Leachate Characterization and Assessment of Water Pollution near Municipal Solid Waste Landfill Site

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Abstract

The rapid industrialization, growing population and changing life style are the root causes for increasing rate of solid waste generation in developing countries. There are various methods adopted for solid waste management like land filling and incineration. In developing countries like India, land filling is of major concern with respect to existing circumstances. The uncontrolled dumping of solid waste on the outskirts of cities is creating serious environmental and public health problems. The improper management results in high possibility of leachate leakage with subsequent impact on soils, plants, groundwater, aquatic organism and human being. Therefore, it is important to know the characteristics of the leachate for effective management of solid waste dump site as well to control its potential impact on water quality of surrounding surface and ground water resources. Hence the present study demonstrates an attempt to investigate the relationship between the characteristics of leachate generated from municipal solid waste and its impact on surrounding ground water resources at landfill site in Turbhe area of Navi Mumbai, India. The ten physico-chemical water quality parameter of leachate, pond and groundwater sample have been analyzed for a comprehensive statistical analysis. The result shows that the ground water quality is highly deteriorating and may lead to increase in human health risk at nearby dwellings.

Keywords: Solid waste, Landfill, Leachate, Water pollution, Groundwater

Introduction

Increased rate of exploitation of natural resources and generation of huge amount of municipal solid waste (MSW) are the results of rapid population growth and urbanization in developing countries[1]. The dumping of solid waste in open is a very common practice of solid waste management. The quantum of municipal solid waste generated in India is about 0.15 million tonnes per day. This is approximately 50 million tonnes annually. Out of the total municipal waste collected, on an average 94% is dumped on land and 5% is composted. The average rate of MSW generation in India (0.35 to 0.60 kg/ person/day) is very low as compared to developed countries[2].

Landfilling is generally the most economical method of disposing of municipal solid waste[3]. However, there are a number of environmental drawbacks associated with landfills which have aroused social and environmental attention in recent decades[4]. Amongst the drawbacks, disposal of solid waste in landfills constitutes a considerable source of groundwater pollution[5]. Landfills have been identified as one of the major threats to groundwater resources[6]. After waste is disposed of at landfills, it undergoes a number of physical, chemical and microbiological changes. Consequently leachate has generated which percolates through waste layers of landfill and pollutes groundwater[7]. According to MSW rules 2000, the leachate must be treated before discharging. Leachate may contain large amounts of organic and inorganic compounds[8]. If leachate is not controlled, it can contaminant the surrounding soils, surface water resources and ultimately to the groundwater.

In the present study, the impact of leachate migration on groundwater quality was estimated from a Turbhe landfill site, Navi Mumbai. Various physicochemical parameters were analyzed in leachate, pond and groundwater samples to understand the possible link of groundwater contamination.

Study Area

The selected study area for research is Navi Mumbai, Maharashtra. The total area of it is 108.5 km^2. It is located between 19° 5’ and 19° 15’ (N) latitude and 72° 55’ (E) longitude. As per Urban Health Post (UHP) survey, the population residing within Navi Mumbai Municipal Corporation (NMMC) area during 2010-11 was 12.09 lakhs. Its temperature varies from 12° to 41°C. Out of total rainfall, 90% rainfall is experienced during June to September. Based on station observations, total rainfall during the year 2009 was recorded as 1670.17 mm. The maximum and minimum temperature was 38.38°C and 23.68°C[9]. The NMMC area with site is shown in Fig. 1 with proper notation.

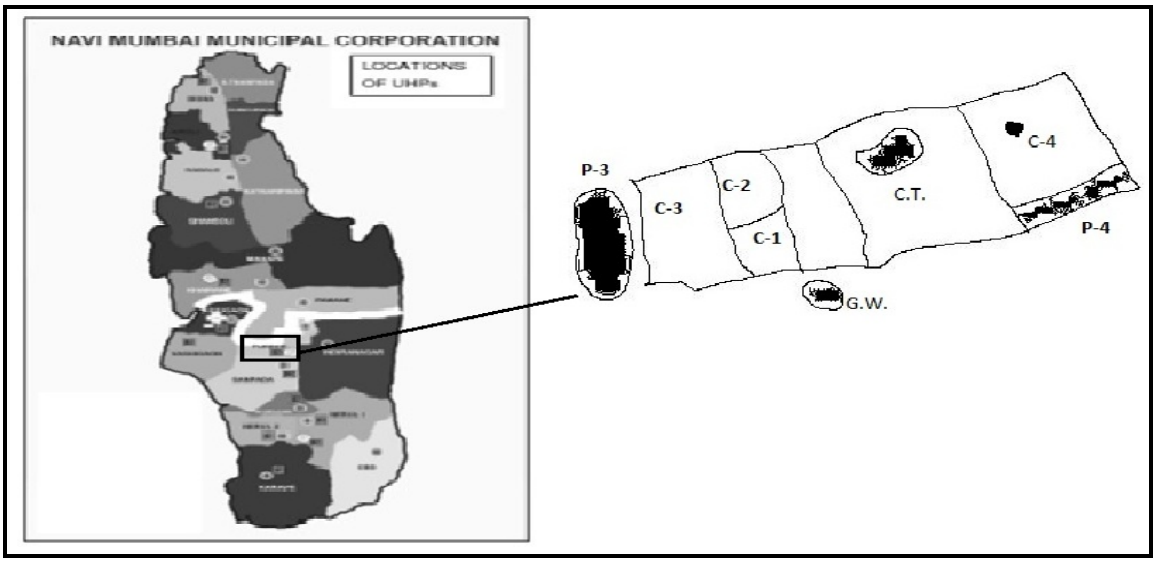

Figure 1: Location map of Turbhe landfill site, Navi Mumbai, India

Turbhe landfill site

The Turbhe landfill site started since in the year 2005 and still in use. It spreads over an area of approximately of 66 acre situated in Navi Mumbai. About 550 MT/D of municipal solid waste is generated in Navi Mumbai which is then disposed at Turbhe landfill site. Site has total four cells. Three cells are already scientifically closed with single liner system polyethylene material. The fourth cell is a current dumping site which is designed scientifically and is sanitary landfill[9]. The details of site specification are shown in Table 1.

Materials And Methods - Sampling of leachate, pond and groundwater-

The sampling was done from June to August 2012 with 15 days intervals period. The samples were collected in pre-cleaned polyethylene container of 5L capacity. The structure of site is shown in Table 2.

Table 1: Site specification for sampling

S. No.	Sampling locations	Type	Notation
1	Cell-4	Leachate	C-4
2	Collection tank	Leachate	C.T
3	Pond near to cell-3	Surface water	P-3
4	Pond near to cell-4	Surface water	P-4
5	Tube well	Groundwater	G.W

Table 2: Structure of Turbhe landfill site, Navi Mumbai (NMMC, 2010)

Cell	Area (m^2)	Waste dumped (tonne)	Duration
Cell-1	13750	211350	May-05 to June-06
Cell-2	29990	414722	June-06 to March-08
Cell-3	44200	724552	April-08 to March-11
Cell-4	44200	195989 (Up to Jan, 2012)	April-11 to Present

Table 3: Physico-chemical characteristics of leachate (C-4)

Parameter/ Sample	I[a]	II[a]	III[a]	IV[a]	V[a]	VI[a]	Average
pH	7.75	7.48	7.82	7.36	7.57	7.52	7.58
EC	30590	28280	28010	20260	22120	22750	25335
TA	13488	10010	9740	11475	14320	13360	12065
DOC	3548	4326	5220	3431	1472	2122	3353
Total solid	27795	27141	21788	17160	23424	23710	23503
TDS	24000	23760	20260	15720	21320	22340	21233
SS	3795	3381	1528	1440	2104	1370	2270
Chloride	3945	3692	3418	3455	3558	3379	3574
Sulphate	802	928	685	794	745	836	798
COD	11000	8920	14640	6360	4750	4435	8350
BOD_5	5925	5028	6892	3195	2940	2775	4459

[a]All values are in mg/l, except pH, EC (µS/cm)

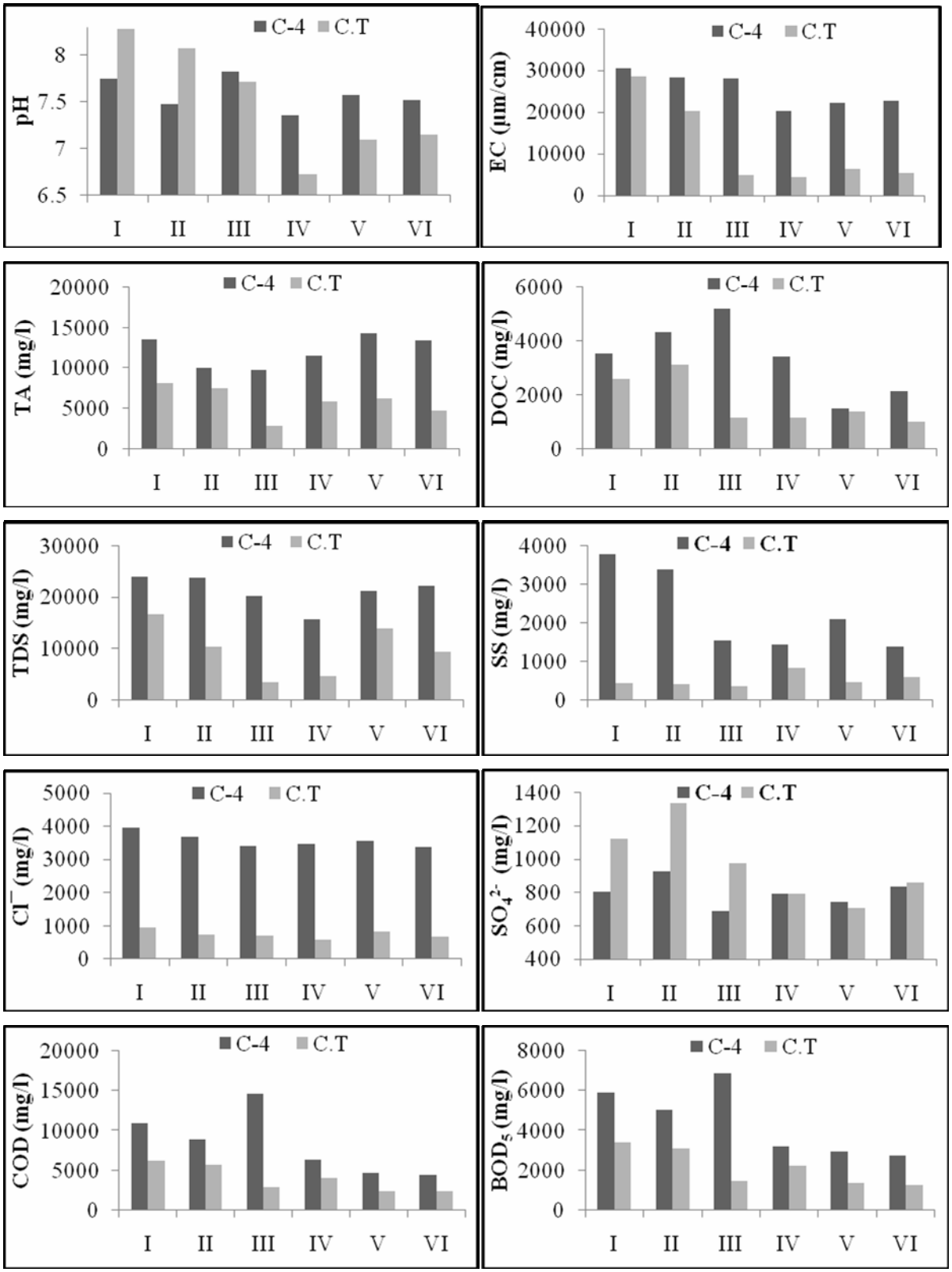

Fig. 2: Variation in concentration of pH, EC, TA, DOC, TDS, SS, chloride, sulfate, COD & BOD_5 of leachate(C-4 & C.T)

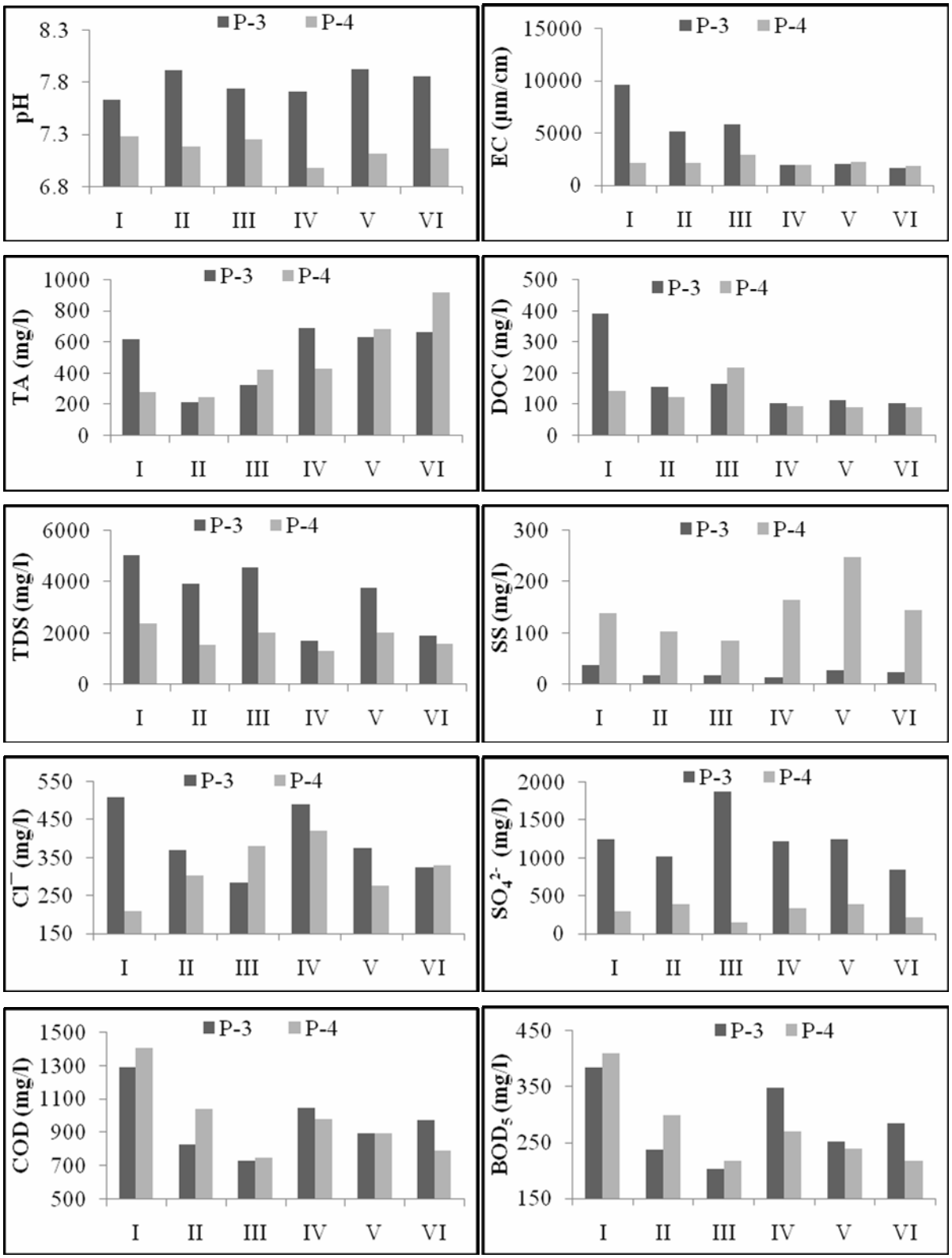

Fig. 3: Variation in concentration of pH, EC, TA, DOC, TDS, SS, chloride, sulfate, COD & BOD_5 of surface water (P-3 & P-4)

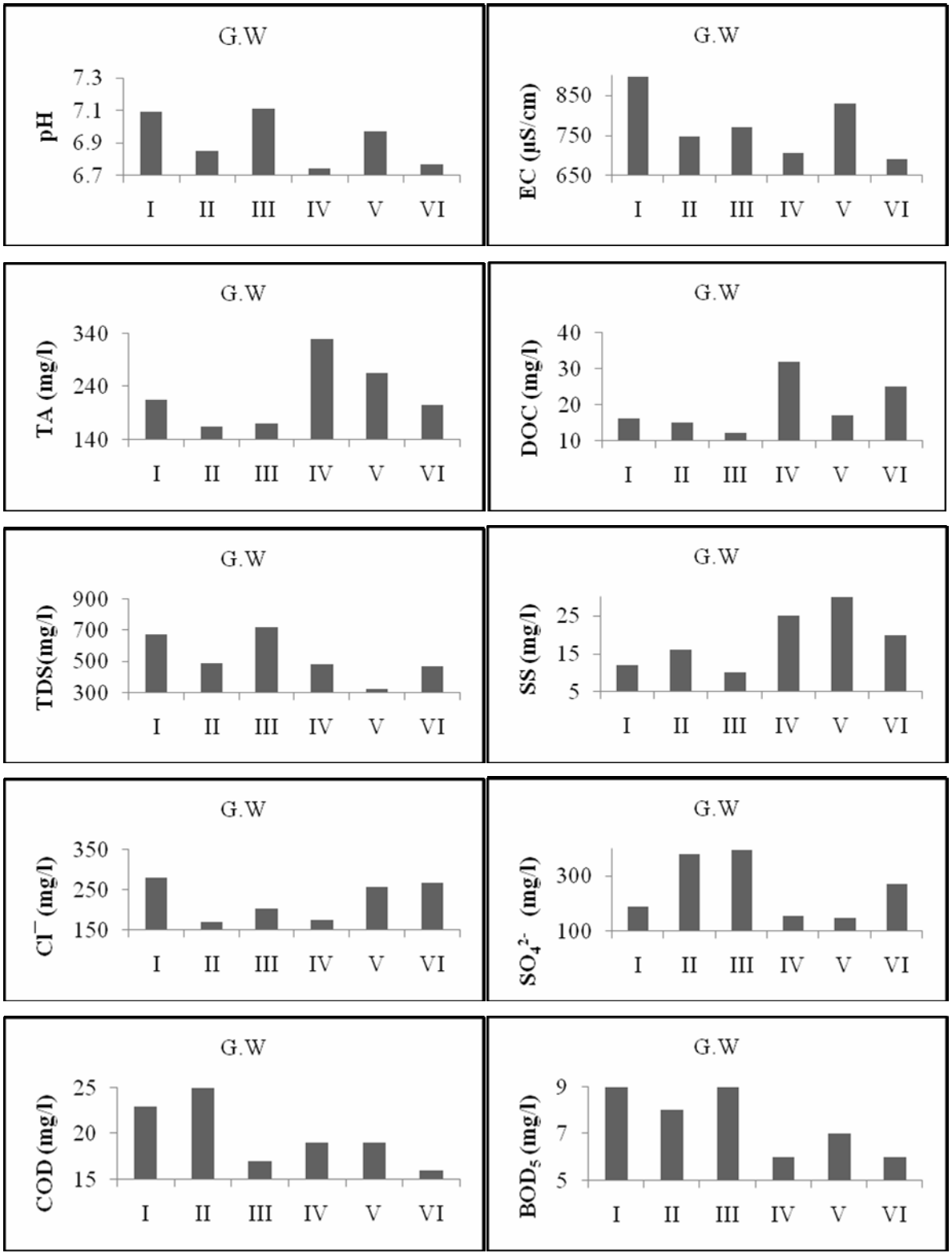

Fig. 4: Variation in concentration of pH, EC, TA, DOC, TDS, SS, chloride, sulfate, COD & BOD_5 of groundwater (G.W)

Analytical methods-

After sampling, the collected samples were immediately brought to the laboratory and kept in cold room at temperature below 4°C until analyzed. All the samples were analyzed for selected relevant physicochemical parameters according to internationally accepted procedures and standard methods[10]. The various physicochemical parameters examined in leachate, pond and groundwater includes pH, Electrical Conductivity (EC), Total Alkalinity (TA), Total Dissolved Solid (TDS), Suspended Solid (SS), Dissolved Organic Carbon (DOC), Chloride (Cl^-), Sulfate (SO_4^{2-}), 5-day Biological Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD). All the experiments were carried out in triplicate and results were found reproducible within ±3% error.

Results and Discussions

Leachate characterization- Physico-chemical characteristics of the leachate depend primarily upon the waste composition and water content in total waste. The leachate characterization was carried out for two types of leachate with six number of sample. The average municipal solid waste leachate composition and its variation along with time are shown in Table 3 and 4.

The pH and EC- the pH of leachate sample ranges from 7.09-8.28 with an average concentration of 7.50. The EC of sample ranges from 4450-30590 µS/cm. The extremely high value of EC indicates higher concentration of anions and cations. BOD_5, COD and DOC- the BOD_5 and COD of leachate sample were ranges from 1262-6892 mg/l. The high values for BOD_5 and COD are indicative of high organic matter in the wastes. The ratio for 5-day BOD_5/COD ranges from 0.47-0.62. This indicates that majority of organic compound is biodegradable[6]. The high values of DOC in leachate samples are mainly due to decomposed and unrecompensed product of organic waste. Anions- the chloride concentration of leachate samples varies from 584-3945 mg/l. The high amount of chloride in leachate is due to mixing of domestic waste[11]. The total alkalinity of leachate varies from 2739-14320 mg/l. The high alkalinity imparts with unpleasant taste that may be affect on human health.

Ground and surface water characterization- Groundwater in the tube well is mainly used for gardening purposes near the landfill area. During monsoon season, surface water is collected in pond near to cells due to flow of rainfall over surface. The variation in water quality of ground and surface water is shown in Table 5, 6 and 7. It is evident from the results that pond and ground water close vicinity of dumping site are the most affected due to leachate percolation. The pH of ground water sample was close to neutral. But the pond water sample pH was high and ranges from 6.98-7.92. The EC of ground water and surface water also high indicates amount of material dissolved in water. The total alkalinity concentration in surface water and groundwater varies from 692-213 mg/l. The higher values of alkalinity show the water is not used for drinking because of unpleasant taste.

Table 4: Physico-chemical characteristics of leachate (C.T)

Parameter/ Sample	I[a]	II[a]	III[a]	IV[a]	V[a]	VI[a]	Average
pH	8.28	8.07	7.72	7.37	7.09	7.15	7.50
EC	28600	20330	4950	4450	6280	5310	11653
TA	8153	7520	2739	5760	6237	4648	5842
DOC	2595	3111	1138	1127	1369	982	1720
Total solid	17026	10759	3815	5428	14280	10004	10218
TDS	16600	10350	3460	4600	13840	9430	9713
SS	426	409	355	828	440	574	505
Chloride	957	749	710	584	830	690	753
Sulphate	1120	1336	974	792	704	859	964
COD	6240	5720	2890	4035	2375	2484	3957
BOD_5	3417	3111	1484	2218	1369	1262	2143

[a]All values are in mg/l, except pH, EC (µS/cm)

Table 5: Physico-chemical characteristics of surface water (P-3)

Parameter/ Sample	I[a]	II[a]	III[a]	IV[a]	V[a]	VI[a]	Average
pH	7.63	7.91	7.74	7.71	7.92	7.86	7.79
EC	9630	5140	5800	1960	2090	1640	4376
TA	620	213	330	692	633	668	526
DOC	391	156	163	102	112	103	171
Total solid	5077	3937	4598	1704	3788	1944	3508
TDS	5040	3920	4580	1690	3760	1920	3485
SS	37	17	18	14	28	24	23
Chloride	510	370	285	490	375	325	392
Sulphate	1246	1018	1884	1215	1245	852	1243
COD	1292	825	729	1046	894	972	959
BOD_5	385	237	203	348	252	284	284

[a]All values are in mg/l, except pH, EC (µS/cm)

The BOD_5 and COD of the surface water shows higher values because of organic matter present in the surface water. The average BOD_5 values for surface water are 275-284 mg/l and the average COD values for surface water are 959-976 mg/l respectively. It means that water has high organic strength. Organic load on water is high due to pollutants dissolved in water. The dissolved organic Carbon concentration in surface water and groundwater ranges from 89-391 mg/l with an average concentration of 171 mg/l. Also the total dissolved solid concentration in surface water is higher due to the leaching of various pollutants into water. Total dissolved solid indicates the general nature of water quality. The average dissolved solid concentration of surface water is 1820-3485 mg/l respectively and for groundwater it is 525 mg/l.

Table 6: Physico-chemical characteristics of surface water (P-4)

Parameter/ Sample	**I[a]**	**II[a]**	**III[a]**	**IV[a]**	**V[a]**	**VI[a]**	**Average**
pH	7.28	7.18	7.25	6.98	7.12	7.16	7.16
EC	2120	2190	2950	1930	2210	1880	2213
TA	284	246	423	431	684	920	498
DOC	141	123	217	91	90	89	125
Total solid	2539	1633	2125	1495	2289	1725	1967
TDS	2400	1530	2040	1330	2040	1580	1820
SS	139	103	85	165	249	145	147
Chloride	210	302	381	422	275	330	320
Sulphate	290	385	150	330	394	210	293
COD	1405	1038	749	982	894	792	976
BOD_5	409	298	217	269	239	218	275

[a]All values are in mg/l, except pH, EC (µS/cm)

The chloride concentration in surface water varies from 210-510 mg/l. The average concentration of chloride in case of ground and surface water is 225.5 mg/l and 320 mg/l respectively. The excess of chloride ion is an index of pollution and considered as tracer for groundwater contamination. The sulfate ion is one of the major anion occurring in the natural water. The sulfate ion concentration in groundwater is higher due to domestic waste. The average sulfate concentration in ground water is 255 mg/l. The sulfate concentration in surface water varies from 1246-210 mg/l with an average concentration of 1243 and 293 mg/l respectively.

Table 7: Physico-chemical characteristics of groundwater (G.W)

Parameter/ Sample	I[a]	II[a]	III[a]	IV[a]	V[a]	VI[a]	Average
pH	7.09	6.85	7.11	6.74	6.97	6.77	6.92
EC	896	747	771	707	829	691	773
TA	215	165	170	330	265	205	225
DOC	16	15	12	32	17	25	19.5
Total solid	682	506	730	505	350	490	543
TDS	670	490	720	480	320	470	525
SS	12	16	10	25	30	20	18
Chloride	280	170	204	175	256	268	225.5
Sulphate	190	380	395	155	145	270	255
COD	23	25	17	19	19	16	19
BOD_5	9	8	9	6	7	6	7.5

[a]All values are in mg/l, except pH, EC (µS/cm)

Table 8: Drinking water quality standard recommended by WHO and BIS

Parameter	WHO Standards	BIS Standards	
		Desirable	Max. Permissible
pH	6.5-9.2	6.5-8.5	6.5-8.5
Alkalinity (mg/l as $CaCO_3$)	-	200	600
Total dissolved solid (mg/l)	500	500	1500
Suspended solid (mg/l)	-	100	-
Chlorides (mg/l)	250	250	1000
Sulphate (mg/l)	200	200	400
COD (mg/l)	-	250	-
BOD_5 (mg/l)	-	30	100

Correlation analysis- The correlation analysis is a preliminary descriptive technique to estimate the degree of association among the variables involved. The purpose of the correlation analysis is to measure the intensity of association between two variables. Such association is likely to lead to reasoning about causal relationship between the variables. Correlation matrix between various parameters of leachate, pond and groundwater are shown in Table 9, Table 10, Table 11, Table 12 and Table 13 respectively.

Table 9: Correlation matrix for different leachate parameter (C-4)

	pH	EC	TA	DOC	TDS	SS	Cl^-	SO42-	COD	BOD5
pH	1									
EC	0.7110	1								
TA	-0.0485	-0.3082	1							
DOC	0.3861	0.6181	-0.8932	1						
TDS	0.4293	0.6974	0.1991	-0.0367	1					
SS	0.2276	0.7427	0.0546	0.1839	0.6979	1				
Cl^-	0.2815	0.6849	0.2076	0.1062	0.5870	0.9603	1			
SO42-	-0.5677	0.1134	-0.0835	-0.0546	0.4046	0.4852	0.3221	1		
COD	0.7616	0.7774	-0.6237	0.8829	0.1477	0.2736	0.2650	-0.3513	1	
BOD5	0.7807	0.8731	-0.5697	0.8504	0.3049	0.4200	0.3951	-0.2420	0.9849	1

Table 10: Correlation matrix for different leachate parameter (C.T)

	pH	EC	TA	DOC	TDS	SS	Cl^-	SO_4^{2-}	COD	BOD_5
pH	1									
EC	0.8479	1								
TA	0.3969	0.7962	1							
DOC	0.8006	0.8991	0.7841	1						
TDS	0.4316	0.6885	0.7720	0.5369	1					
SS	-0.7476	-0.4005	-0.0074	-0.4275	-0.3620	1				
Cl^-	0.6869	0.7467	0.5695	0.5508	0.8790	-0.6576	1			
SO_4^{2-}	0.8592	0.7609	0.4322	0.8761	0.1826	-0.4713	0.3057	1		
COD	0.7087	0.9073	0.7657	0.8801	0.3964	-0.1115	0.4295	0.7938	1	
BOD_5	0.6859	0.9070	0.7987	0.8832	0.4266	-0.0995	0.4469	0.7650	0.9976	1

Table 11: Correlation matrix for different surface water parameter (P-3)

	pH	EC	TA	DOC	TDS	SS	Cl^-	SO_4^{2-}	COD	BOD_5
pH	1									
EC	-0.6014	1								
TA	-0.2684	-0.3352	1							
DOC	-0.6603	0.9354	-0.0042	1						
TDS	-0.2211	0.8363	-0.4976	0.7053	1					
SS	-0.2506	0.5211	0.3891	0.7326	0.5028	1				
Cl^-	-0.5804	0.3113	0.4839	0.5212	-0.0306	0.3357	1			
SO_4^{2-}	-0.4051	0.3449	-0.3239	0.1403	0.5244	-0.1297	-0.2533	1		
COD	-0.6191	0.3977	0.6415	0.6782	0.0097	0.6575	0.8564	-0.3590	1	
BOD_5	-0.6563	0.2748	0.6738	0.5465	-0.1579	0.4609	0.9132	-0.3524	0.9692	1

Table 12: Correlation matrix for different surface water parameter (P-4)

	pH	EC	TA	DOC	TDS	SS	Cl^-	SO_4^{2-}	COD	BOD_5
pH	1									
EC	0.5143	1								
TA	-0.2390	-0.3053	1							
DOC	0.6656	0.9173	-0.4557	1						
TDS	0.7570	0.4275	-0.1827	0.4744	1					
SS	-0.4802	-0.4385	0.4633	-0.6874	0.0738	1				
Cl^-	-0.6098	0.1612	0.1282	0.0867	-0.7028	-0.2240	1			
SO_4^{2-}	-0.4255	-0.4815	-0.2434	-0.6267	-0.1825	0.5700	-0.3160	1		
COD	0.2732	-0.3261	-0.6024	-0.0823	0.4271	0.0003	-0.6661	0.3827	1	
BOD_5	0.3569	-0.2493	-0.6454	0.0153	0.4564	-0.1029	-0.6630	0.3074	0.9936	1

Table 13: Correlation matrix for groundwater parameter (G.W)

	pH	EC	TA	DOC	TDS	SS	Cl^-	SO_4^{2-}	COD	BOD_5
pH	1									
EC	0.7979	1								
TA	-0.4357	-0.1071	1							
DOC	-0.8194	-0.5897	0.7718	1						
TDS	0.6009	0.2528	-0.4756	-0.3938	1					
SS	-0.5479	-0.2098	0.7413	0.5483	-0.9291	1				
Cl^-	0.3433	0.5177	-0.0632	-0.1390	-0.0186	0.0285	1			
SO_4^{2-}	0.1921	-0.2860	-0.8517	-0.5461	0.4878	-0.6945	-0.4132	1		
COD	0.1155	0.4317	-0.2098	-0.3247	0.0567	-0.2244	-0.2354	0.0829	1	
BOD_5	0.8866	0.6787	-0.6348	-0.8605	0.7377	-0.7815	0.0552	0.4666	0.4367	1

Some of the parameters were found to bear statistically significant correlation with each other indicating close association of this parameter with each other. The EC had correlation with number of parameters like DOC, TDS, SS, BOD_5 and COD. DOC is closely related with TDS, chloride, BOD_5 and COD. In case of groundwater, the pH is correlated with EC, TDS and BOD_5. Also the TA closely correlated with DOC and SS.

An Indian standard for drinking water quality given by Bureau of Indian Standards (BIS: 1991) is shown in Table 8 along with World Health Organization (WHO: 2004) standards[12, 13]. On comparing the water quality of the groundwater sources in the surroundings of MSW landfill with the water quality standards mentioned in Table 8, some parameter like TA, TDS, chloride and sulfate were found to be critical and rest of the other parameters were found to be permissible.

The variations in different parameters of leachate are shown in fig. 2. Also the variations of different parameters of surface water groundwater are shown in fig.3 and fig.4 respectively.

Conclusion

Leachate contains a wide range of contaminants including inorganic cations, anions, heavy metals and organic compounds. The study is a preliminary investigation on possible groundwater contamination due to leachate percolation. The three month samples with 15 days interval collected during monsoon show possibility of groundwater contamination due to leachate percolation from cell. The present study has monitored the ten major physico-chemical parameters of leachate samples. The moderately high concentration of EC, TDS, sulphate and chloride in ground water near landfill deteriorates water quality. It has also been investigated that the groundwater is not used for domestic purpose, as there is no natural or other possible reason for high concentration of these pollutants, it can be concluded that leachate from cell-1 has significant impact on ground water quality near the landfill area. Although, the concentrations of few contaminants do not exceed drinking water standard even through the ground water quality represents a significant threat to public health. Therefore some remedial measures may be needed in future to stop further ground water contamination.

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