EFFECTS OF LEACHATE MIGRATION ON SURFACE AND SUBSURFACE WATER QUALITY IN AND AROUND A MUNICIPAL SOLID WASTE OPEN DUMPING SITE

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ABSTRACT

Ground water and Surface water samples were collected from Mayiladuthurai Municipal Solid Waste open dump site and its adjacent area to study the possible impact of migrated leachate on ground water and on the near by surface water bodies. Ground water samples were collected from fifteen bore holes that exist in the periphery of the unprotected landfill. The samples of water were also collected from four surface water bodies located near to the open dump site. The concentration of various physico-chemical parameters, pH, Electrical conductivity (EC), Total solids (TS), Total Dissolved solids (TDS), Hardness, Turbidity, Chlorides, Dissolved oxygen, Acidity, Sulphate, biological parameter Biochemical Oxygen demand (BOD) and Chemical Oxygen demand (COD) were determined in all the samples. A moderately higher concentration of EC, TS, TDS, Chlorides, BOD, COD and other pollutants indicate that the ground water is affected significantly by the migration of leachate. The correlation matrix indicates the likely significant positive and negative correlation between various pollutant parameters. A comparative analysis of results with other related studies reveals the fact that the pollutant concentration measured could have major influence on ground water quality.

Keywords: Municipal Solid Waste, Leachate, ground water quality.

INTRODUCTION

From the days of primitive society, humans and animals have used the resources of the earth to support life and to dispose wastes. In those days the disposal of waste did not pose significant problem as the population and the waste generation was less and large land area was available for disposal and assimilation of waste.

The Municipal Solid waste (MSW) is heterogeneous in nature and contains paper, plastics, rag, metal, glass piece, ash and compostable matter (Jha, et.al 2003). In India even though the Municipal Solid Waste (Handling and Management) rules 2000 comes into effect, no significant changes has occurred in its handling, transportation, processing and in ultimate disposal. Land filling is one of the simplest, cheapest and cost effective method of disposing of waste in developing and developed countries (Barrett and Lawlor, 1995). The newly generated wastes were burnt to reduce its volume and dumped over the

stabilized waste due to non availability of space for dumping. The refuse were periodically leveled and compacted. The leachate is the liquid emanating from the refuse due to decomposition, a process during which the waste under go physical, chemical and biological changes. When water percolates during the rain the extracts of the contaminants enters liquid phase and tend to flow within the landfill due to pressure gradient (Mor, et.al 2006). The leachate contains higher concentration of dissolved organics and inorganic substances and heavy metals (Lee and Jones-Lee 1993: Christensen et.al, 2001). The quantum of leachate and the characteristics of leachate emanating from the waste dump site is factor influenced by age of the landfill, degree of stabilization of waste, composition of waste and the local environmental factors like temperature, moisture and climate. There has been a growing concern on the environmental safety of landfill application of waste products, such as long term build up of heavy metals in the soil, effects on ground water and pathogenic effects. The leachate pose a serious threat to the local environment as well as for the health. The influence of new leachate emanating from the waste is a source and has higher potential to pollute soil and ground water due to its migration. Other than these factors Solid Waste open dumping site cause serious aesthetic pollution and degrade the economic value of the properties located near to the vicinity of landfills. In India treatment and disposal of Municipal Solid Waste is almost absent in many cities and the major method of disposal is by crude dumping in about 94% of the cases and cause serious environmental degradation. Since the ground water plays a very vital role in hydrological cycle and 95% of fresh water is available in the form of ground water it becomes imperative to study effects of open dumping on the quality of ground water.

STUDY AREA

The study was carried out in Mayiladuthurai, town of Nagapattinum district, India, located at a distance of 290km South of Chennai, the capital city of the state of Tamilnadu. The town is situated on the banks of river Cauvery. The area is covered by residential and commercial units, and served by a population of 88000 (2009) with an average growth rate 1.38% per annum. The town is extended over an area of 11.27sq.km and designated as III grade municipality in 1866 and upgraded to II grade municipality in 1949 and then to I grade during 1969. The landfill is located between 11º6'N latitude and 79º39'E longitude along the coast of Bay of Bengal. The landfill operations were started during the 1983 and till it is being operated. The landfill operations were started over an extent of 4.62acres now extended to more than 6.0 acres. The open dumping site is surrounded by many human dwellings, water bodies and cultivable lands. Nearly 33 to 35 tonnes (based on actual measurement) of Municipal Solid Waste is being dumped per day at a per capita rate of 350 - 400gms/head/day. Figure1.0 gives the layout of existing Municipal Solid Waste open dumping site.

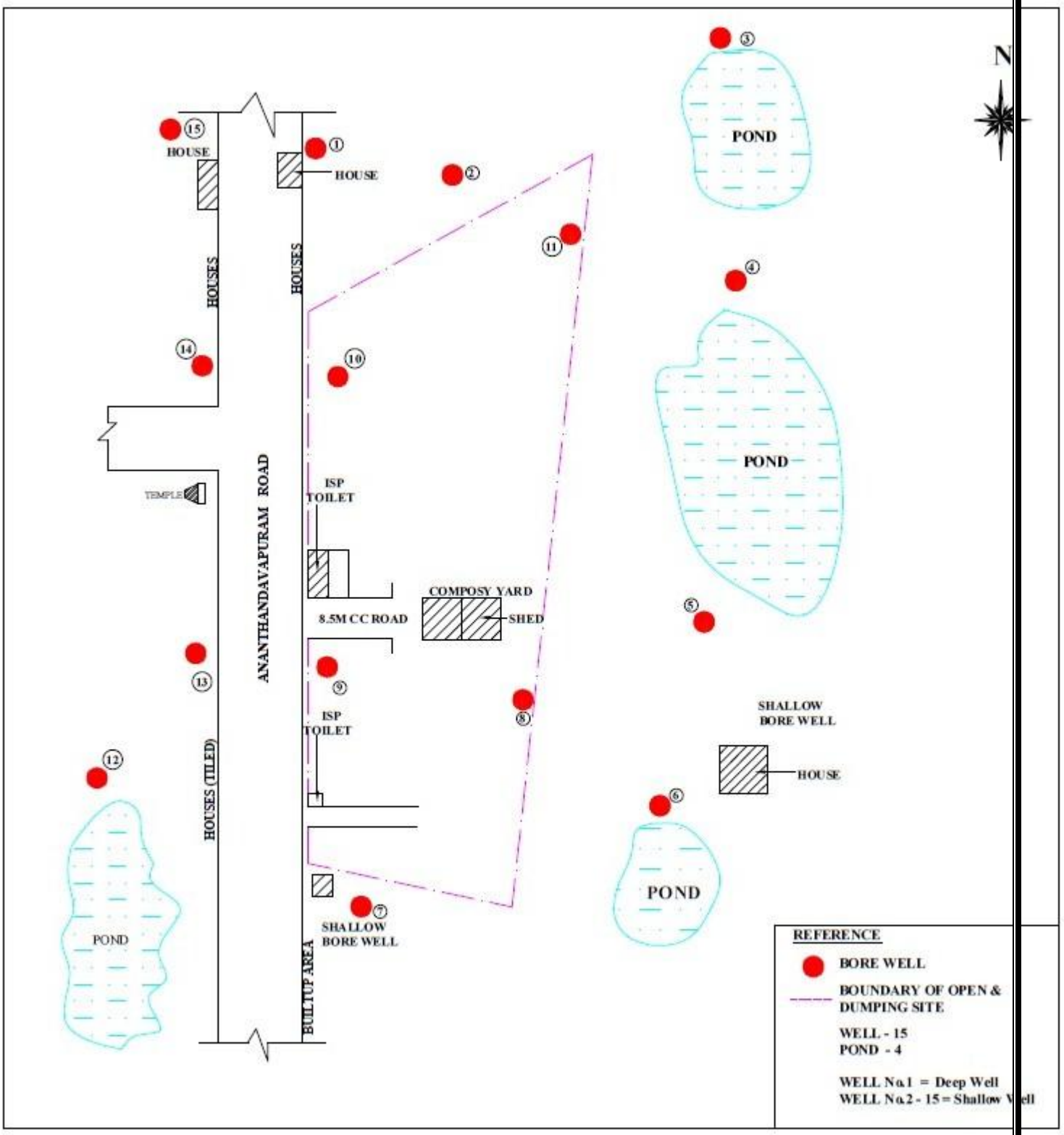

Fig : 1.0 Layout of MSW Open Dumping Site
Mayiladuthurai Town

The depth of hand driven bore wells in this region varies from 7.5m to 40m. The fluctuations in water table level show a minimum water table depth of 1.2m during rainy season and 9.4m during the dry season of the year. The annual maximum and mean minimum temperature recorded are 40.4ºC and 33.8ºC respectively. The town receives rainfall in two spells during Southwest monsoon which spreads from June to August and during Northeast monsoon from October to December, with an average rainfall of 1150mm (India Meteorological Department).

HYDROGEOLOGY

The predominant geological formation is Pliocene to recent and major water bearing formations includes lower Miocene deeper aquifers and Pliocene quaternary shallow aquifers. The transmisivity of soil in the region is 1 to 1200m²/day. The Pliocene shallow aquifers are represented by sand, gravel, sandy clay and variegated clays. Heterogeneity in lithology is also noticed. The thickness of the aquifer ranges from 10 to 35m. Ground water occurs under water table as well as in confined conditions and is developed by means of shallow tube wells. The depth of tube wells ranges from 30 to 100m below ground level. The entire region shows a wide variation in the positions of sandy clay and silts both laterally and depth wise resulting in wide variations in permeability values (CGWB, 2008).

The topography of the town indicates a gentle fall from North to South and from West to East. Though the soil does not possess any mineral deposit for commercial use, high fertile alluvial soil is predominant along the river Cauvery. The top 0.5m depth of soil possess organic content varying between 5-7%. Fine soil is available from 0.5m to 2.0m depth. A fine sandy soil with water bearing capacity extends from 2.1m to 3.2m.

MATERIAL AND METHODS

A well inventory was carried out during March 2011. A Garmin global positioning system (GPS) was used for identifying the location of wells. Sampling wells and surface water bodies were identified / selected along the radial direction from the open dumping site, keeping the distance as zero meters for open dumping site to a maximum of 250m. Leachate samples were collected in a fresh 2 liter plastic container from the leachate pit driven with augur at a depth of three to four foot from the leveled top of waste. The characteristics of leachate is given in Table 1.1. Similarly ground water and Surface water samples were collected in 1000ml laboratory cleaned plastic pet bottles after rinsing it with the water to be sampled and capped tightly. All the samples were shifted immediately to the laboratory for examination of its quality. The experiments were carried out using the standard procedure given in APHA (2005).

CORRELATION COEFFICIENT

Determination of correlation is important to characterize the significant of the relationship between the two interdependent variables. If a graph between the two variables x and y, is plotted the straight line will indicate strong relationship while the scattering of the points will show weak relationship.

Statistically this relationship is obtained by calculating an index called as correlation coefficient (r). The correlation coefficient (r) was determined using the following expression,

Correlation coefficient

$$r = \frac{N\ \Sigma(X_i Y_i) - \Sigma X_i . \Sigma Y_i}{\sqrt{\left[N \sum X_i^2 - (\sum X_i)^2\right]\left[N \sum Y_i^2 - (\sum Y_i)^2\right]}}$$

The limits of r are from +1 to -1 as follows:

(a) r = +1: Perfect positive correlation, all the points on the graph on a straight line. Any increase in one variable is accompanied by the increase in other.
(b) r = 0 : No correlation, all the points on the graph are scattered irregularly.
(c) r = -1 : Perfect negative correlation, all the points on the graph on a straight line. Any increase in one variable is associated by decrease in the other. The correlation matrix for the ground water and surface water quality parameters are given in Table 5.0 and Table 6.0.

RESULTS AND DISCUSSION

The concentrations of various pollutants in the ground water samples were determined. The ground water quality characteristics of wells like well number, type of well, depth of water table and the distance from the open dump site were given in Table 1.0. Table 2.0 gives the water quality characteristics of surface sources, nature of source and the distance from the open dump site. The average, minimum, maximum mean, median and standard deviation for each water quality parameter were analysed and given in Table 3.0.
The data indicate that the open dump site located in mayiladuthurai town is acting as a point source of pollution to both ground water as well as for surface water, this trend was identified from the fact that concentration of pollutants decreases radially with increase in distance from the open dump site. Since the ground water is in dynamic condition, the flow helps in dispersion and diffusion of leached pollutants in ground water. The pollutant concentration varies at different depths of water samples because the leachate movement in ground water varies with hydraulic gradient much faster in X-Y coordinate than in Z coordinate.
The pH of ground water around the open dump site in Mayiladuthurai town is slightly acidic and all the values are less than 7, with lowest value tested 6.04. This may be due to the infiltration of acetogenic leachate, and also attributed to the release of carbon dioxide during the anaerobic biodegradation of open dumped Municipal Solid Waste (Badmus, B.S, et.al 2001). The pH value measured for pond water samples located in the periphery of open dump site has the value between 6.57 and 8.35, indicating a near neutral pH.

Turbidity stems from the reduction of transparency due to the presence of particulate matter such as clay, silt, finely divided organics, plankton or other microscopic organisms. The colloidal and suspended impurities offer adsorption sites to chemicals and may cause health hazard, undesirable taste and odour (Adekunle,I.M, et.al 2007). The lowest turbidity value of less than 5 NTU is observed for sample from wells 6, 8, 9, 10,11 and 5. The sample from well no 14 has zero turbidity and the maximum turbidity of 85 NTU is measured for well no 12 located at 50m from the open dump site. The turbidity values of samples obtained from ponds 2,3,4 are 6,3 and 4NTU respectively, Indicating that the water is more transparent. A maximum turbidity of 50NTU is measured in pond no1 and this could be due to localized factors.

The thresh hold for DO is 5mg/l for drinking water and should be more than 5mg/l for agricultural purpose (Cruise, J and Miller R.L, 1994). Very low DO is an indication of anaerobic condition that cause bad odour. The results of the study reveals that the low to very low DO has been recorded in majority of the wells indicating that the water is unfit for use. The dissolved oxygen (DO) concentration of ground water samples vary between the lowest DO value of 1.0 mg/l in well no 14 and a maximum DO of 5.0mg/l in well no 6. The maximum DO concentration observed in the pond water is 4.70 for sample 4, despite a BOD of 132mg/l. The lower concentration of inorganics, the oxidation and reduction process that takes place due to the symbiotic relationship, natural surface re-aeration are responsible for the increased DO in the surface water.

The temporal variation of EC of the ground water samples around the landfills is mainly due to migration of contaminants from the landfill leachates. The samples obtained from the well no 2,3,6,7,8,9,10, 11, 12, 13,and 14 which are located very near to the vicinity of landfill has higher EC. In general the EC is high in all the samples except in well no 1 and 15, which has EC as 1.96 mmhos /cm and 1.108 m mhos/ cm respectively.

The observed EC values of surface water bodies are comparatively very less and unobjectionable. The minimum EC of 0.354 mmhos/ cm is observed in pond water 1 and a maximum of 1.098mmhos / cm for pond water 03.

The concentration of chlorides is high I all samples and vary between 40mg/l in well no 04 to a maximum of 2140mg/l in well no 13. The increase in chloride concentration may perhaps due to rise in water table, post monsoon, which allow the salts coated in soil to dissolve in rain water. The other source may due to leachate that seeps along the rain water. The presence of chlorides in surface sources is well within the desirable limit of 250mg/l prescribed in Drinking water standards (IS 10500 - 1991).

The hardness of the ground water sample obtained from the study area ranges between 88 mg/l for well no 15, located at a distance of 200m and the maximum hardness of 2000 mg/l is observed in well no 8 located at a distance of 10m from the open dump site. The increased concentration of hardness in well no 8 indicates the possibility for point source of pollution, caused by migration of leachate. The presence of hardness is generally attributed to leaching of rocks, but in the study area the hardness in ground water samples show gradual reduction with increase in distance of well from the open dump site. All

the samples of water obtained from surface sources located near to the vicinity of open dump site has lesser concentration of hardness.

The total phenolphthalein acidity measured in terms of CaCo3 in mg/l is varying between 2mg/l in well no 4 to a maximum of 24mg/l in well no 14. In surface water samples except the from pond no1, all the other samples are free from acidity. An acidity of 8mg/l is measured in pond no1 may be due to localized pond use factors.

The sulphate concentration present in the ground water samples vary between a minimum of 21 mg/l in well no 15 and a maximum of 64 mg/l in well no 3 and well no 9, indicating that concentration of sulphate is not so significant and it is well below the desirable limit of 200 mg/l prescribed in the drinking water standards IS 10500 -1991. In pond no1 and pond no3 the concentration of sulphate is 18mg/l and 17mg/l respectively. In all the surface water samples the sulphate concentration is varying between 4mg/l in pond 4 and 61mg/l pond no 2 located 100m and 50m respectively from open dumping site.

The electrical conductivity (EC) which is a direct measure of TDS is very high in all the water samples obtained from the sampling wells located near to the vicinity of open dump site. The lowest TDS value of 465.33mg/l was observed in well no 4 located at a distance of 200m and highest TDS value was observed is 4857.5 mg/l for well no 9 located at a distance of 30m from the Municipal Solid Waste duping site. The TDS concentration of well nos 2,3,6,8,10,12,13,14 gives exceptionally higher concentration of TDS. The spatial and temporal variations in TDS occur due to changes in migration of contaminants from open dump site and attributed to the fact that leachate seeps into the soil and their by reaches the water table. The TDS concentration of surface water sample show a minimum of 232.49mg/l and a maximum of 735.66mg/l in pond no 4 and in pond no3 located at a distance of 100m and 200m from the open dumping site. The change in TDS concentration of surface sources is mainly due to water use pattern of the respective ponds and not due to the horizontal seeping of leachate in x-y coordinate.

The drinking water sources should have a BOD of less than 1mg/l, and if this value is exceeded coagulation followed by rapid sand filtration process will get affected. Also inadequate and unhygienic handling of the Solid Waste could generate higher microbial population (Ugboaja, A.N, 2004). The presence of BOD is highly objectionable and not permitted as it will lead to severe health consequences. The test for microbial contamination of ground water show all the ground water samples irrespective of its depth of water table are having higher BOD, indicating the presence of life forms in the samples. The lowest BOD of 12mg/l is observed in well no 6 and the maximum BOD of 187 mg/l was measured in the sample obtained from well no 2 located just 10m from the open dump site. All the well water samples are tested positive for presence of life forms, indicating a possible contamination of aquifer system due to migration of leachate. The presence of BOD is reported in surface water samples and it varies between a minimum of 110 mg/l and a maximum of 132mg/l in the pond water located 200m and 110m respectively from the open dump site.

For drinking water supply the COD should not exceed 2.5mg/l and potable water with COD of 7.5mg/l is regarded as poor (Esa, R, 1983). The ground water samples are having a minimum of 60 mg/l COD

observed in well no 1 and the COD is maximum at 576 mg/l in ground water sample no 8 indicating that the ground water is polluted by in-organics. All ground water samples are having higher COD concentration making the ground water in the region unfit for domestic use.

CONCLUSIONS

The results obtained from the study shows that the leachate generated from the Municipal Solid Waste open dump site acts as a source for impact on the physio-chemical characteristics of ground water. The soil parameters in the study area have influenced the leachate migration. The reaction within the open dump site is most likely to be in accetogenic phase since all pH values of the ground water samples are slightly acidic.

The parameters in the ground water like hardness, chlorides, EC, BOD,COD, Total Solids, Total dissolved solids are in higher concentration than the limit prescribed by IS 10500, Standards for drinking water. The pollutants were detected up to 250m from the from the pollution source, and the quality of water in most of the bore wells located near to the vicinity of open dump site is unfit for human consumption and needs treatment before its use.

It is evident from the correlation study that the distribution of TDS with EC, Hardness, Chlorides and sulphate were significantly correlated, for which the r value if greater than 0.950, 0.873, 0.953 and 0.716 respectively. Positive correlation is obtained for 54 unions (69.23%) and the remaining 24 unions (30.76%) demonstrate a negative correlation. Highly positive correlation is observed between EC and TDS and an highly negative correlation is seen among BOD and Total Solids (-0.506). A direct and a positive correlation is also observed between EC and hardness, chlorides, sulphate and COD. Significant positive correlation of 0.716 is observed between TDS and sulphate.

Similarly among the surface water quality parameters a total of 53 positive correlations and 38 negative correlations is observed. The source for surface water pollution is mainly due to surface runoff from the open dump site during the rainy days and due to localized water use practices.

The possible remedial measures for prevention of pollution on water resources, includes a restriction on the quantum of organic waste entering the open dump site, by implementing a concept of home composting and since the organic fraction is more in Municipal Solid Waste the option of energy recovery can be very useful in terms of revenue generation and in preventing the practice of open dumping of waste.

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Table 1.0 Ground Water Quality characteristics near the existing Solid Waste dumping site

Sample / Well No	Distance from SW dumping site (m)	Type of Well	Depth of water table (m)	pH	Hardness mg/l	Turbidity NTU	EC mmhos/cm	Chlorides mg/l	DO mg/l	Acidity mg/l	Sulphate mg/l	Total Solids mg/l	TDS mg/l	BOD mg/l	COD mg/l
1	5	Bore	45.75	6.04	440	16	1.96	190	1.80	12	57	1500	1319.23	100	60
2	10	Bore	12.19	6.22	832	36	3.72	940	2.70	6	63	3300	2492.40	187	300
3	15	Bore	9.14	6.37	640	8	3.29	664	2.50	4	64	3000	2204.30	100	248
4	200	Bore	5.50	6.40	280	23	0.69	50	5.50	2	19	1500	468.33	55	125
5	250	Bore	12.20	6.50	400	14	0.76	70	4.80	4	19	700	509.20	75	90
6	15	Bore	9.00	6.75	1400	3	4048	1196	5	8	33	6300	3001.60	12	408
7	30	Bore	13.40	6.28	600	11	3.33	694	2.0	9	52	1300	2231.10	162.5	212
8	10	Bore	7.32	6.31	2000	3	6.13	1748	3.5	13	62	4500	4107.10	90	576
9	30	Bore	12.20	6.35	1280	1	7.25	1940	2.5	7	64	4300	4857.50	62	520
10	35	Bore	13.72	6.41	1300	1	6.18	1430	4.0	15	62	3600	2465.50	100	260
11	45	Bore	10.67	6.50	800	2	3.68	910	4.0	5	57	1900	2465.60	150	230
12	50	Bore	12.20	6.14	1080	85	4.75	1380	1.8	10	56	2700	3182.50	145	190
13	55	Bore	8.23	6.38	1680	5	6.23	2140	4.0	10	61	400	4174.10	166	180
14	150	Bore	12.00	6.19	1200	nil	4.05	764	1.0	24	53	4400	2713.50	92	69
15	200	Bore	8.53	6.32	88	10	1.10	170	2.2	5	21	3800	742.36	87	125

Table 2.0 Surface Water Quality characteristics near the existing Solid Waste dumping site

Sample No	Distance from SW dumping site (m)	Type of Source	pH	Hardness mg/l	Turbidity NTU	EC mmhos/cm	Chlorides mg/l	DO mg/l	Acidity mg/l	Alkalinity mg/l	Sulphate mg/l	Total Solids mg/l	TDS mg/l	BOD mg/l	COD mg/l
1	250	Pond	8.35	120	50	0.354	90	3.2	Nil	8.0	18	1700	237	113	101
2	50	Pond	7.18	180	6	0.908	180	4.0	Nil	12	61	2700	608	140	132
3	200	Pond	6.75	200	3	1.098	110	3.0	4	nil	17	400	735	110	98
4	100	pond	6.57	200	4	0.347	50	4.7	1.0	nil	4	2000	232	132	126

Table 1.1 Quality characteristics of Municipal Solid Waste Leachate

Sample No	pH	EC mmhos/cm	Chlorides mg/l	Hardness mg/l	Turbidity NTU	Sulphate mg/l	Fe mg/l	Ammonia mg/l	Na mg/l	Ca mg/l	K mg/l	Phosphate mg/l	COD mg/l	Acidity mg/l	BOD mg/l
1	7.65	6.80	1800	960	51	180	50	10	330	265	84	25	3800	125	1076
2	7.61	5.64	1640	1040	47	295	17.5	50	98	282	45	14	3920	70	1224
3	7.78	5.88	1560	1380	39	360	26.0	40	96.5	146	78	4	1080	92	790

Table 3.0 Statistical Analysis of Ground Water Samples

Sample / well No	Parameter	Min	Max	Mean	Median	SD
1	pH	6.04	6.75	6.39	6.35	0.1695
2	Hardness	88	2000	934.66	956	544.76
3	Turbidity	01	85	15.60	09	22.25
4	EC	0.69	6.23	3.84	3.72	2.075
5	TDS	468	4857	2462.28	2465.60	1320.75
6	Chlorides	50	2140	952.40	910	679.43
7	DO	2.0	5.0	3.22	3.5	4.522
8	Acidity	2.0	24	8.94	8.0	5.56
9	Alkalinity	nil	nil	nil	---	---
10	Sulphate	19	64	49.54	57	17.24
11	Total Solids	400	6300	2880	3000	1656.24
12	BOD	12	187	105.57	100	47.88
13	COD	60	576	239.53	212	156.10

Table 4.0 Statistical Analysis of Surface Water Samples

SlNo	Parameter	Min	Max	Mean	Median	SD
1	pH	6.57	8.35	7.21	6.965	0.69
2	Hardness	120	220	180	190	37.41
3	Turbidity	3.0	50	15.75	5.0	19.80
4	EC	0.354	1.098	0.676	0.631	0.333
5	TDS	232	735	453	422.5	223.07

6	Chlorides	50	180	107.5	100	47.10
7	DO	3.00	4.70	3.725	3.6	0.67
8	Acidity	Nil	4.0	1.25	0.5	1.63
9	Alkalinity	Nil	12	5.0	4.0	5.19
10	Sulphate	4.0	61	25	17.5	21.50
11	Total Solids	400	2700	1700	1850	833.66
12	BOD	110	140	123.75	122.50	12.61
13	COD	98	132	114.25	113.50	14.93

Table 5.0 Correlation Matrix - Ground water quality parameters

parameters	pH	Hardness	Turbidity	EC	Chlorides	DO	Acidity	Sulphate	Total solids	TDS	BOD	COD
pH	1											
Hardness	0.148	1										
Turbidity	-0.429	-0.165	1									
EC	0.043	0.887	-0.132	1								
Chlorides	0.099	0.898	-0.057	0.966	1							
DO	0.125	-0.153	-0.111	-0.103	-0.108	1						
Acidity	-0.379	0.510	-0.153	0.424	0.299	-0.140	1					
Sulphate	-0.391	0.568	-0.005	0.742	0.656	-0.095	0.403	1				
Total solids	0.249	0.408	-0.175	0.387	0.283	-0.306	0.306	0.092	1			
TDS	0.009	0.873	-0.082	0.950	0.953	-0.101	0.348	0.716	0.367	1		
BOD	-0.478	0.016	0.342	0.137	0.188	0.228	0.040	0.519	-0.506	0.155	1	
COD	0.310	0.660	-0.199	0.690	0.674	-0.002	-0.053	0.395	0.590	0.715	-0.193	1

Table 6.0 Correlation Matrix - Surface water quality parameters

parameter	**pH**	**Hardness**	**Turbidity**	**EC**	**Chlorides**	**DO**	**Acidity**	**alkalinity**	**Total solids**	**TDS**	**BOD**	**COD**	**Sulphate**
pH	1												
Hardness	-0.994	1											
Turbidity	0.960	-0.937	1										
EC	-0.387	0.292	-0.561	1									
Chlorides	0.103	-0.170	-0.177	0.676	1								
DO	-0.478	0.553	-0.427	-0.437	-0.225	1							
Acidity	-0.548	0.489	-0.483	0.620	-0.153	-0.434	1						
alkalinity	0.604	-0.617	0.381	0.027	0.745	-0.064	-0.733	1					
Total solids	0.162	-0.112	0.049	-0.373	0.331	0.669	-0.896	0.692	1				
TDS	-0.387	0.292	-0.561	1	0.676	-0.437	0.620	0.027	-0.373	1			
BOD	-0.334	0.370	-0.448	-0.076	0.360	0.824	-0.565	0.415	0.869	-0.076	1		
COD	-0.378	0.420	-0.471	-0.117	0.285	0.868	-0.543	0.344	0.851	-0.117	0.996	1	
Sulphate	0.135	-0.180	-0.142	0.493	0.967	-0.018	-0.375	0.841	0.559	0.493	0.550	0.478	1