ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Adverse Effects of Physicochemical Parameters of Solid Waste Disposal on Ground water Quality- a Case Study.

P Vijayalakshmi*[1] and Marykutty Abraham[2].

[1]Department of Civil Engineering, Sathyabama University Chennai, Tamilnadu, India
[2] CRSG, Sathyabama University Chennai, Tamilnadu, India

ABSTRACT

Ground water is a gift of nature and is essential for supply all over the world. Many regions are facing water shortage and quality deterioration due to pollution by human activities, industrialization and high population growth. To meet out the rising demand it is crucial to identify and recognize fresh water resources and also to find remedial measures for improvement of water quality. In this study ground water samples of bore wells and open wells were collected from different locations at Periya eri landfill at Chrompet, Chennai, and were analyzed for physicochemical parameters such as pH, total hardness, iron, chlorides, total dissolved solids, zinc, biochemical oxygen demand, chemical oxygen demand, electrical conductivity and the impacts of leachates on ground water quality was evaluated. The report summarizes the laboratory results of the collected samples and analyzed from the study area and that obtained from the regular monitoring wells of surface water resource data centre (SGRDC), and these values were compared with the standards given by the Bureau of Indian Standards (BIS) and World Health Organization (WHO) Standards. The general and adverse health effects of Solid Waste Disposal on ground water quality are summarized.

Keywords: Ground water, leachate, Municipal Solid Waste, physicochemical, Quality

Corresponding author
Email: vijayalakshmipanneerselvam@yahoo.in

INTRODUCTION

Municipal solid waste leachate induced a non-specific immunotoxic effect in rats and may be of public health importance as there is continuous residential and occupational exposure of human population to hazardous substances from solid wastes landfill[1]. The dumped solid wastes gradually release its initial interstitial water and some of its decomposition by products gets into the water moving through the waste deposit and such liquid containing innumerable organic and inorganic compounds is called “leachate”. This leachate accumulates at the bottom of the landfill and percolates through the soil[2].The present poor system of waste management is very high risk association as it constitutes the threat to surface and ground water resources[2].

The ground water quality varies with location, depth of the water table, seasons, extent and composition of dissolved solids[4].Ground water pollution causes very high extent of damage to soil, plants and animals including man[5]. Once the ground water is contaminated, it is difficult to restore the original water quality. It will degrade by producing an objectionable odour, taste and excessive hardness [5]. Record of ground water levels and analysis of their behaviour forms an important tool to understand hydrogeology [6].The Pallavaram ‘periya eri’ (the big lake), true to its name, was once a sprawling water body, spread over nearly 200 acres. It is situated on the eastern side of railway track from Pallavaram to Chrompet, Chennai.(Fig 1.1).

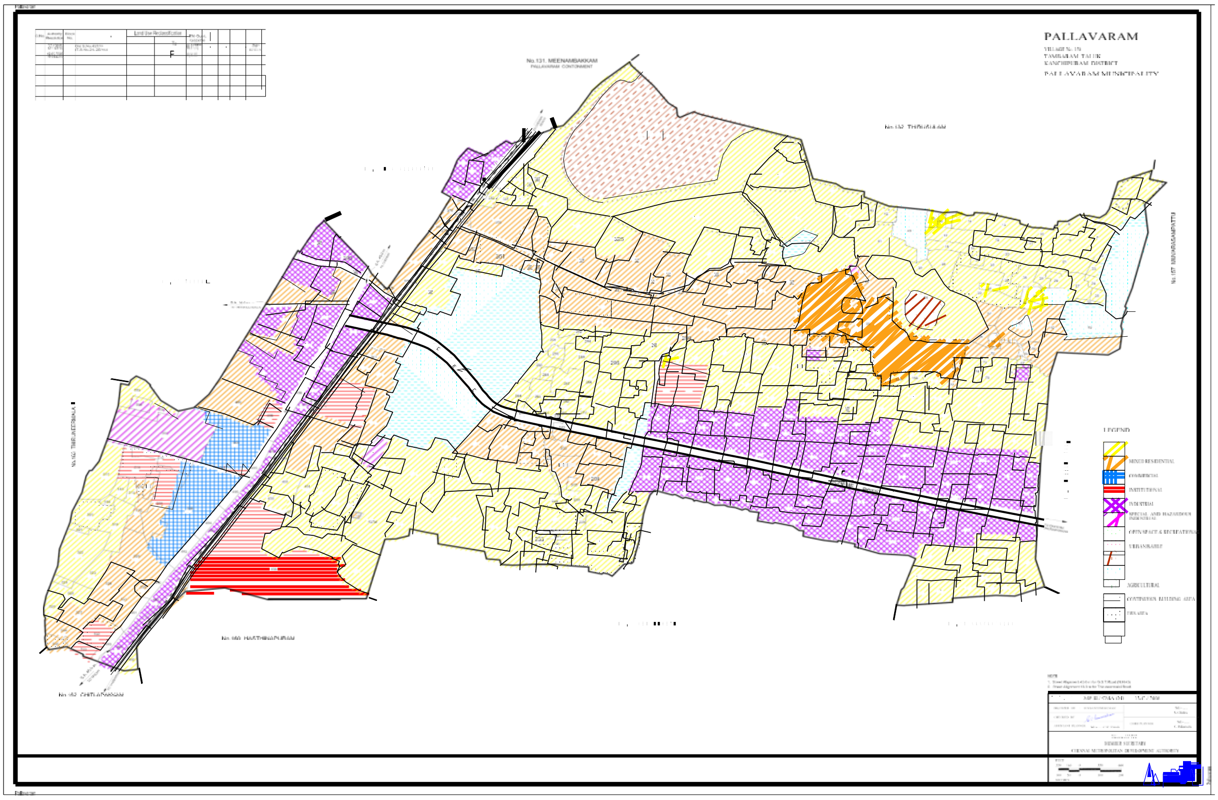

Fig 1: CMDA Land use map (Study area- water body)

The main reason for the water body hanging by a threat is dumping of garbage for nearly a decade. The lake has shrunk to just about 175acres from 200 acres. Due to encroachments, the extent 25 acres had been lost. By laying 200feet Pallavaram to Thoraipakkam Radial Road, the lake was virtually bisected into two halves, one part near Chrompet and the other part near Pallavaram (Fig:1). Now the dumping of waste has been stopped. The garbage collected from the Pallavaram Municipality is being transferred to Venkatamangalam MSW plant.

To determine the effects of physicochemical parameters in the ground water due to the discharge of leachate from the open dumpsite to the underlying ground water aquifers system in the area the present study is undertaken.

LITERATURE STUDY

Barjinder Bhalla1 et al (2014)[7]assessed municipal solid waste landfill leachate treatment efficiency by Leachate Pollution Index (LPI). Leachate sample of Jamalpur landfill site of Ludhiana City, Punjab (India) was collected and analyzed for pH, total dissolved solids (TDS), five day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and chloride (Cl^-) to estimate its pollution potential. The LPI value for the disposal of leachateto the Inland surface water is 7.378(Municipal Solid Waste (Management and Handling) Rules, 2000, Government of India). LPI values of leachate before and after treatment were 26.45 and 7.03 which is under permissible limits.

Dinesh Kumar & Babu J. Alappat (2005)[8]has evaluated the leachate contamination potential of landfill sites using leachate pollution index by comparing the leachate contamination potential of two active and two closed landfill's sites in Hong Kong. The studied concluded that the leachate generated from the closed landfills can have equal or more contamination potential than the active landfill sites. At the closed landfills, till the leachate generated is stabilized and poses no further threat to the environment, the remediation actions and post-closure monitoring should be ensured.

Nanda Balan et al (2012) [9] using water quality index (WQI), the ground water quality in Chennai has been assessed. Based on the legislative constituency, the city was divided into three zones. Nine ground water samples were collected and analyzed physicochemical properties. The ground water quality ranged from excellent to good and fit for human consumption.

A leachate concentration of different MSW dump sites was obtained from literature study and is presented in table 1.The WQI of the study area obtained from literature (Karpagam & Ramesh 2015) varying poor (or) very poor, thus shows the impact of leachate concentration affects the ground water quality.

Comparison of ground water characteristics due to dumpsite leachate of study area from literature studies are presented in table 2. Ground water quality details of Tambaram taluk of Kancheepuram district, collected from State Ground and Surface water Resource Data Centrefor the period of 2006 to 2016 is presented in table 3.

Table 1: Comparison of MSW landfill/dump site leachate concentration (Literature)

Sl. No.	Leachate pollutant variable	Pallikkaranai Landfil, Chennai [3[	Periyaeri Landfill Chennai [3]	Chengalpattu dumping site [14]	Disposal of Treated leachates – Standards* (Land disposal)
1	pH	7·50	8·08	7.77	5.5 – 9.0
2	Total Dissolved Solids	16428	6341	1416	2100
3	BOD	5195	313	210	100
4	COD	25975	1189	739	-
5	Iron as Fe	63	17.77	5.37	
6	Zinc as Zn	1·41	0.753	0.05	-
7	Chlorides as Cl	4735	1987	449	600

*** The Municipal Solid Waste (Management and Handling) Rules, 2000-Schedule IV**

Table 2: Comparison of Ground water Characteristics (Literature Study)

Sl. No	Parameter	Pallavaram (2008)[17]	Pallavaram (2011)[11]	Chromepet (2012)[3]	Chromepet (2012)[12]	Pallavaram (2014)[13]	Chromepet (2015)[10]	AVERAGE (Range of Concentration)
1	pH	7.07 – 7.63	4.18-8.60	5.24-6.59	7.6	-	7.5	4.18-8.60
2	Total Hardnes (Ca Co3)	-	544-2560	450-661	-	77-1831	1370	77 - 2560
3	Iron (Fe)	-	0.243-2.54	-	-	-	-	0.243-2.54
4	Chloride (Cl)	173 -496	136-4474	729-877	336.1	-	242	136-4474
5	Dissolved Solids (TDS)	998 - 1718	588-11050	44.98-482.2		-	1001.5	44.98 - 11050
6	Zinc (Zn)	-	0.015-0.047			0.02-0.36	0.32	0.015 – 0.36
7	BOD	6 -14	-	-	-	-	-	6 -14
9	COD	15 -37	-	-	-	-	-	15 -37
8	EC microS/cm	-	810-16490	2950-3290	2326.5	983-14725	1600	810-16490

Table 3: Details of ground water quality, Tambaram taluk, Kancheepuram district 2006 to 2016

Well No	Village	Latitude	Longitude	Date/Year of collection	Average					
					TDS	Cl	F	pH_ GEN	EC_ GEN	HAR_ Total
13180	Akkarai	12°54'00"	80°14'57"	2006,2007 2008,2010	289	47	0.6 6	8.08	451	420
13186	Injambakkam	12°55'00"	80°15'07"	2006, 2008, 2010	428	86	1	8	710	320
HP 11955	Ponmar	12°51'10"	80°10'40"	2010, 2014	380	14 8	0.0 5	7.65	685	283
13231	Vengivasal	12°51'00"	80°10'13"	5/7/2007	121 4	44 7	0.3 5	7.5	2200	670
13230	Pallikaranai	12°56'06"	80°12'25"	2007, 013	955	26 8	1	8	1665	350
13232	Tambaram	12°55'50"	80°07'60"	20,072,01 0	750	20 1	0.2 9	8	1315	368
	Thiruneermalai	12°57'43"	80°06'51"	2007, 2010	804	17 6	0.4 6	7.55	1325	338
MWS5	Thiruneermalai	12°57'33"	80°07'11"	7/7/2015	817	14 9	0.1 2	7.7	1440	375
13235	Pallavaram	12°58'21"	80°09'13"	2007, 2010	124 8	38 3	0.3 6	7.7	2155	573
HP 11933	Madambakkam	12°54'00"	80°08'52"	2007, 2010	562	13 7	0.3 7	8.2	1005	340
13009	Sadayankuppam	13°16'10"	80°16'32"	25-07-2007	727	13 5	0.0 2	8.3	1290	385
13009	Malaivaiyavoor	13°16'10"	80°16'32"	5/7/2011	394	50	0.1 5	8.4	600	185

MATERIALS AND METHODS

Study area: The study was carried around the Periya eri dumping site at Chennai. The experimental site is located at latitudes 12° 57' 21.11" N, longitude 80° 09' 1.00" E and an altitude of 55 feet above the mean sea level (Fig. 2).The area is having low humidity and high temperature. During winter, the temperature is around 20°C and the temperature increases upto the maximum of 44°C in summer. The average annual rainfall of this region is about 1200 mm and forty percentage of the annual rainfall contributed by the southwest monsoon from June to September contributes. More than 60% of the annual rainfall from October to December is due to northeast monsoon. Topography of this region gently slopes towards west and east. Table 4 gives the details of sampling locations of the study area. Samples were collected from the nine sampling locations to study the impact of Municipal Solid Waste leachate on ground water, randomly distributed near Periya eri dumping site, Chennai (Fig.3).

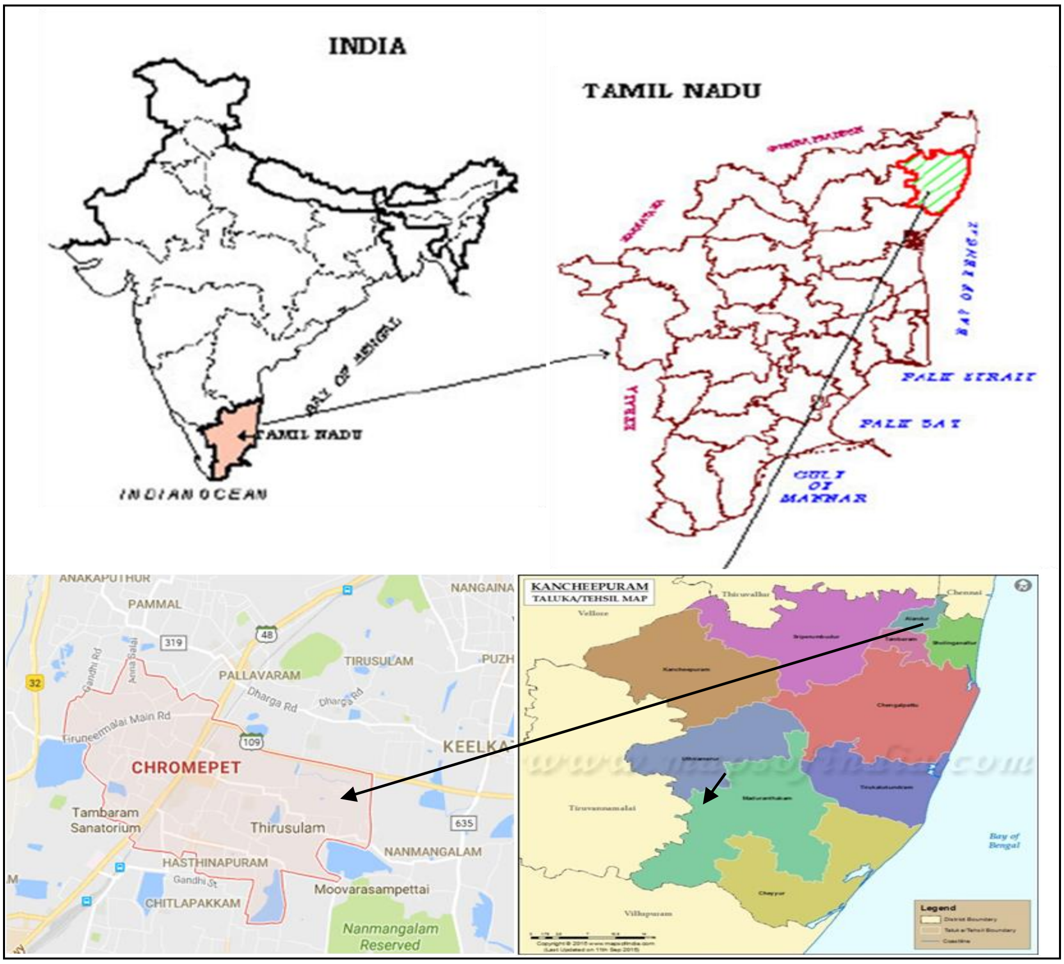

Fig 2: Study area

Fig 3: sampling locations

Table 4: Details of sampling locations of the Study Area

Sl. No	Details of Sampling station	Latitude	Longitude	Type of source	Distance *	Water Use	Land Use/ Specific Activity
1	No. 9, Yerikarai st. Ganapathy Nagar.Chromepet [GS1]	12°57' 17.20" N	80°09' 3.14" E	Bore well	162	Cleaning purpose	Residential
2	No.5, Vallal Perumal st., Canapathy Nagar, chromepet. [GS2]	12°57' 14.44" N	80°09' 1.73 "E	Bore well	233	Cleaning purpose	Residential
3	5 Palatshi Illam, Vallal perumal st., Ganapathy Nagar. [GS3]	12°57' 13.71" N	80°09' 1.69 "E	Bore well	252	Cleaning purpose	Residential
4	No.5, Rajapalayam colony, Chromepet. [GS4]	12°57' 14.98 "N	80°08' 59.97 "E	Bore well	215	Cleaning purpose	Residential
5	N0.15 Rajapalayam colony[GS5]	12°57' 15.58" N	80°08' 59.61" E	Bore well	198	Cleaning purpose	Residential
6	8/11, Jesudaran st. Chromepet. [S6]	12°57' 15.81" N	80°08' 57.78" E	Bore well	208	Cleaning purpose	Residential
7	Sanjai Gandhi Nagar 3rd Street. (Ration Shop). [GS7]	12°57' 14.44 "N	80°09' 1.69"E	Open well	265	Gardenin g Cleaning	Residential
8	Plot o: 8/1, Shanthi Nagar. (Women'sCollege) S8]	12°57' 14.44 "N	80°09' 1.69 "E	Bore well	526	Cleaning purpose	Commercial
9	No: 9, Naidu Shop Road. (Radha Nagar) [GS9]	12°57' 14.44 "N	80°09' 1.69"E	Bore well	525	Cleaning purpose	Commercial

*Distance between Landfill & sampling locations in meters

Collection of samples and their analysis:

To study the ground water contamination due to migration of leachate from the dumpsite, a detailed investigation on ground water quality was carried out by collecting samples from nine representative wells in the study area. The samples were analyzed for pH, total hardness, iron, chlorides, TDS, Zinc, BOD, COD and Electrical conductivity by following standard methods cited in APHA (2012)[15].The test results were compared with regular monitoring wells of SGRDC. The same was also compared with the standards given by the BIS[7] and WHO standard.

RESULTS AND DISCUSSION

Physicochemical Characteristics of Groundwater: Collected water samples were analyzed for the nine different physicochemical parameters such as pH, total hardness, iron, chlorides, total dissolved solids, zinc, BOD, COD, and EC result is shown in the table5. These results were compared with regular monitoring wells of SGRDC, the standards given by the BIS[16] and WHO standards. The same is presented in table 6.The general and adverse health effects are summarized.

Table 5: Results of Physicochemical concentration

Sl.No	Parameters*	Ground water Samples								
		GS_1	GS_2	GS_3	GS_4	GS_5	GS_6	GS_7	GS_8	GS_9
1	pH at 25 °C	6.92	8.5	8.05	7.96	8.2	8.1	7.7	7.8	7.8
2	Total Hardness as CaCo3	1204	368	752	891	412	312	490	500	430
3	Iron	NT	0.187	BDL*	BDL*	0.259	0.132	0.10	0.15	0.15
4	Chlorides as Cl	729.3	126	391	479	168	113	480	430	450
5	Total dissolved solids	2782	937	1561	1684	1208	714	1840	1775	1735
6	Zinc Zn	NT	0.373	0.01	0.02	0.484	0.351	NA	NA	NA
7	BOD at 27 C for 3 days	19.8	BDL*	BDL*	BDL*	BDL*	BDL*	NA	NA	NA
8	COD as O2	64.6	BDL	BDL*	BDL*	BDL*	BDL*	NA	NA	NA
9	EC	NT	1823	2730	2900	2451	1382	2830	2730	2670

*All parameters are in mg/l except pH and EC (µmhoscm), NA – Not analysed *BDL - (<0.05)

Hydrogen Ion Concentration (pH): Acidic or alkaline of water is indicated by the value of pH. For drinking, the water with a pH range of 6.5 to 8.5 is generally satisfactory. It damages the parts of the human body if the pH is higher than the prescribed limit.

The minimum and maximum pH value of the samples collected from the study areas lie within6.92 to 8.5respectively (Table 6), and the value of some samples exceeds the value obtained from the regular monitoring wells of SGRDC. And the values of some samples are within the standards given by the Bureau of Indian Standards and WHO Standards.

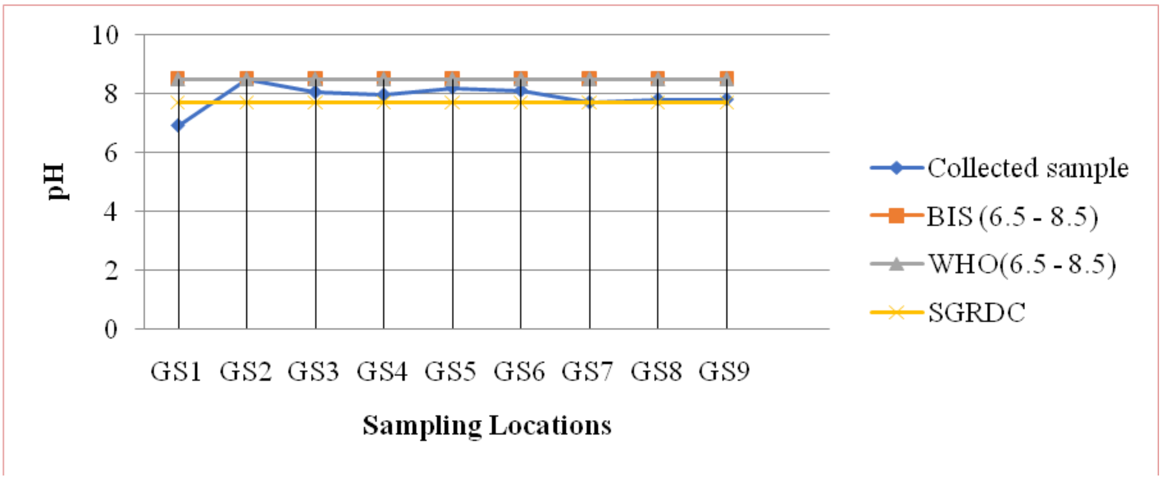

Fig 4: Variation in Hydrogen Ion Concentration (pH)

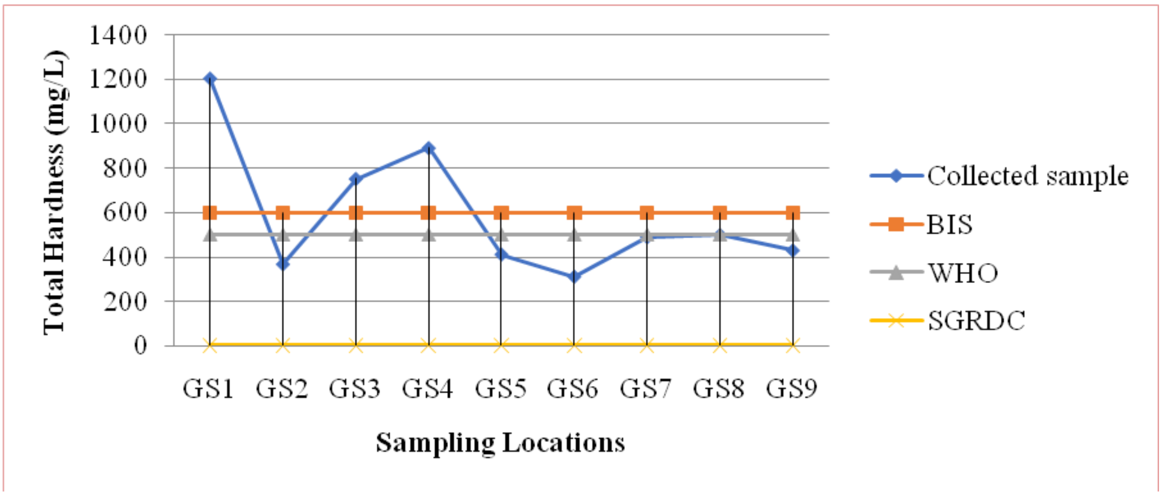

Fig 5: Variations in Total Hardness (TH)

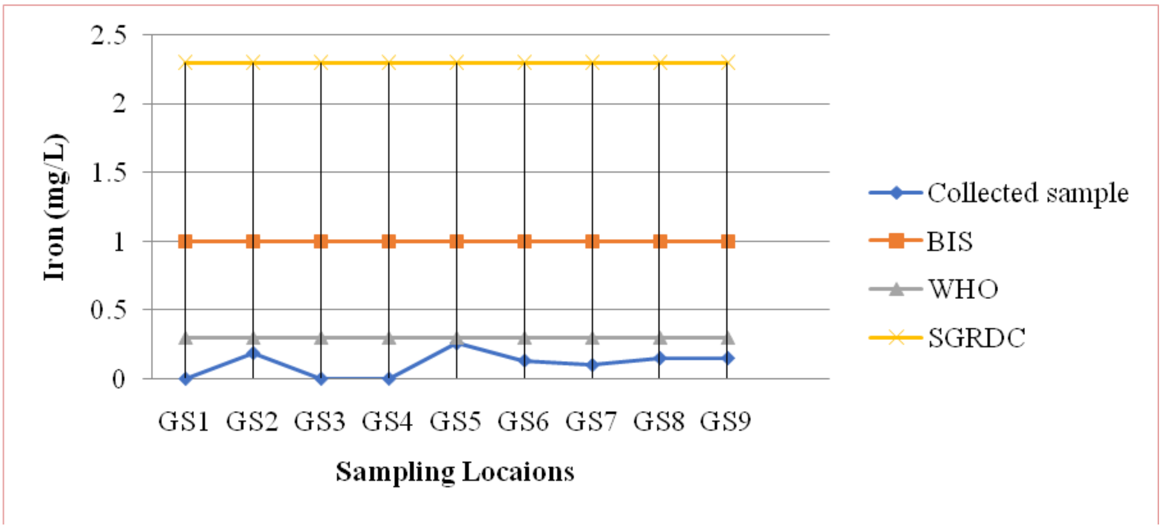

Fig 6: Variations in Iron (F)

Total Hardness (TH): To determine the suitability of water samples for domestic and industrial purposes, hardness is important as it is involved in making the water hard. The presence of calcium and magnesium salts is the reason for the water hardness. High level of hardness may affect water supply system. Due to hardness the soap consumption is more. Kidney problem, stomach disorders, urinary problems etc., occurs due to high level of hardness in water.

The minimum and maximum values of total hardness of the collected samples are 312 mg/L and 1203.6 mg/L respectively (Table 6). The minimum value is within the study area value (Literature) and regular monitoring wells of State ground and surface water resource data centre and also within the desirable limit of BIS and WHO. The maximum value exceeds the value of study area and regular monitoring wells of SGRDC and also the desirable limits of BIS and WHO standards. Fig. 5 shows the variations in Total Hardness.

Iron: an adverse effect on domestic uses and water supply structures are due to High content of iron. The minimum and maximum values of Iron in the study area are 0.1mg/L and 0.259 mg/L respectively. All the values of the collected samples are within the desirable and permissible limits of BIS standards and WHO standards and also less than the values for regular monitoring wells of SGRDC.Fig.6 shows the variations in iron content.

Table 6: Comparison of Ground water Quality Parameters

Sl. No	Parameters	Ground water quality (from literature)	Ground water quality (study area)		SGRDC	BIS standards[16]		WHO standards
			Min	Max		Desirable Limit	Permissible Limit	Permissible Limit
1	pH at 25 °C	4.18-8.60	6.92	8.5	7.7	6.5 - 8.5	No relaxation	6.5 - 8.5
2	Total Hardness as $CaCo_3$	77 - 2560	312	1203.6	573	300	600	150 - 500
3	Iron	0.243-2.54	0.10	0.259	0.36	0.3	1.0	0.3
4	Chlorides as Cl	136-4474	113	729.3	383	250	1000	250
5	Total dissolved solids	44.98 - 11050	714	2782	1248	500	2000	Nil
6	Zinc	0.015 – 0.36	0.01	0.484	-	5	15	3
7	BOD at 27º C for 3 days	6 -14	BDL*	19.8	-	-	-	-
8	COD as O_2	15 -37	BDL*	64.6		-	-	Nil
9	EC	810-16490	1382	2900	2155	-	-	250

*All in mg/l except pH and EC (µmhoscm)

Chloride (Cl): High concentration of chloride may be injurious to some people suffering from heart and kidney diseases. The taste, palatability and indigestion are also due to high concentration of chloride.

The minimum and maximum values of chloride are113 mg/L and 729.3 mg/L respectively (Table 6).The minimum value is within the value of study area (Literature) and regular monitoring wells of SGRDC and also with the desirable limits of BIS standards and WHO standards. The maximum value exceeds the value of study area (literature) and within the regular monitoring wells of SGRDC and also with the permissible limit of BIS standards.Fig.7 shows the variations in chloride.

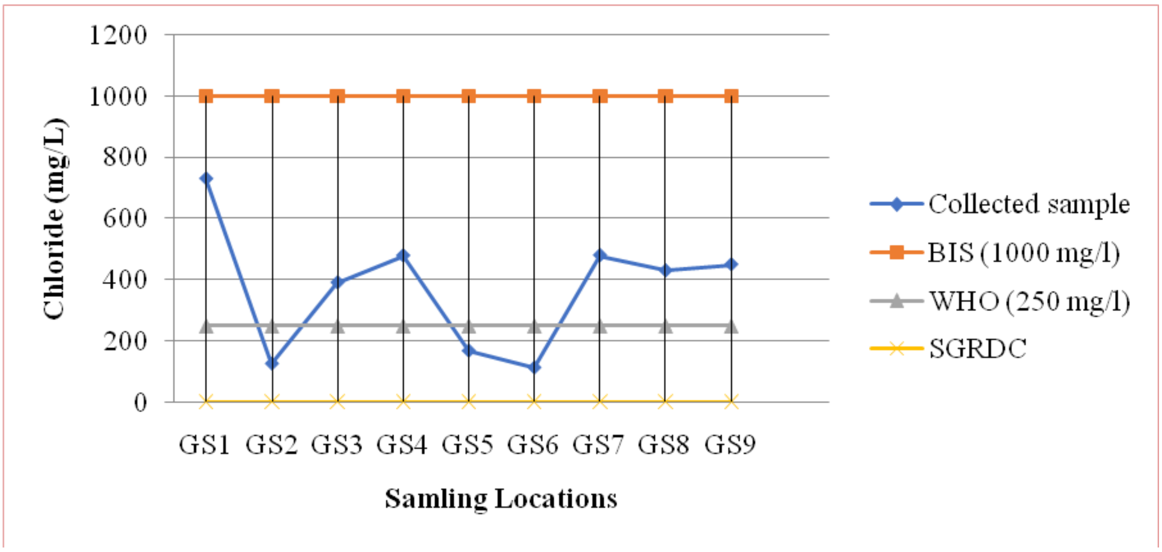

Fig 7: Variations in Chloride (Cl)

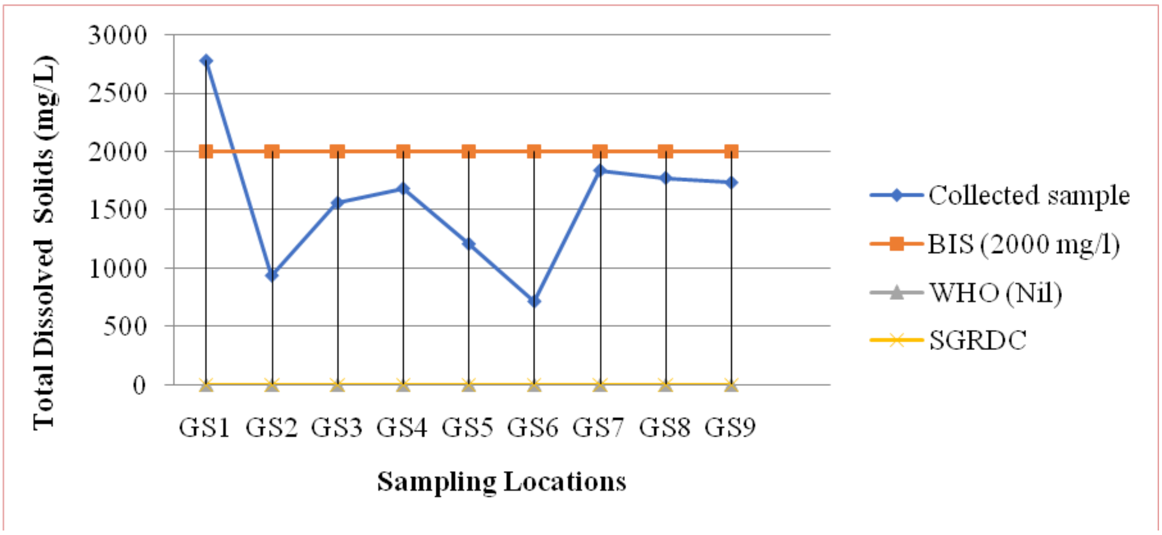

Fig 8: Variations in Total Dissolved Solids (TDS)

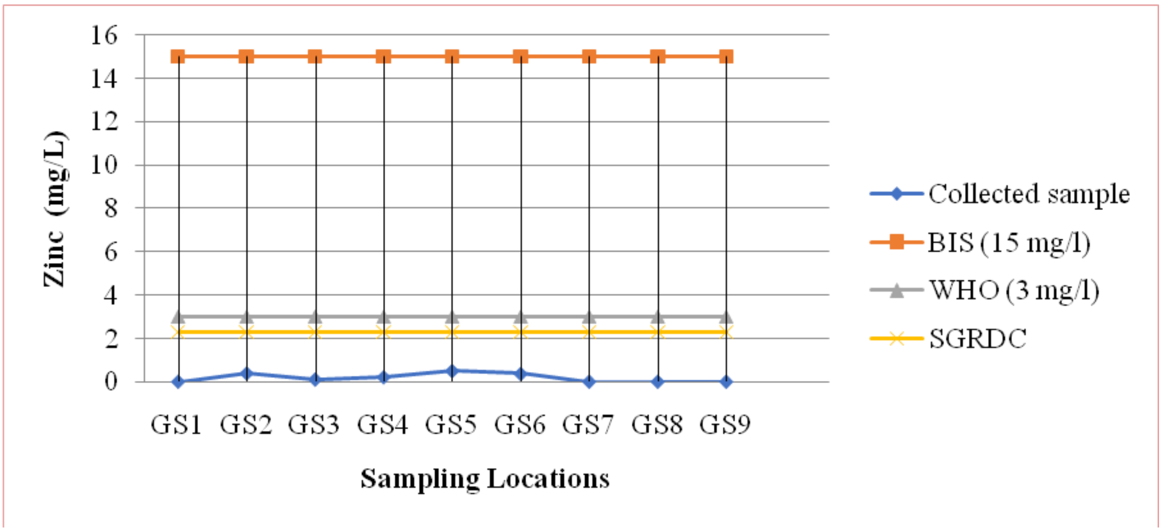

Fig 9: Variations in Zinc (Zn)

Total Dissolved Solids (TDS): TDS is the index impurity of the water. Palatability and causes gastrointestinal irritation in human beings are decreases due to high TDS. The prolonged intake of water with high concentration of TDS causes kidney stones.TDS is an indication of aesthetic characteristics of drinking water. Total Dissolved Solids of the collected sample ranges between714 mg/L and 2782mg/L (Table 6).The maximum value exceeds the value of study area (Literature), the permissible limit of BIS and regular monitoring wells of SGDRC.

Table 5 shows that the ground water samples GS2 &GS6 are permissible for drinking and GS1, GS3, GS4, GS5, GS7, GS8, GS9 are useful only for irrigation. Overall it shows that 29% of the samples fall in drinking category and 71%in irrigation category as far as TDS alone is concerned. The concentration of other parameters may not make it fit for drinking purpose.Fig.8 shows the variations in total dissolved solids.

Zinc (Zn): For human metabolism, the zinc is an essential element. Zinc concentration of ground water samples ranges from 0.01 to 0.484 mg/l with an average of 0.247 mg/l (Fig.9).Concentration of zinc in the study area is much less than the permissible limit and this means, there is no zinc pollution in the ground water.

Biochemical oxygen demand (BOD): is the amount of dissolved oxygen required by aerobic biological organisms at certain temperature and time to break down organic material present in a given water sample. Among nine samples, the sample taken very near to the dumping site (i.e.GS1) has 19.8 mg/l which exceed the value of the study area (Literature) and the regular monitoring wells of SGRDC and also the limits of BIS standards and WHO standards. Fig: 10show the variations in Biochemical oxygen demand.

Chemical Oxygen Demand (COD): COD indirectly measure the amount of organic compounds in water. Among nine samples, the sample taken very near the dumping site (i.e. GS1) gives the value of 64.6 mg/l which exceeds the value of study area (Literature) and regular monitoring wells of State and ground water resource data centre and also with the limit of BIS standards and WHO standards. Fig.11shows variations in chemical oxygen demand.

Electrical Conductivity (EC): The electrical conductivity of water estimates the total amount of solids dissolved in water. The range of EC of the study area from various literature studies is 810µmhoscm to 16490 µmhoscm. Thus Higher EC in the study area indicates the enrichment of salts in the ground water.

In the study area, Electrical Conductivity of samples lies with a minimum and maximum values of 1382 µmhoscm and 2900 µmhoscm respectively (Table 6). The minimum value exceeds the value of study area (Literature) and WHO standards. The maximum value exceeds the value of study area (Literature) and regular monitoring wells of SGRDC and also with WHO standards.Fig.12 shows the variations in electrical conductivity in the study area.

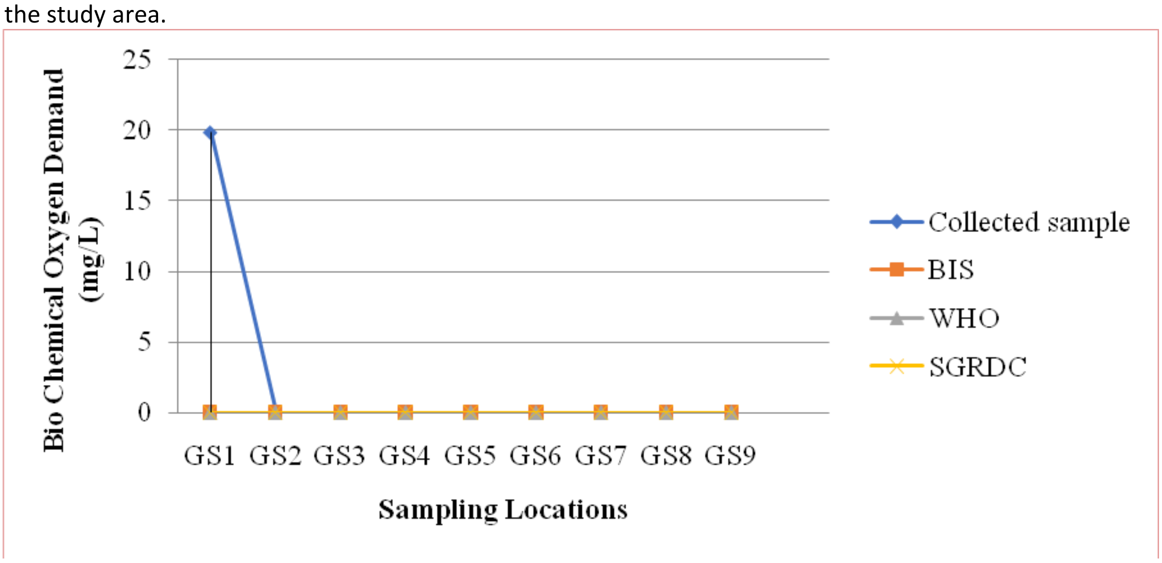

Fig 10: Variations in Bio Chemical Oxygen Demand (BOD)

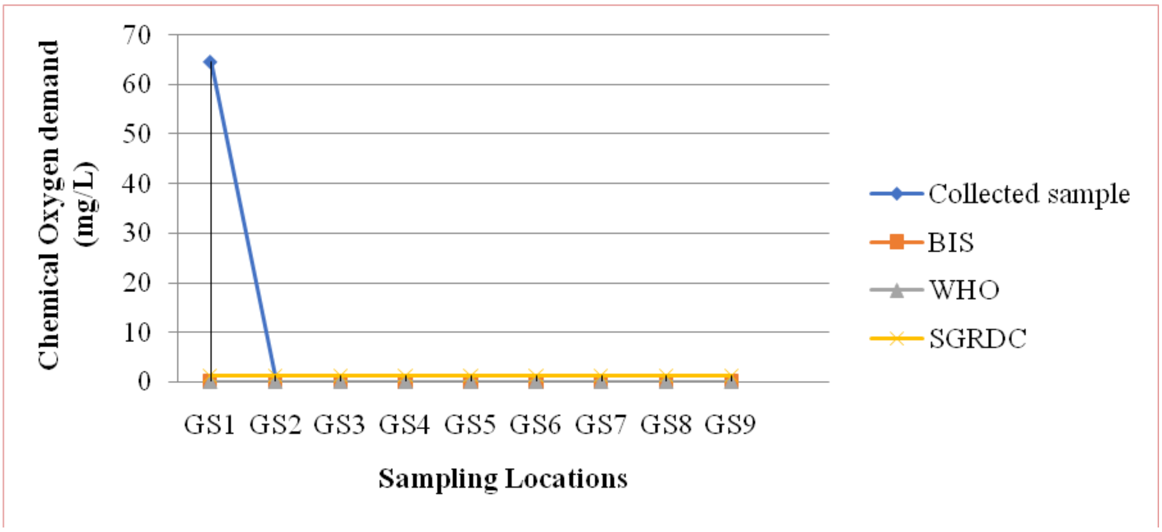

Fig 11: Variations in Chemical Oxygen Demand (COD)

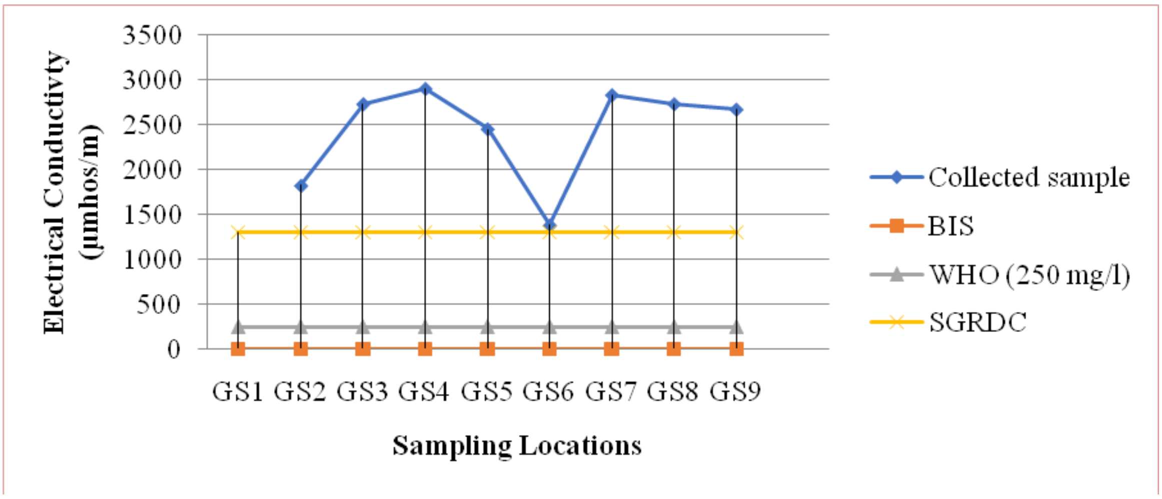

Fig 12: Variations in Electrical Conductivity (EC)

CONCLUSIONS

Ground water from nine sampling sites has been selected and analyzed for the physic-chemical characteristics of water. From the result and discussion it was observed that except zinc, the range of concentration of pH, total hardness, Iron, chloride, total dissolved solids, BOD, COD and EC are very high. It can be concluded that the ground water near Periya eri dumpsite in Chrompet is highly polluted in comparison with the range of concentration of literature studies and moderately polluted with regular monitoring wells of SGRDC and also with BIS and WHO Standards. To enhance the ground water quality, some effective measures are required. It is necessary to properly design, construct, and manage the dumpsite using engineering principles in order to minimize the impact of leachate concentration on ground water quality and the environment. Regular monitoring of ground water in the region is required. Ground water resource must be protected from the contamination, since it is the major available source of water for the domestic and irrigation purpose in this region.

REFERENCES

[1] Chibuisi G. Alimba, Adekunle A. Bakare and Olatubosun G. Arinola (2009) Effects of Municipal Solid Waste Leachate on Leucocyte and Differential Counts in Rats Global Journal of Environmental Research 3 (3): 135-140, 2009, ISSN 1990-925X

[2] Olaniyan, Isaac O1, et al (2012) Hydrochemical Analysis of Leachate Characteristics from Landfill Sites in Kaduna, Nigeria IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT) ISSN: 2319-2402, ISBN: 2319-2399. Volume 2, Issue 1 (Nov. - Dec. 2012), PP 48-53.
[3] Ms. B. Manimekalai and P.Vijayalakshmi (2012) Analysis of Leachate Contamination Potential of a Municipal Landfill Using Leachate Pollution Index IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT) ISSN: 2319-2402, ISBN: 2319-2399. Volume 2, Issue 1 (Nov. - Dec. 2012), PP 16-39.
[4] M.Govindarajan and T.Senthilnathan (2014) Ground water quality and its health impact analysis in an industrial area International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706 Volume 3 Number 7 (2014) pp. 1028-1034
[5] Gawsia John, Harendra K. Sharma1, Vikas Vatsa (2014) Impact of municipal solid waste dump on ground water quality at Danda Lokhand landfill site in Dehradun city India International Journal Of Environmental Sciences ISSN 0976 – 4402 Volume 5, No 3
[6] Status Of Ground water Quality In India -Part-II, Ground water Quality Series: GWQS/ 10/2007-2008, Central Pollution Control Board (Ministry Of Environment And Forests) Website: www.cpcb.nic.in, e-mail: cpcb@nic.in April, 2008
[7] Barjinder Bhalla1, M.S. Saini and M.K. Jha (2014) Leachate contamination potential of unlined municipal solid waste landfill sites by leachate pollution index International Journal of Science, Environment,ISSN 2278-3687 (O) and Technology, Vol. 3, No 2, 2014, 444 – 457.
[8] V Karpagam & Dr. K Ramesh (2015) Dinesh Kumar Æ Babu J. Alappat (2015), “Evaluating leachate contamination potential of landfill sites using leachate pollution index”, Clean Techn Environ Policy (2005) 7: 190–197 DOI 10.1007/s10098-004-0269-4.
[9] Nanda Balan M Shivakumar P D Madan Kumar (2012) An assessment of ground water quality using water quality index in Chennai, Tamil Nadu, India DOI: 10.4103/2229-5186.98688, Vol. 3 | Issue 2 | Apr-Jun 2012
[10] Karpagam & Ramesh (2015) Assessment of Ground water Quality of Chrompet Industrial Area by Water Quality Index Method” International Journal of Engineering Technology, Management and Applied Sciences July 2015, Volume 3, Issue 7, ISSN 2349-4476
[11] Raman and D.Sathiyanarayanan (2011) Quality assessment of ground water in pallavapuram municipal solid waste dumpsite area nearer to Pallavaram in Chennai, Tamilnadu RASAYAN J. Chem. Vol.4, No.2 (2011), 481-487 ISSN: 0974-1496 CODEN: RJCABP
[12] K. Brindha & L. Elango (2012) Impact of Tanning Industries on Ground water Quality near a Metropolitan City in India Water Resource Manage (2012) 26:1747–1761 DOI, 0.1007/s11269-012-9985-4.
[13] K.Ramesh, V.Thirumangai (2014) Trace metals contamination of ground water in and around tannery industrial area of pallavaram, chennai city, India IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308, Volume: 03 Issue: 05 | May-2014.
[14] P.vijayalakshmi, M .Gowtham& S.Dinakaran (2014) Analysis of leachate contamination potential of a solid waste dumping site using leachate pollution index
[15] APHA (1992) Standard Methods for the Examination of Water and Waste Waters, American Public Health Association, 18th Edition, Washington, DC. 2.
[16] BIS (2012) Specifications for Drinking Water, IS:10500:2012, Bureau of Indian Standards, New Delhi 110002
[17] N.Raman and D.Sathiya Narayanan (2008) Impact of solid waste effect on ground water and soil quality nearer to Pallavaram solid waste landfill site in Chennai RJC Rasayan J. Chem. Vol.1, No.4 (2008),828-836