INFOGAIN PUBLICATION

International Journal of Advanced Engineering, Management and Science (IJAEMS)
Peer-Reviewed Journal
ISSN: 2454-1311 | Vol-10, Issue-4; May-Jun, 2024
Journal Home Page: https://ijaems.com/
DOI: https://dx.doi.org/10.22161/ijaems.104.1

Characterization of Leachate and its Impact on the Groundwater Quality at Shivari Landfill, Lucknow

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Received: 18 Mar 2024; Received in revised form: 25 Apr 2024; Accepted: 05 May 2024; Available online: 15 May 2024

Abstract— *Water is essential for living and is used for drinking, irrigation and other purposes. Groundwater, in general terms, is defined as water that is present beneath the underlying rocks in the earth's surface. When an unwanted contaminant changes the physical, biological and chemical properties of water, it is known as water pollution. A Landfill is the most common waste disposal practices used in many parts of the world. It is the cheapest of all waste management practices. The aim of this project is to characterize the landfill leachate and assess the groundwater quality in the vicinity of landfill to find out the impact of landfill leachate on groundwater. The samples were taken for both groundwater and the leachate to evaluate physico-chemical properties along with heavy metal assessment. The samples for leachate were collected from the outlet near the landfill site while the groundwater samples were collected from the handpump near the landfill site. It was observed that the mean value of TDS, EC, CL, Total Alkalinity, Mg, Na and Mn are found exceeding the permissible limits of BIS and WHO standards.*

Keywords— ***Municipal Solid Waste treatment plant, Leachate, Groundwater, Piper Diagram Pearson's correlation coefficient.***

I. INTRODUCTION

Pure water had been a prime requisite for the existence of Human civilisation from past till now and groundwater is an important component of pure water especially in a developing country like India for drinking, domestic, irrigation purposes. But currently India is facing a water crises it had only 4% of fresh water reserves and 16% of world's total population and this condition is going to be worsen in future as India will be the most populous country in the world. In such situation contamination of groundwater is the major problem in India especially in rural areas. Contamination of ground water may lead to outbreak of diseases like hepatitis, diarrhea, vomiting, abdominal pain, dysentery etc.

According to world bank estimate 21% of communicable diseases in India is linked with unsafe drinking water and lack of hygiene practices. More than 500 children under the age of 5 die each day from diarrhea in India alone. As per WHO, about 80% of all the diseases in human beings are caused by water (Kavitha and Elongova, 2010). Therefore the suitability of groundwater for various purposes were determined by it's physical, chemical and biological characteristics. MSW treatment plant significantly affect the local environment in various ways such as contamination of surface and groundwater bodies by the percolation of leachate from MSW treatment plant, contamination of soil strata as during leachate percolation some amount of leachate usually reside in the soil strata, awful gases are released during the decomposition of organic waste that may also effect local people's health. The present study was carried out to assess the groundwater quality around MSW Treatment plant during pre-monsoon season(2021-2022)and compare the result with BIS drinking water quality standard.

STUDY AREA

Lucknow, the state capital of Uttar Pradesh is situated at an altitude of 123 meters above mean sea level. Lucknow covers an area of 3244 Km^2 with a population of 3.4704 million (Census of India, 2011). It receives an average precipitation of 896.2 mm between July to September from

South West monsoon winds and occasionally from frontal rainfall occurring in January. Lucknow city generates around 1534 tonnes per day with an average generation rate of 0.39 kg per capita per day.

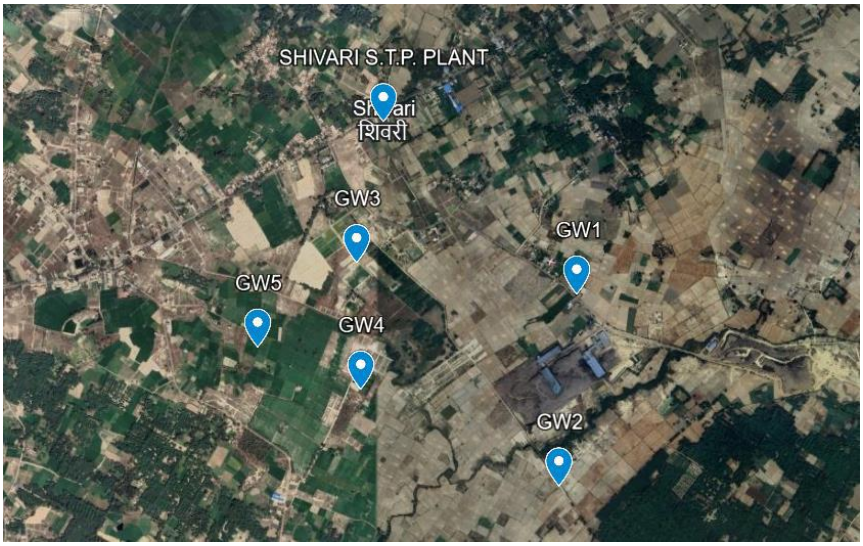

Fig. 1 View of study area (Source: Google earth)

II. MATERIALS AND METHOD

The samples of leachate as well as groundwater were collected from 5 locations. The water samples are collected in clean 1 litres plastic bottles, rinsed properly before taking the samples from the sampling points. The duration of taking leachate sample was between November 2021 to April 2022 and one sample per month was taken from the base of the landfill site. The leachate was collected from the outlet pipe which drains out the leachate from the disposal site to the nearby drainage system.

The groundwater sampling was done at different 5 locations nearby the Shivari landfill area from November 2021 to April 2022 and three samples were collected from each sampling location. All the samples of groundwater were taken randomly from the handpumps installed nearby localities of the landfill. Samples were immediately transferred to the laboratory and were stored under refrigeration.

Table 1: Details of Sampling Point

S.No	Sample Code	Source of Sample
1	GW1	Tube well
2	GW2	Handpump
3	GW3	Handpump
4	GW4	Handpump
5	GW5	Handpump

All the samples of leachate as well as groundwater were analyzed for physical parameters, chemical parameters as well as for estimating the heavy metals concentration. The leachate samples were examined for pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Electrical Conductivity (EC), Salinity, Total hardness, Alkalinity, Chemical Oxygen Demand (COD), Chloride (Cl), Sulphates (SO_4), Nitrate (NO_3), Total Phosphate (TP), Sodium (Na), Potassium(K), Calcium(Ca), Magnesium(Mg), Iron (Fe), Copper (Cu), Cadmium (Cd), Chromium (Cr), Zinc (Zn), Manganese (Mn), Nickel (Ni).

Table 2: Instruments and Methods used for analysis

S.No.	Parameters	Instruments
1.	Ph	Hanna Instruments Phep Pocket Sized Ph Meter
2.	Total Dissolved Solids	Thermo Orion A329 Multi Meter
3.	Total Suspended Solids	Whatmann 40 Filter Paper
4.	Electrical Conductivity	Thermo Orion A329 Multi Meter
5.	Salinity	Thermo Orion A329 Multi Meter
6.	Chloride	Volumetric Titration
7.	Hardness	Volumetric Titration
8.	Chemical oxygen Demand	Cod Digestor

9.	Nitrate	Labtronics Model Lt 290 Spectrometer
10.	Total Phosphates	Labtronics Mode Lt 290 Spectrometer
11.	Sulphates	Labtronics Model Lt 290 Spectrometer
12.	Sodium	Systronics Flame Photometer 128
13.	Calcium	Systronics Flame Photometer 128
14.	Potassium	Systronics Flame Photometer 128
15.	Lithium	Systronics Flame Photometer 128
16.	Iron	Novaa 350 Analytik Jena
17.	Copper	-do-
18.	Cadmium	-do-
19.	Zinc	-do-
20.	Chromium	-do-
21.	MANGANESE	-do-
22.	NICKEL	-do-

III. RESULTS AND DISCUSSION

LEACHATE ANALYSIS: Physical and chemical properties of the leachate are directly related to the waste composition of the landfill and also on the precipitation. The minimum, maximum, average along with the standard deviation is evaluated for each parameter and these values are compared with the general standards for discharge of environmental pollutants in inland surface water body, by Central Pollution Control Board, Lucknow. The parameters analyzed from the experiments conducted in the laboratory have shown in the Table 3.

Table 3: Characteristics of Shivari Leachate Sample

S.No.	Parameters	Leachate Samples			CPCB
		Min	Max	Mean ± STD DEV	
1.	Colour	Black	Black	Black	-
2.	Odour	Offensive	Offensive	Offensive	-
3.	pH- value	7.7	8.3	7.9± 0.233	5.5-9
4.	Electrical Conductivity (µS/cm)	39602	45800	42500 ± 2155	-
5.	Salinity (mg/l)	176	232	200 ± 24	-
6.	Total Suspended Solids (mg/l)	8096	9100	8660± 338	100
7.	Total Dissolved Solids (mg/l)	19165	25830	20980 ±2436	-
8.	Total hardness(mg/l)	4264	5320	4800 ± 357	-
9.	Calcium hardness (mg/l)	1353	1602	1440 ± 119	-
10.	Magnesium hardness (mg/l)	2994	3718	3360 ± 241	-
11.	Alkalinity (Bicarbonate)(mg/l)	3210	4295	3660 ± 381	-
12.	Chemical Oxygen Demand (mg/l)	7738	8240	8040 ± 168	250
13.	Chloride (mg/l)	3758	5770	4800 ± 704	-
14.	Nitrate (mg/l)	179	212	193.5± 12.9	10
15.	Total Phosphate(mg/l)	122	221	160.70 ± 35.4	5

GROUNDWATER ANALYSIS: The groundwater of the studied area is utilized for washing, cleaning and other domestic purposes except drinking. All the water samples are collected from the handpumps near the landfill locality. The samples collected were analyzed for its physico-chemical characteristics along with heavy metal concentrations. The following table shows the results of the laboratory analysis of groundwater samples. The mean, maximum, minimum and standard deviation for each water quality parameter analyzed for all the samples are shown in (Table 4)

Table 4: Physical & Chemical Characteristics of Groundwater Samples

S.No.	Parameters	Groundwater Samples			Standards	
		Min	Max	Mean	BIS	WHO
1.	Ph	6.8	7.3	7.02±0.12	6.5-8.5	6.5-8.5
2.	TDS (mg/l)	736	2918	1308.67±447	500	1000
3.	EC (µS/cm)	1936	5230	2830.55±705	-	1400
4.	Salinity(mg/l)	1.108	3.218	1.883±0.513	-	-
5.	Chloride(mg/l)	142	1180	419.11±168	250	250
6.	Total Alkalinity(mg/l)	185	1695	541.52±304	200	200
7.	Total Hardness(mg/l)	167.5	522.5	303.33±71	200	500
8.	Calcium(mg/l)	72.5	292.5	139.28±44	75	200
9.	Magnesium(mg/l)	88.6	268.9	164.04±36	30	50
10.	Sulphate(mg/l)	76.582	170.17	132.55±23	200	250
11.	Nitrate(mg/l)	4.27	33.60	15.16±7.06	45	50
12.	Total Phosphate(mg/l)	0.018	0.513	0.222±0.117	-	-
13.	Sodium(mg/l)	123.8	874.1	341.55±149	-	200
14.	Potassium(mg/l)	107.5	420.5	187.50±71	-	200
15.	Iron(mg/l)	0.117	0.502	0.257±0.07	0.3	0.05-0.3

CORRELATION ANALYSIS FOR WATER QUALITY PARAMETERS: Correlation is a technique to assess the degree of interrelation and alliance between two variables. A correlation value of +1 indicates a perfect positive relation between two variables while -1 indicates the inverse relationship of the variables. A value of 0 shows no relationship between the variables (Kanmani & Gndhimathi, 2013). The value from 0.5 to +1 shows moderate relationship between the respective parameters. Table 4.5 represents the Pearson correlation coefficient matrix among the physical and chemical parameters evaluated from the groundwater samples near the Shivari landfill site. A fairly good correlation was observed between TDS & EC, TDS & Cl^-, EC & Cl^-, Na^+ & Cl^-, Na^+ & EC, Mg^{+2} & Ca^{+2}, showing all of them have similar source. Few parameters show moderate relationship like K & TDS, K^+ & EC, Ca^{+2} & Mg^{+2}, Na^+ & Mg^{+2}, Mg^{+2} & SO_4^{-2}, and Na^+ & K^+. Many parameters show good correlation with conductivity because conductivity increases with dissolution of metals through ion exchange oroxidation-reduction reaction in a groundwater aquifer system (Subba Rao 2002).

Table 5: Pearson Correlation coefficient matrix for water quality parameters of groundwater

	TDS	*EC*	*Cl^-*	*Mg^{+2}*	*Ca^{+2}*	*-2 SO_4*	*$-$ NO_3*	*TP*	*Na^+*	*K^+*
TDS	1									
EC	0.990767	1								
Cl^-	0.927759	0.953984	1							
Mg^{+2}	0.43306	0.452004	0.463588	1						
Ca^{+2}	0.275395	0.280074	0.321824	0.857605	1					
-2 SO_4	0.17373	0.176115	0.197736	0.725428	0.750554	1				
$-$ NO_3	-0.11929	-0.14765	-0.2166	0.074895	0.097202	-0.07678	1			

TP	0.101828	0.104404	0.02134	-0.04965	0.099693	-0.1313	-0.08335	1		
Na^+	0.941374	0.957121	0.970627	0.464059	0.290694	0.237118	-0.16699	0.03719	1	
K^+	0.667901	0.645345	0.568199	0.340243	0.320903	-0.05629	0.115491	0.151866	0.605704	1

The Pearson correlation coefficient matrix for heavy metals found in groundwater analysis of Shivari landfill area is presented in Table 5. The relationship between the heavy metals studied offer remarkable information on the sources and pathway of the heavy metals. The metals have shown that there is hardly any relativity between each others as values were neither near -1 or +1. However Cadmium and chromium has shown direct relation (r=0.982625) which means they are directly proportional to each other.

IV. CONCLUSIONS

The disposal of solid waste is made in a rampant way in the Shivari landfill site of Lucknow is major problem identified in the present study. In November 2002, the Shivari relocation outpost was created for about eleven clusters on the excuse of beautification of the city near the present disposal site due to which waste generated by these colonies was dumped in a chaotic ill mannered way.

The next greatest menace due to the Shivari landfill site is the generation of considerable quantity of leachate, which is been generated when the waste thrown in the landfill makes contact with the water through atmospheric precipitation and moisture.

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