and anthropogenic pollution. It can be concluded that landfill site had impact on groundwater quality in the surrounding area of Ghazipur landfill, as there is no other natural and anthropogenic source other than landfill site which can be responsible for the presence of higher concentration of these pollutants. From the results, it can be concluded that the groundwater treatment is a necessity, prior to drinking or for domestic consumption of water. It is suggested that the surrounding area of Ghazipur landfill should be protected from further contamination and also to minimize associated adverse impacts.

6. Acknowledgement

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