GROUND WATER QUALITY NEAR MUNICIPAL SOLID WASTE DUMPING SITE AT THIRUPPERUMTHURAI, BATTICALOA

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ABSTRACT

Groundwater is a precious natural water resource considered as a readily available and safe source of water for domestic, agriculture and industrial uses. In Sri Lanka, groundwater is being polluted due to various human activities. Improper solid waste management is one of the major sources of environmental pollution deteriorating groundwater quality around landfill sites. In this view, present study was carried out to assess the impact of existing landfill site on groundwater quality at Thirupperunthurai, Batticaloa. In order to achieve this, 20 well water samples around landfill site at different distance were analyzed. Parameters analyzed are pH, EC, TDS, BOD, COD, total hardness, phosphate, nitrate, copper, lead and coliform population. Results revealed that concentration of all the parameters except for pH, are higher than acceptable limits for safe drinking water. The distance from the landfill site also influences on groundwater quality. Overall, the groundwater is highly polluted due to existing landfill site in this study area. Therefore, the relevant authority should take immediate measures to rescue this area.

Keywords: *Groundwater, Leachates, Municipal Solid Waste, Water Quality*

INTRODUCTION

At present, Municipal Solid Waste (MSW) is become as global issue. A huge amount of solid waste is being generated every year in the world. However, generation of waste due to various human activities is inevitable. In most of the developing countries, MSW are being dumped on land without adopting any acceptable sanitary land filling practices (Kumar and Singh, 2013). These landfills have been identified as one of the major sources of groundwater deterioration because leachate accumulates at the bottom of the landfill and percolates through the soil and reaches the groundwater (Mor *et al*., 2006). The leachate generated in such a way has high concentration of toxic substances and pathogenic microorganisms. However, concentration of these elements and compounds in leachate and the groundwater surrounding it depends on the composition of wastes dumped (Alker *et al*., 1995).

The Batticaloa Municipal Council operates an open waste dumping site at Thirupperunthurai. And they are in the process of establishing landfill system in the same land. However, during this study the solid waste were dumped in an open place near proposed landfill site. This garbage dumping has been carried out continuously several years in this region without any sort of proper management. Moreover, not only the garbage but fecal deposition also takes place in that region. Hence, there is high risk of groundwater contamination. Since people residing near this dump-site use the ground water for their drinking and agriculture purposes, it is essential to study the impact of this open dumping on groundwater quality that would be valuable data to undertake proper management decision in future. This study therefore aimed to assess the impact of municipal solid waste dumping-site on well water quality in the vicinity of Thirupperunthurai area of Batticaloa.

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MATERIALS AND METHODS

Description of study area

The study was conducted at the municipal solid waste dump-site at Thirupperunthurai, Batticaloa during October 2010 to March 2011 (Figure 01). It is located in the Eastern province of Sri Lanka (longitude of 7^0 43' and East latitude of 81^0 45') and bounded in the North by Verugal River and on the East by Bay of Bengal. Study period covered the monsoon season started in November 2010 and continued until February 2011 which caused the flood in early January 2011. The annual rainfall varies from 865 mm to 3080 mm while temperature varies from 22^0C to 37^0C (Statistic hand book, 1995). The dump-site Thirupperumthurai is a rural area administrated by Manmunai North Divisional Secretariat division.

Site selection and sampling

Shallow wells (semi-protected wells) which draw water from unconfined aquifer at twenty locations namely W1 to W20 (Figure 01) were selected to collect monthly water samples during October 2010 to March 2011. These all locations were selected from the surrounding area of the municipal dumping site (within 600 m distance from the dump-site). The water samples were collected in well cleaned autoclaved bottles. The bottles prior to take water sample were rinsed several times with sample water. Electrical conductivity (EC), Total Dissolved Solids (TDS) and pH were measured immediately after collection and then, the samples were immediately transferred to the laboratory and stored at temperature below 4^oC for the analysis of other parameters.

Analytical methods

Water quality parameters such as pH, EC and TDS were measured at the site using digital pH/EC/TDS Meter (Model HI 98130). Spectrophotometer (HACH 2010) was used to measure COD, Phosphate and Nitrate. Winkler's method was adopted to estimate BOD. Heavy metals and total hardness were analysed using atomic absorption spectrophotometer (AAS) and Versenate method respectively. The coliform analysis was done immediately after collection of samples by a statistical estimation called Most Probable Number method (MPN) using MacConkey broth (Collins *et al*., 1976).

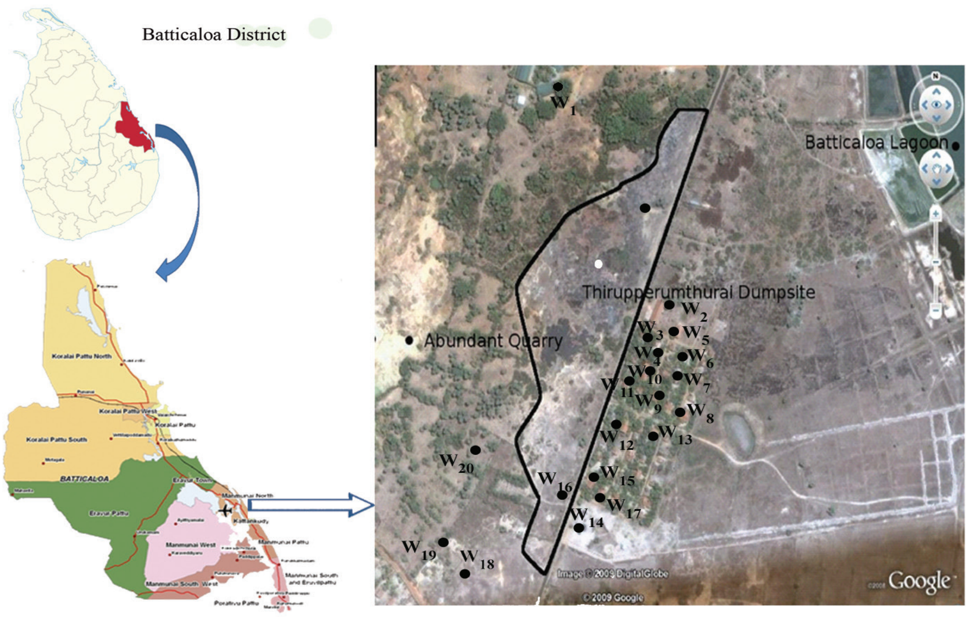

Figure 01: Sampling locations at the study area.

Statistical analysis

Descriptive analysis was done using Statistical Package for Social Sciences (SPSS 16.0) software package. Graphical presentation of results was done using Microsoft Excel Software.

RESULTS AND DISCUSSION

Physico-chemical characteristics:

The results show that the pH of well water ranges from 6.8 to 8.9 (Figure 02 and Figure 04) with an average concentration of 7.3, and the pH remains within the allowable WHO range of 7.0 – 8.5. Hence, the pH of the well water would not adversely affect its uses in this area. The Electrical Conductivity (EC) of the well water was high in range from 163 and 1744µS/cm across different period with an average concentration of 653µS/cm (Table 01). The highest desirable level of EC at 25^{0}C is 750µS/cm (SLS,1983). A high value of EC indicates high concentration of anions and cations. The water samples near dumping site (W1, W2 & W3) had high concentration of EC and exceeded the highest desirable level. It is a clear indication of the effect of dumping site on the groundwater quality. Similarly, Total Dissolved Solids (TDS) were high in the range of 81 and 872 mg/L across different period of study in the study area (Table 2). The highest values of TDS were recorded at W1, W2, W3 and W4 which are very closer to the dump-site and exceeded the maximum allowable limit of 250mg/L for drinking water (WHO, 1997). The concentration of EC and TDS were high during the months of January and February irrespective of well location. The presence of high amount of inorganic materials might have attributed for highest values of TDS in the well water sampled near to the dumping site. Olaniya and Saxena (1977) reported that the groundwater pollution from the vicinity of the dumping sites is detectable through the increased TDS concentration in water.

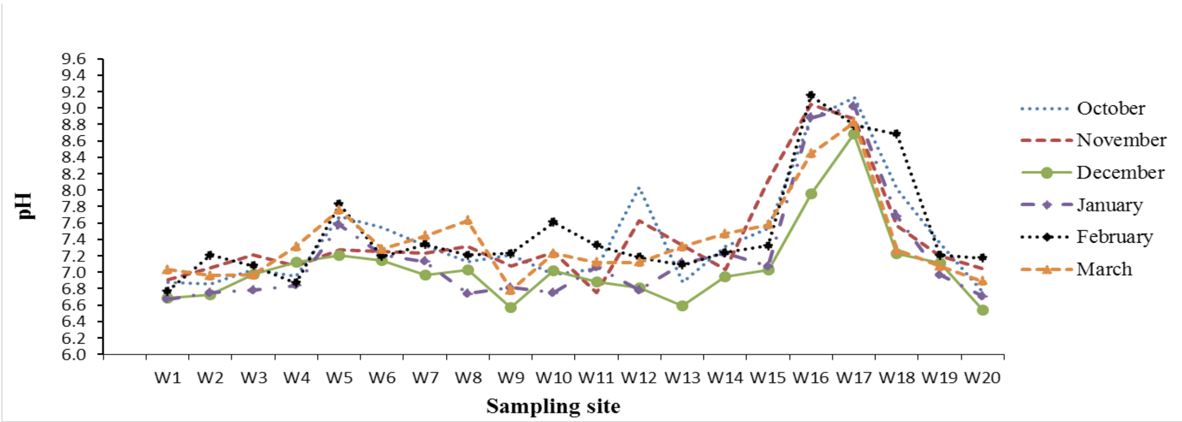

Figure 02: Temporal Variation of pH in groundwater samples during study period

Table 01: Variation of EC (µS/cm) in the groundwater near the dumping site during study period

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
October	1573	1623	1312	888	583	567	475	605	597	543	382	512	177	183	565	588	268	323	342	217
November	1603	1678	1201	950	680	601	521	592	617	574	394	547	163	197	591	610	273	377	327	201
December	1698	1744	1197	997	711	617	532	644	675	679	473	643	207	244	630	681	307	412	378	242
January	1712	1733	1252	1012	702	665	527	651	681	681	487	632	241	261	652	706	331	432	376	238
February	1623	1645	1192	937	697	572	478	608	612	623	423	563	175	241	605	623	287	389	357	220
March	1637	1589	1271	927	692	596	501	593	592	595	402	550	188	234	587	618	269	393	341	213

Table 02: Variation of TDS (mg/L) in the groundwater near the dumping site during study period

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
October	786	813	657	443	295	284	236	302	298	271	191	256	89	91	283	294	134	161	171	109
November	802	837	601	475	342	301	260	297	308	286	197	273	81	98	295	305	136	188	163	101
December	849	872	598	497	355	304	266	322	338	340	237	324	103	121	315	341	153	205	189	121
January	857	866	625	507	354	332	261	325	340	341	243	315	118	129	327	354	166	217	188	119
February	813	822	598	469	347	286	241	304	307	311	211	283	88	122	303	313	143	195	179	110
March	817	793	633	465	351	298	250	296	297	298	205	273	94	119	293	310	133	195	171	104

Hardness is one of the important properties of ground water from utility point of view particularly for domestic purposes (Adelekan, 2010). The Total Hardness (TH) was found in range of 75 to 351 mg/L, all the analyzed water samples fall within the maximum allowable limit of 400mg/L (Table 3). Highest values were recorded during rainy season. Total hardness is normally expressed as the total concentration of Ca^{2+} and Mg^{2+} in mg/L, equivalent $CaCO_3$. The Figure 4 shows that total hardness is high in the vicinity of the landfill. However, concentration was also high at W17, this may be due to dissolution of polyvalent metallic ions from sedimentary rocks, seepage, and runoff from the adjacent site. Dissanayake et al. (1982) also reported that the maximum hardness indicates the presence of Ca^{2+} and Mg^{2+}, which could due to a substantial contribution from the weathering of more basic rocks in the vicinity.

It was observed that the concentration of phosphates and nitrate were ranged from 0.24 to 1.63 mg/L and 48 to 171 mg/L respectively (Table 04 and 05). The highest phosphate concentration of 1.28, 1.48, 1.63 and 1.42 mg/L were found at W3, W4, W5 and W8 respectively that exceeded the WHO maximum allowable limit of 0.5 mg/L. In addition, the measured values of both parameters were high in January. According to the results, highest concentration of phosphate was found in the vicinity of the dumping site (Figure 4). The results also show that the nitrate concentration of all the analyzed samples exceeded the maximum permissible limit of 45mg/L in the study area (SLS,1983). The common sources of nitrate in water samples at study area might be the leachates from the open dumping sites, local agricultural fields or domestic sewage pits.

Table 03: Variation of TH (mg/L) in the groundwater near the dumping site during study period

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
October	146	186	265	122	118	107	101	147	103	187	125	153	104	75	128	114	253	154	89	97
November	142	191	263	127	131	112	109	159	113	191	122	151	113	81	132	118	265	148	91	102
December	177	226	292	142	163	142	132	172	142	217	156	187	127	92	141	138	315	173	112	127
January	183	241	337	162	158	155	137	183	155	268	162	192	143	104	163	142	351	187	127	139
February	165	213	283	143	121	124	127	164	127	216	144	163	121	86	143	126	326	169	109	121
March	148	191	268	128	113	120	115	157	119	204	131	152	115	78	127	108	267	160	98	102

Table 4: Variation of Phosphate (mg/L) in the groundwater near the dumping site during study period

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
October	0.83	0.32	0.93	1.24	1.31	0.40	0.74	1.28	0.79	0.79	0.76	0.85	0.78	0.24	0.38	0.36	0.46	0.67	0.73	0.56
November	0.87	0.36	0.91	1.29	1.35	0.42	0.71	1.33	0.83	0.83	0.73	0.88	0.81	0.27	0.38	0.38	0.48	0.73	0.75	0.61
December	0.96	0.48	1.12	1.41	1.48	0.54	0.92	1.38	0.91	0.92	0.94	0.93	0.91	0.34	0.42	0.47	0.59	0.84	0.86	0.68
January	1.07	0.57	1.28	1.48	1.63	0.67	1.15	1.42	1.17	1.03	0.97	1.21	0.96	0.41	0.58	0.56	0.63	0.88	0.97	0.73
February	0.91	0.54	0.97	1.27	1.57	0.53	0.94	1.32	0.92	0.92	0.85	1.04	0.87	0.34	0.47	0.51	0.51	0.73	0.82	0.67
March	0.86	0.46	0.94	1.22	1.37	0.48	0.83	1.24	0.88	0.81	0.77	0.95	0.85	0.29	0.43	0.40	0.46	0.71	0.77	0.61

Table 05: Variation of Nitrate (mg/L) in the groundwater near the dumping site during study period

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
October	78	83	107	91	132	69	121	149	95	118	78	117	135	48	54	58	66	72	72	88
November	79	84	103	94	137	72	127	153	98	115	87	121	137	51	57	62	67	76	76	93
December	87	102	118	102	153	82	135	162	104	126	93	132	148	63	61	68	76	81	84	94
January	94	108	127	107	157	87	146	171	113	131	96	143	154	67	74	77	83	93	97	102
February	85	96	116	97	148	78	137	154	96	128	87	134	144	56	59	72	77	71	89	96
March	74	87	109	93	137	73	128	151	93	123	82	125	137	49	55	61	65	68	83	91

Table 06: Variation of BOD (mg/L) in the groundwater near the dumping site during study period

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
October	2.21	2.04	2.86	3.84	5.74	3.14	4.67	6.03	4.22	4.93	4.73	4.24	5.83	1.46	1.86	1.82	1.87	1.93	1.83	2.18
November	2.26	2.15	2.85	3.82	5.82	3.18	4.83	6.01	4.38	5.01	4.75	5.03	5.89	1.52	1.92	1.85	1.91	1.96	1.90	2.34
December	3.61	2.33	3.15	4.43	7.07	3.63	5.86	6.82	5.08	6.13	5.26	6.58	6.53	1.61	2.14	2.07	2.15	2.27	2.11	2.83
January	3.86	2.42	3.49	4.64	7.35	3.71	6.28	7.05	5.37	6.27	5.61	6.87	6.77	1.67	2.26	2.14	2.31	2.78	2.31	3.25
February	2.97	2.34	3.05	4.51	7.13	3.67	5.73	6.53	5.22	5.88	5.12	6.43	6.41	1.63	1.96	2.03	1.94	2.45	1.97	2.85
March	2.76	2.13	2.89	3.94	6.81	3.28	5.12	6.37	4.97	5.13	4.87	5.85	6.04	1.57	1.85	1.87	1.87	2.18	1.84	2.46

Biochemical Oxygen Demand (BOD) is used to determine the quantity of oxygen demanding waste in water. Based on this study, BOD at all sites ranges from 1.46 – 7.35 mg/L and the values were high during monsoon period (Table 06). It is found that BOD remarkably high at sites W5, W 7, W8, W10, W12 and W13. Presence of high concentration of organic matter in the groundwater may be the reason for high BOD in this area. Kim (2005) has reported that the BOD value of 1mg/L is indicates the presence of oxidizable organic contaminants or water of high quality. On the other hand, high BOD values (5 – 10 mg/L) indicate the presence of water with high amount of organic contaminants or water of low quality.

Chemical Oxygen Demand (COD) is a measure of oxygen equivalent to the organic matter content of the water susceptible to oxidize a strong chemical oxidant and thus is an index of organic pollution. The level of COD in the groundwater samples varied from 11 to 71 mg/L and exceeded the SLS maximum permissible level of 10 mg/L (Table 07). Flood increased the COD level in all well water samples. The high concentration of COD was found at the locations closer to the dump-site (Figure 03). Water in this area is contaminated with organic pollutants rendering it not suitable for drinking purpose. Esa (1983) reported drinking water supply should not exceed chemical oxygen demand level of 2.5mg/L and the potable water with greater than 7.5mg/L of COD considered as poor quality. Xiaoli *et al.* (2007) mentioned that most of the organic chemical substances are either degraded through biochemical reactions in the landfill, or leached out from the landfill site with water movement.

Coliform populations

It is an indicator for pathogenic organisms. The number of total coliforms in the samples varied from 2 to 36 per 100ml. The highest number of total coliforms was found at sites W5, W8 and W13, especially in January (Table 08). Coliform bacteria must not be detectable in any 100 ml sample of all water intended for drinking (WHO, 1994). High coliform populations in all the water samples are an indication of poor quality of water. According to the Sri Lankan Standard (SLS, 1983), maximum permissible number of

Coliforms is 10 per 100 ml in drinking water. High concentration of coliform bacteria was found in well water sample closer to dump-site (Figure 04). Stuart and Klink (1999) stated that when leachate diluted with the bacteria-free groundwater there will be an increase in the number of thermo tolerant coliform.

Heavy metals

The level of copper (Cu) and lead (Pb) were ranged from 0.02 to 0.16 mg/L and 0.03 to 0.14 mg/L respectively. Further, the highest concentration of Cu and Pb were observed during the monsoon period. The highest desirable limit of Cu in drinking water is 0.05 mg/L while maximum permissible limit of Pb is 0.05 mg/L (SLS, 1983). The concentration of Cu was found to be remarkably high at sites W5, W7, W8 and W9 while the water samples from W7, W9 and W10 showed high content of Pb (Figure 4). Average concentration of Pb in all locations except W14 and W20 exceeds the maximum permissible limit and thus water in these locations is not suitable for drinking. Heavy metals leached from the dumping sites are usually found in the form of dissolved organic compound complex, particulate and colloid (Oygard *et al*., 2007).

Table 07: Variation of COD (mg/L) in the groundwater near the dumping site during study period

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
October	7	5	7	11	18	8	16	24	16	15	11	16	21	3	5	2	5	7	5	8
November	7	7	8	13	17	11	18	27	18	16	13	18	24	4	6	3	5	7	7	9
December	6	6	9	12	26	9	21	31	21	22	13	19	27	4	7	3	7	9	8	12
January	8	7	10	15	36	10	26	34	23	25	16	23	31	6	7	6	9	12	13	14
February	7	6	9	17	28	15	19	27	17	21	18	26	36	9	9	4	8	9	10	11
March	5	5	8	14	24	12	17	26	15	20	15	18	26	7	6	3	7	7	8	9

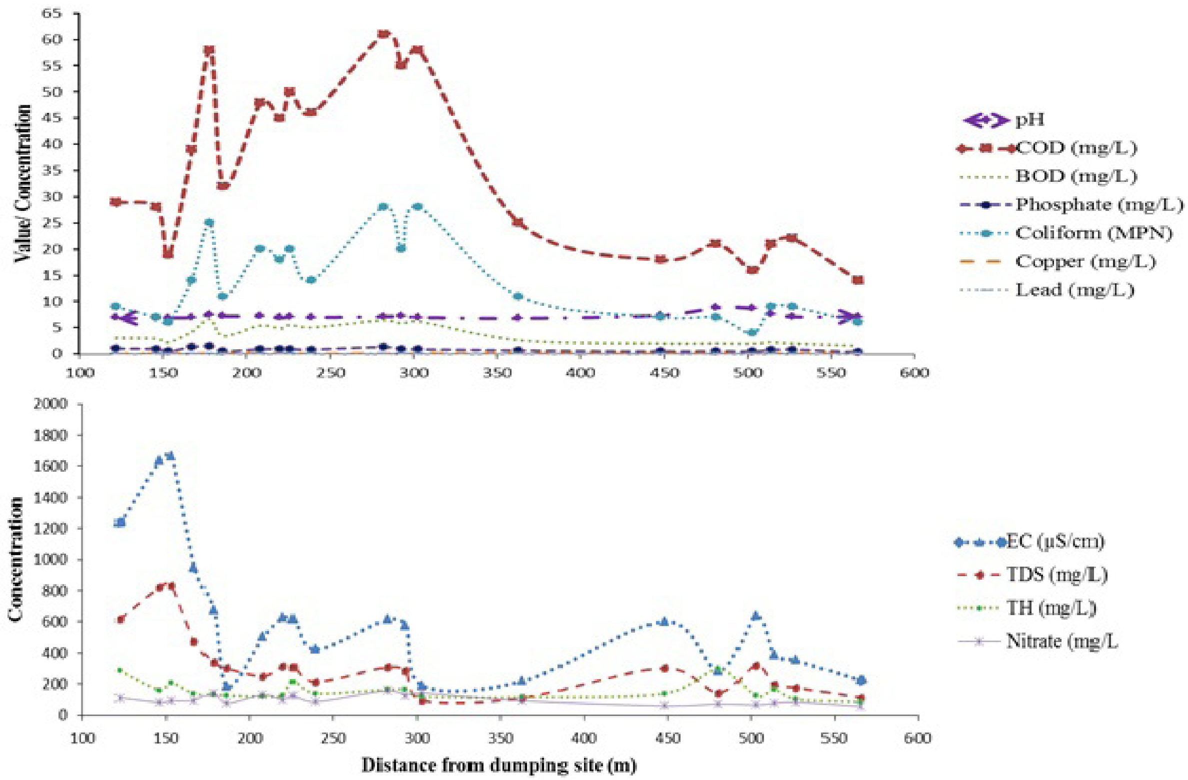

Figure 03: Spatial variation of water quality parameters in groundwater samples.

Table 08: Coliform number per 100 ml in the groundwater near the dumping site during study period

Month	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
October	24	16	22	30	47	27	35	51	35	38	31	46	48	11	13	12	15	15	17	18
November	26	17	26	33	51	30	41	55	38	44	36	48	54	13	15	15	16	17	19	22
December	29	21	33	44	61	33	53	65	53	57	54	57	65	16	19	17	23	20	21	27
January	33	24	35	49	68	36	56	71	57	61	58	65	69	17	23	21	27	29	28	31
February	28	18	29	41	62	34	52	64	46	53	48	57	61	13	18	18	25	26	27	26
March	27	16	27	35	56	29	48	58	43	46	46	54	52	12	17	15	18	18	20	23

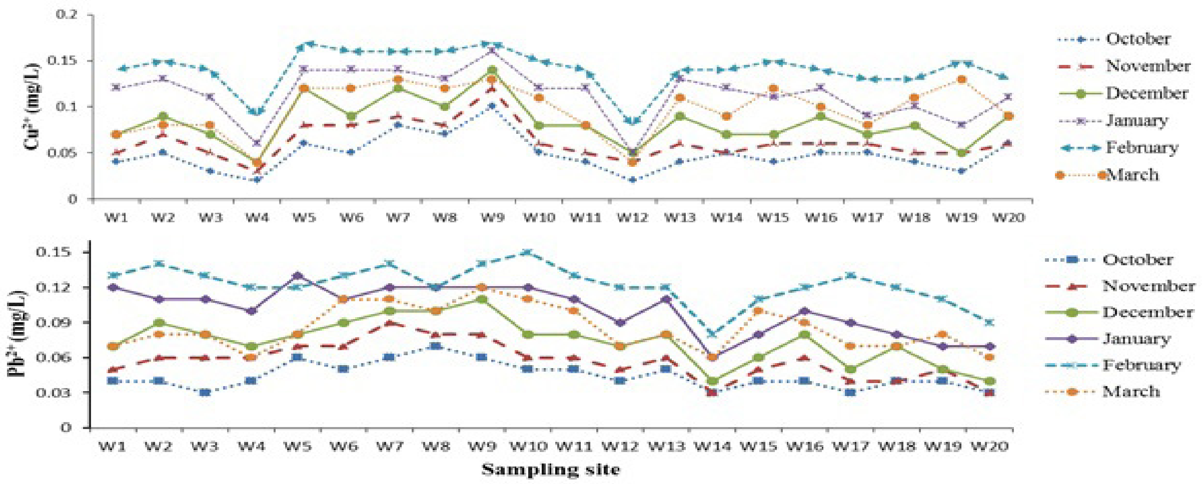

Figure 04: Temporal Variation of Cu and Pb in groundwater samples during study period

CONCLUSIONS

Based on the results, it can be concluded that Municipal Solid Waste dump-site at Thirupperunthurai, Batticaloa has adversely affected the groundwater. The concentration of EC, TDS, total hardness, PO_4^{3-}, NO_3^-, BOD, COD, coliform population, Cu and Pb were high in the months of January and February. The average concentrations of the above parameters were moderately high in the well water in the vicinity of landfill and hence, this well water is found to be not suitable for drinking and other domestic purposes. Leachate slowly percolates through soil and pollutes the groundwater resource. Therefore, there is a need to have an effective management programme of existing open dumping site and the landfill to control the environmental pollution.

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