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Hydrological Implication of Municipal Solid Waste Disposal on Groundwater Quality at Thirupperunthurai, Batticaloa

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Abstract

The present study focused on characterization of leachate generated from Thirupperunthurai dumpsite and ascertaining the magnitude of dumpsite pollution on groundwater quality. The leachate and well water samples from the vicinity of dumpsite were collected and analysed for some physicochemical parameters such as pH, Dissolved Oxygen (DO), Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Nitrate and Phosphate. The results showed that the leachate at dumpsite is in methanogenic phase with high concentration of pollutants. The pH of well water samples ranged from 6.5-8.2. The DO, EC, TDS, TH, Nitrate and Phosphate ranged from 2.86 mg/l - 4.93 mg/l, 240 µS/cm - 2686 µS/cm, 120 mg/l - 1340 mg/l, 66 mg/l - 207 mg/l, 43 mg/l - 172 mg/l and 0.31 mg/l - 1.47 mg/l, respectively. Groundwater flow direction greatly influences on level of pollution in well water near the dumpsite. Water quality parameters except pH and TH exceeded the maximum allowable limits for drinking purpose at some locations. Positive correlation was found between parameters except DO. Further, tested parameters except DO showed negative correlation with distance from dumpsite. Overall, groundwater in this study area is polluted by generated leachate, especially in the vicinity of the dumpsite. Therefore, existing dumpsite should be upgraded to a well-engineered standard landfill to prevent future contamination of groundwater in this area.

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1. Introduction

Generation of solid waste due to various anthropogenic activities is inevitable. A huge amount of solid waste is being generated every year in the world and the generation of this municipal solid waste (MSW) has been accelerated due to rapid increase in population growth and industrialization, and changes in peoples' lifestyle. Appropriate management of this generated solid waste is therefore vital to avoid environmental pollution and associated human health problems. In most of the developing countries, generated solid waste is being dumped on open lands. This method of waste dumping poses serious threats to surface and groundwater water resources. On the other hand, municipal solid waste landfills are the engineered systems, designed to protect the environment from contamination. The liner systems in these landfills minimize the migration of contaminants from the wastes. However, some are non-engineered landfills which are neither having any liner nor any leachate collection and treatment system. Therefore, the leachate generated in such landfills finds its way into the surrounding environment.

Landfill leachate is the liquid which is generated on account of the infiltration of water into the waste disposal sites and percolation through waste as well as by the squeezing of the waste due to self-weight. Waste deposited in landfills or on garbage dumps immediately becomes part of the prevailing hydrological system (Taylor and Allen, 2006). Fluid derived from rainfall and groundwater, together with liquids generated by the waste itself through the processes of hydrolysis and solubilization, brought about by a whole series of complex biochemical reactions during degradation organic wastes, percolate through the deposit and mobilize other components within the wastes. The leachate generated in such a way has high content of organic matter, electrical conductivity (EC) and high concentration of nitrogen, phosphorous, toxic compounds, heavy metals and pathogenic microorganisms. However, the composition of leachate varies with different sites and environmental conditions, depending on nature/composition of the deposited wastes, elapsed time, soil characteristics, rainfall pattern, temperature, available oxygen (Kamboj and Choudhar, 2013) and age of the landfill. Besides, dumpsite operations also play a significant role on the quality of leachate. In many parts of the world, these landfills have been identified as one of the major sources of groundwater pollution as the leachate, accumulated at the bottom of the landfill, percolates through the soil and reaches the groundwater (Mor et al., 2006).

Municipal solid waste dumpsite at Thirupperunthurai is being operated by the Batticaloa Municipal Council. Waste dumping has been carried out continuously for several years in this area. In general, collected waste comprises of garbage as well as fecal deposition. Hence, there is high risk of groundwater contamination. People in the vicinity of this dumpsite use groundwater for drinking and domestic purposes. There has been a suspicion that groundwater might have been polluted in this area due to improper design and management operations of the solid waste. In the above context, the present study aimed at characterizing the leachate generated from Thirupperunthurai dumpsite, assessing temporal and spatial variations of groundwater quality around the landfill site and identifying hot spots of groundwater contamination due to migration of leachate from the dumpsite.

2. Materials and Methods

2.1 Study area and sampling

The present study was carried out at the municipal solid waste dumpsite, Thirupperunthurai in Batticaloa district. The latitude and longitude of the study area are $7^{o}43'$and $81^{o}45'$, respectively. The annual rainfall varies from 865 mm to 3080 mm while temperature varies from 22^{0}C to 37^{0}C. This dumpsite is in a rural area, administrated by Manmunai North Divisional Secretariat division.

The present study was carried out in dry season from June – August, 2018. Leachate sample was collected and analyzed to assess its characteristics. In addition, monthly well water samples at fifteen locations (W1-W15) near the dumpsite were collected for physicochemical analysis. Figure 01 shows location of dumpsite and well water sampling locations.

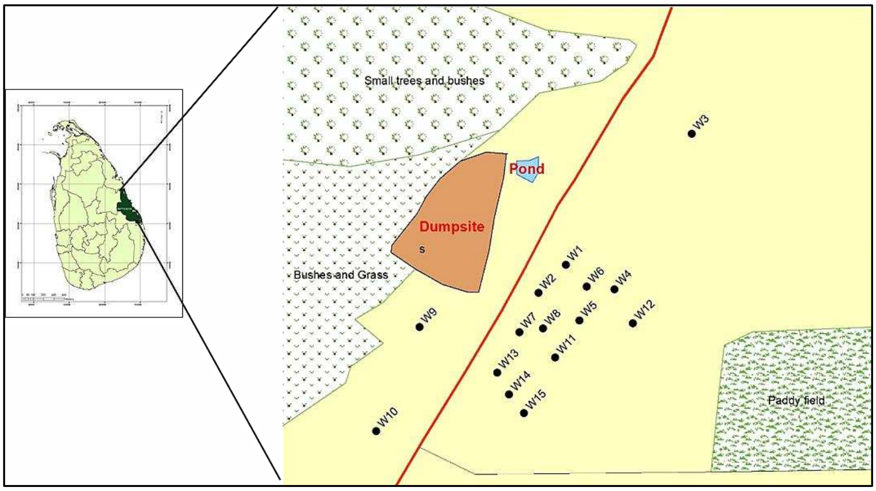

Figure 01: Location of dumpsite and sampling locations

Well water samples were collected in 1 litre sterilized polyethylene bottles and stored at 4^{0}C before laboratory analysis. The details of sampling distance from the dumpsite and well water depth are presented in Table 01.

2.2 Analysis of water samples

The collected water samples were analysed for some important water quality parameters by following accepted procedures and standard methods (APHA, 1999). Water quality parameters such as pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) were taken in-situ using digital pH/EC/TDS Meter (Model HI 98130). Dissolved oxygen was analyzed by DO meter (model: Sension TM^{+} DO6). Calcium was analyzed by complex metric titration method using 10% of NaOH and Calcon as an indicator. Total Ca^{2+} and Mg^{2+} concentration were determined using NH_4Cl and NH_4OH as a buffer and Eric Chrome Black T (EBT) as an indicator. From which the Magnesium concentration was found by subtracting from the total concentration of Ca^{2+} and Mg^{2+} (USDA HANDBOOK 60). Nitrate and Phosphate were analyzed using Spectrophotometer (Model: HACH 2010).

Table 01: Distance of sampling points and well water depth during study period

Wells	Distance from the dumpsite (m)	Depth to water level in wells (m)		
		June	July	August
W1	152	1.80	1.89	2.05
W2	140	1.47	1.55	1.69
W3	327	1.42	1.50	1.63
W4	222	1.61	1.69	1.84
W5	203	1.99	2.08	2.26
W6	188	2.12	2.23	2.42
W7	163	2.12	2.23	2.34
W8	177	1.48	1.56	1.69
W9	142	1.69	1.78	1.96
W10	288	2.73	2.87	3.11
W11	216	1.51	1.59	1.72
W12	263	1.49	1.57	1.70
W13	200	2.11	2.22	2.34
W14	232	2.08	2.21	2.40
W15	261	2.10	2.19	2.38

2.3 Statistical analysis

Descriptive statistical analysis was done using Statistical Package for Social Sciences software package. Graphical presentation of results was done using Microsoft Excel Software.

3. Results and Discussion

3.1 Leachate characterization

In this study, leachate sample of Thirupperumthurai dumpsite was characterized in terms of pH, DO, EC, TDS, total hardness (TH), calcium, magnesium, nitrate and phosphate. In general, chemical composition of landfill leachate depends on several factors such as solid waste composition, landfill management, age of the waste, hydro-geological conditions in and around the landfill site, rate of water flow through the waste, landfill chemical and biological activities, seasonal weather variations and temperature, pH and moisture content of landfill. The pH of landfill leachate was 8.5, indicating that the leachate is in methanogenic phase (Table 02). The pH of young leachate is found to be less than 6.5 due to high concentration of volatile fatty acids. However, stabilized leachate shows fairly constant pH with little variations and it may vary from 7.5-9. Further, DO was 0.2 which shows oxygen deficiency in the leachate.

The level of TDS reflects the extent of mineralization while EC represents the ability of water to carry an electrical current. In general, both EC and TDS are influenced by the total amount of dissolved organic and inorganic materials. The leachate sample was found to have high concentration of EC (10820 μS/cm) and TDS (5487 mg/l). Water hardness is another parameter that reflects the amount of calcium and magnesium compounds present in water. The TH of leachate sample was 266 mg/l. The concentration of Ca^{2+} and Mg^{2+}

ions influences its hardness. The values of Ca^{2+} and Mg^{2+} in leachate were 416 mg/l and 223 mg/l, respectively. In addition, nitrate and phosphate levels were 678 mg/l and 135 mg/l, respectively. Hence, treatment of leachate generated from this dumpsite is vital to remove pollutants before discharge into environment. Coagulation/flocculation process and constructed wetland could be a viable option to remove contaminants from the leachate (Thivyatharsan and Rajendran, 2017).

Table 02. Characteristics of leachate sample of Thirupperunthurai dumpsite

No	Parameters	Unit	Values
1	pH	-	8.5
2	EC	µS/cm	10820
3	TDS	mg/l	5487
4	TH	mg/l	266
5	DO	mg/l	0.2
6	Ca^{2+}	mg/l	416
7	Mg^{2+}	mg/l	223
8	NO_3^-	mg/l	678
9	PO_4^{3-}	mg/l	135

3.2 Physicochemical characteristics of well water

Figure 02 shows variation of pH in well water samples during study period. Accordingly, the pH of well water ranges from 6.5 – 8.2 with an average value of 7.4. The lowest pH values were observed at W10 during study period. However, the pH of all well water samples falls within the allowable range of 6.5-8.5 (WHO, 2017).

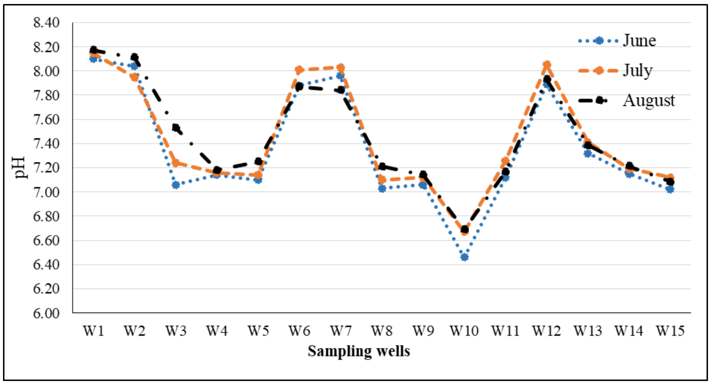

Figure 02: Variation of pH in well water samples during study period

The DO level of well water samples ranged from 2.86 mg/l – 4.93 mg/l. There was high spatial variation in DO levels. However, temporal variation was insignificant. The wells closer to the dumpsite show low level of DO, indicating presence of pollutants that use up the oxygen in water.

Generally, amount of dissolved solids in water determines the EC. According to WHO (2004), maximum permissible limit of EC for drinking water is 1000 µS/cm. The level of EC in well water samples varied from 240 µS/cm -2686 µS/cm with an average value of 1269 µS/cm (Table 03). It indicates that the level of EC in well water exceeds the maximum permissible limit for drinking purpose. This is consistent with results obtained by Sugirtharan and Rajendran (2015). The higher values of EC were observed in wells near the dumpsite. The

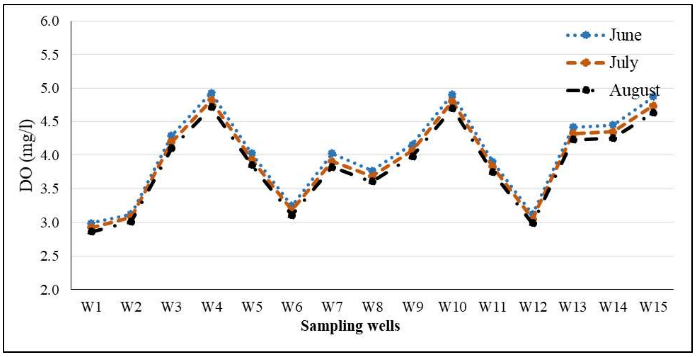

Figure 03: Variation of DO in well water samples during study period

well W12, which is closer to agriculture field, was also showed high level of EC. However, the EC level at W3, W4, W9, W10, W13, W14 and W15 was within the acceptable limit during study period.

Table 03. Spatial and Temporal variation of EC (µS/cm) in well water samples near the Thirupperunthurai dumpsite

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
June	2330	2350	860	520	950	2370	1500	1370	920	240	1120	2180	774	678	534
July	2610	2270	820	600	970	2380	1550	1240	970	260	1161	2205	782	680	543
August	2686	2170	832	618	1024	2421	1632	1256	956	332	1173	2227	791	687	552

The TDS comprise of inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and small amounts of organic matter that are dissolved in water. The concentration of TDS in water reveals the nature of quality or its salinity. The TDS of well water samples varied from 120 mg/l -1340 mg/l. The highest TDS value was recorded at W1 while the lowest value was observed at W10 during study period (Table 04). The TDS value decreases with distance from the dumpsite. However, it depends on groundwater flow direction. For an instance, the TDS level was higher at W3 than level observed at W10 during study period. Further, TDS levels at W1, W2, W6, W7, W8 and W12 exceeded the desirable limit of 600 mg/l for drinking purpose (WHO, 2017).

Table 04. Spatial and Temporal variation of TDS (mg/l) in well water samples near the Thirupperunthurai dumpsite

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
June	1160	1170	430	260	480	1180	750	680	460	120	564	1092	388	339	268
July	1310	1130	410	300	480	1180	780	620	480	130	578	1102	392	337	275
August	1340	1066	416	309	519	1202	816	628	472	163	586	1112	398	343	276

Water hardness is an indication of deposits of calcium and/or magnesium ions. Total hardness (TH) is normally expressed as the total concentration of Ca^{2+} and Mg^{2+} in mg/L, equivalent $CaCO_3$. Based on the hardness, water can be classified into soft (0 – 75 mg/l), moderately hard (75 – 150 mg/l) and hard (151 – 300 mg/l) (Sawyer

1960). Total hardness of well water samples ranged from 66 mg/l -207 mg/l with an average value of 148 mg/l (Table 05). It indicates that the well water in this study area is moderately hard. Higher values were observed near the dumpsite. However, the values are within the maximum allowable limit of 500 mg/l (WHO, 2008).

Table 05. Spatial and Temporal variation of TH (mg/l) in well water samples near the Thirupperunthurai dumpsite

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
June	197	188	127	122	135	191	164	124	127	66	160	174	136	142	118
July	203	192	129	125	137	195	167	126	129	70	164	178	139	145	121
August	207	195	131	126	139	198	170	128	131	71	166	181	141	147	123

Nitrates are potential threat to groundwater pollution. High nitrate concentration has detrimental effects on infants less than three to six months of age (Longe and Balogun, 2010). The nitrate concentration in well water samples ranged from 43 mg/l – 172 mg/l (Table 06). The nitrate level exceeds the maximum allowable limit of 50 mg/l (WHO, 2008). The common sources of nitrate in water samples at study area might be the leachates from the open dumpsite, local agricultural fields or domestic sewage pits.

Table 06. Spatial and Temporal variation of Nitrate (mg/l) in well water samples near the Thirupperunthurai dumpsite

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
June	149	151	91	159	49	154	117	100	96	43	102	148	87	75	52
July	151	156	98	165	59	158	122	109	103	48	105	148	91	76	56
August	154	160	99	172	62	164	127	105	106	55	105	149	91	78	57

High concentration of phosphate in drinking water may cause digestive problems in humans and animals. It was found that the phosphate level in well water samples ranged from 0.31 mg/l- 1.47 mg/l with an average value of 1.02 mg/l (Table 07). High concentration was observed near the dumpsite and agriculture field. Further, phosphate level in well water exceeds the maximum allowable limit of 0.5 mg/l.

Table 07. Spatial and Temporal variation of Phosphate (mg/l) in well water samples near the Thirupperunthurai dumpsite

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
June	1.26	1.21	0.46	1.31	0.54	1.27	1.18	1.04	0.98	0.31	1.08	1.18	0.76	0.92	1.01
July	1.28	1.22	0.50	1.34	0.61	1.32	1.26	1.08	1.02	0.35	1.08	1.21	0.85	0.98	1.07
August	1.29	1.31	0.57	1.47	0.68	1.36	1.35	1.13	1.15	0.40	1.11	1.24	0.89	1.01	1.12

Table 08 shows descriptive statistics of physicochemical parameters in groundwater samples during the study period. Accordingly, concentration of tested parameters slightly increases over the time during dry period. Further, CV (Coefficient of variation) value of pH, DO, EC, TH, nitrate and phosphate decreases with time.

Table 08. Descriptive statistics of physicochemical parameters in groundwater samples

Parameters	June					July					August				
	Min	Max	Mean	SD	CV	Min	Max	Mean	SD	CV	Min	Max	Mean	SD	CV
pH	6.46	8.10	7.36	0.49	6.7	6.67	8.15	7.44	0.46	6.2	6.69	8.17	7.45	0.43	5.8
DO	2.99	4.93	4.02	0.66	16.5	2.92	4.82	3.93	0.64	16.4	2.86	4.72	3.84	0.63	16.4
EC	240	2370	1246	735	59.0	260	2610	1269	754	59.4	332	2686	1290	753	58.3
TDS	120	1180	623	366	58.7	130	1310	634	376	59.4	163	1340	643	374	58.1
TH	66	197	145	35	24.0	70	203	148	35	23.8	71	207	150	36	23.9
Nitrate	43	159	105	40	38.3	48	165	110	40	36.1	55	172	112	40	35.8
Phosphate	0.31	1.31	0.97	0.31	32.5	0.35	1.34	1.01	0.31	30.4	0.40	1.47	1.07	0.31	29.2

SD – Standard Deviation, CV –Coefficient of Variation

3.3 Relationship between water quality parameters and distance

Table 09 shows correlation coefficients of water quality parameters. Out of the total 21 correlations found between quality parameters, 20 were found to have significant. The pH showed strong positive correlation with EC, TDS, TH, and Nitrate. The DO showed negative correlation with all parameters. The EC showed strong positive correlation with TDS, TH and nitrate. TDS showed strong positive correlation with TH and nitrate. A strong positive correlation was observed between nitrate and phosphate. Further, water quality parameters except DO showed negative correlation with distance. The TH and phosphate showed significant negative correlation with distance. It reveals that the pollution levels decreases with distance from the dumpsite in this study area.

Table 09. Relationship between water quality parameters and distance

	PH	DO	EC	TDS	TH	Nitrate	Phosphate	Distance
PH	1							
DO	-.827**	1						
EC	.910**	-.964**	1					
TDS	.911**	-.964**	1.000**	1				
TH	.929**	-.868**	.906**	.907**	1			
Nitrate	.757**	-.625*	.742**	.741**	.721**	1		
Phosphate	.600*	-.429	.563*	.563*	.646**	.758**	1	
Distance	-.440	.496	-.505	-.504	-.527*	-.427	-.593*	1

**. Correlation is significant at the 0.01 level. *. Correlation is significant at the 0.05 level.

4. Conclusions

The present study found that the leachate generated from the dumpsite has high concentration of pollutants.

Concentration of EC, TDS, nitrate and phosphate in well water near the dumpsite exceeds the maximum allowable limits for drinking purpose. Contaminant concentration was high near the dumpsite. However, groundwater flow direction influences level of contaminants in groundwater. Further, there is a positive correlation between major water quality parameters. Therefore, it is recommended to upgrade the existing dumpsite to a well-engineered standard landfill to avoid future contamination of groundwater in this area.

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