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Impact of Leachate On Ground Water Quality Near Kodungaiyur Dumping Site,Chennai, Tamil Nadu, India

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Abstract: Tamil Nadu ranks first in urbanization among the fifteen major states in the country. According to the 2011 Census, Tamil Nadu has emerged as the state with the highest level of urbanization (43.86%) in the country. The urban population requires a wide range of urban services including water supply, sewerage and solid waste management. In most cities, the solid waste is dumped in open dumps without proper lining which affects the environmental media such as air, water and land. So, the present study was focused on the impact of leachate percolation on ground water quality. Leachate and ground water samples were collected from Kodungaiyur Dump site and the surrounding areas of within 1.5 Km radius. The leachate and ground water samples were tested for various physiochemical parameters and heavy metals. The heavy metals tested in the Leachate are Cd, Cr,Cu,Fe,Pb and Zn. The result of the analysis shows that there is a high concentration of EC, Cl^-,TDS, NH_4^+ and SO_4^{2-} present in ground water. This indicates that the groundwater is affected by leachate percolation and further the groundwater is undesirable for domestic water supply and other uses. Also some remedial measures are suggested to avoid further groundwater contamination due to leachate percolation and solid waste management technique.
Keywords: Solid Waste, Kodungaiyur Dumping site,Leachate percolation, Water Quality.

Introduction

One of the most important crisis faced by many of the urban and industrial areas in both developed and developing countries is solid waste disposal and management which directs to environmental issue in day today life. Enormous amount of solid waste is generated daily and its management is a huge task. Solid waste generation has witnessed an increasing trend parallel to the development of industrialization, urbanization and rapid growth of population. The solid waste management encompasses everything from collection, transportation and disposal of waste. In the past, managing solid waste involve transporting waste from cities to distant places for dumping and for the nature to take care. However, today, the increasing land value, inadequate space, limited capacity of nature to handle unwanted emissions and residues pose long-term environmental and human health problems. Uncontrolled open dumping is commonly prevalent in most developing countries as it is the simplest and most cost-effective method of waste disposal. This practice is also adopted in the developed countries to some extent. Therefore, it desperately needs immediate action to be taken to minimize the associated harmful impact. Chennai has also witnessed unprecedented growth of population and urbanization in the past two decades. Due to urbanization, the generation of solid waste is increased and also affect the groundwater quality.[1] Kodungaiyur dumpsite in the north part of CMA located within Mullakadai marsh is growing at much faster rate. Initially it is a small dumpsite and no proper measure has been taken to prevent the leachate entering the groundwater. Presently the dumping area has increased, leachate oozing out pollutes the groundwater and incineration of the waste pollutes the air. These are the two main issues that pollute the environment. In the present study the impact of leachate percolation on groundwater were

analyzed an unlined landfill at kodungaiyur, Chennai, Tamilnadu. The physiochemical and heavy metal concentration were tested from the collected leachate and groundwater samples. The effect of depth and distance of landfill from groundwater were studied and remedial measures were suggested to avoid future contamination by leachate percolation.

Leachate

Leachate is generated on account of the infiltration of water into dumpsites and its percolation through waste as well as by the squeezing of the waste due to self weight. Water that penetrates into landfill picks up the soluble constituents from the wastes and may enter either the ground water or the surface water and thus act as a vehicle, carrying potentially toxic matter from the landfill to the water sources. The important factors that influence leachate quality are waste composition, elapsed time, temperature, moisture and available oxygen.[2] In general, leachate quality of the same waste type may be different in landfills located in different climatic regions. Dumpsite operational practices also influence the leachate quality.

Significant quantity of leachate is produced from the active phases of a landfill under operation during the monsoon season. Leachates which emerge out of the dumpsite percolate down to the aquifer. Characterization of the leachate is necessary in the assessment of ground water contamination near disposal sites.

The following principal groups are contained in leachate. Inorganic macro components: calcium, magnesium, sodium, potassium, ammonium, iron, manganese, chloride, sulphate and bicarbonate. Dissolved organic matter expressed as COD, Total organic carbon and including methane and volatile fatty acids.

Study Area:

The Kodungaiyur dumping yard located at the northen part of Chennai city is in operation since 1980. Initially the leachate generated from the Chennai city has been dumped in Kodungaiyur dumpsite. Due to urbanization, increase in population, changes in lifestyle and consumption pattern, the problem of water waste management in Chennai has been increased. So two other major, Perungudi in south and Kodungaiyur in north have been proposed and being used as open dumps for disposal of Municipal Water Waste from the Chennai city. In this study Kodungaiyur dump site is taken as a study area. It lies between 13'06.75 " N latitude and 80^{o} 14' 06.34" E longitudes.Open dumping and leveling by bulldozer is the method of waste disposal. The dumping site covered about 30 ha in 1995.[3] and increased to 54.75 ha in 2002.[4] which is twice that of the area in 1995. The dumping area is estimated to be 117 ha in 2009 which is again twice as that of in 2002.

Kodungaiyur sewage water treatment plant located adjacent to the dumpsite discharges the sewage water near to the dumpsite. The waste at the site mixes with the sewage water and contaminates it further. The dumpsite lies at 1.5 to 2.0 km from the western side of Buckingham canal and 3 km west of Bay of Bengal coastline. It is situated within a low lying IOC marsh which extends for a length of approximately 10 km from north to south and for a width of 3 to 4 km from west to east that makes the dumpsite always surrounded by water courses. Figure 1 shows the study area map.

Sampling of Leachate and Groundwater

The groundwater samples were collected from 17 observation wells around kodungaiyur dumpsite during the month of January. In order to assess the groundwater quality in kodungaiyur area groundwater samples were collected during post- monsoon season (January 2014).

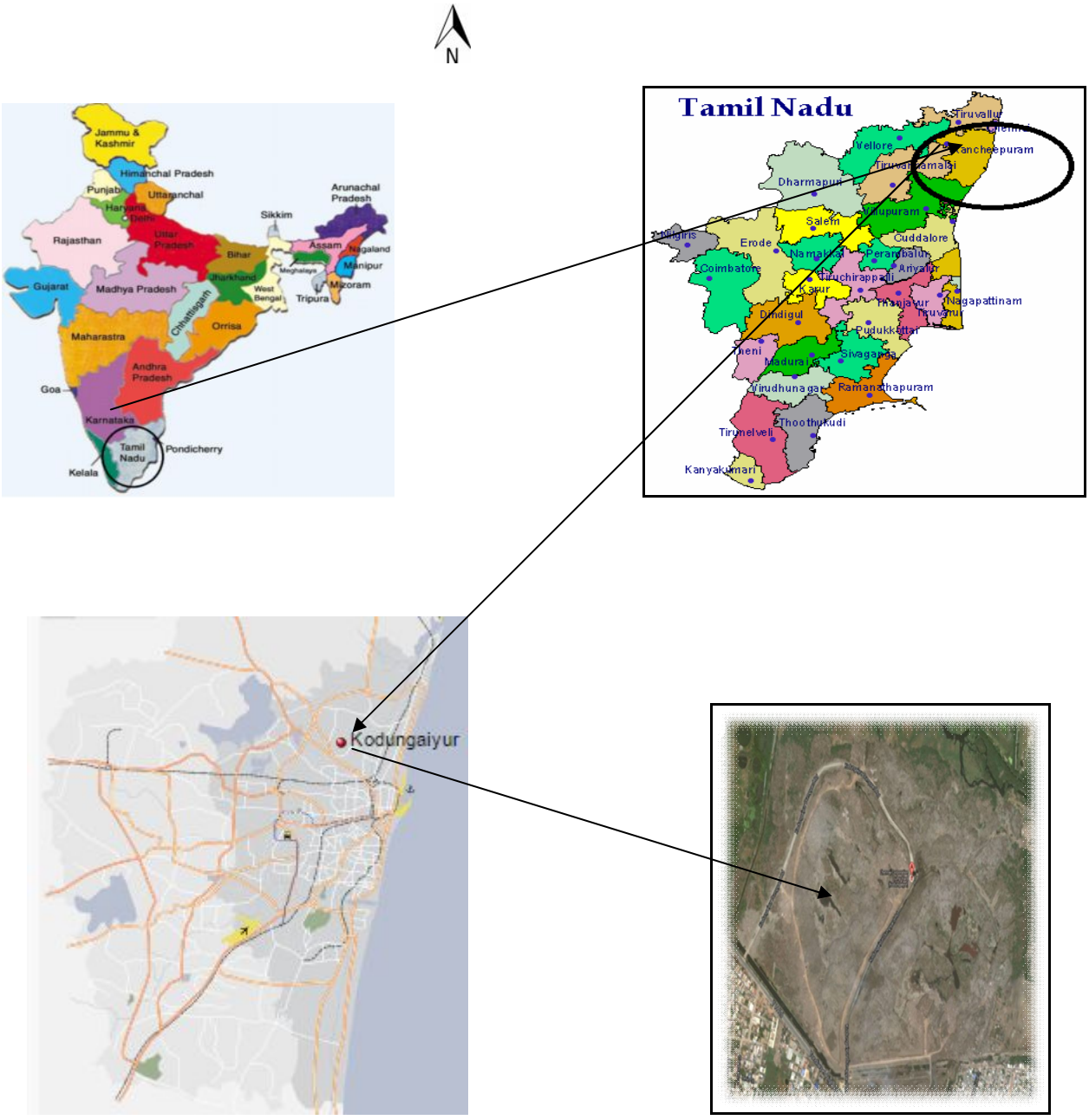

Figure 1. Study Area Map

The field testing kit was taken to the sampling site to study the important insitu parameters. The well locations were collected by using hand held GPS. Figure 2 shows the well location in the kodungaiyur area. The samples were collected in a clean polyethylene bottles. The bottles were cleaned thoroughly with 1% Nitric acid before sample collection and all the collected samples were analyzed.[5]

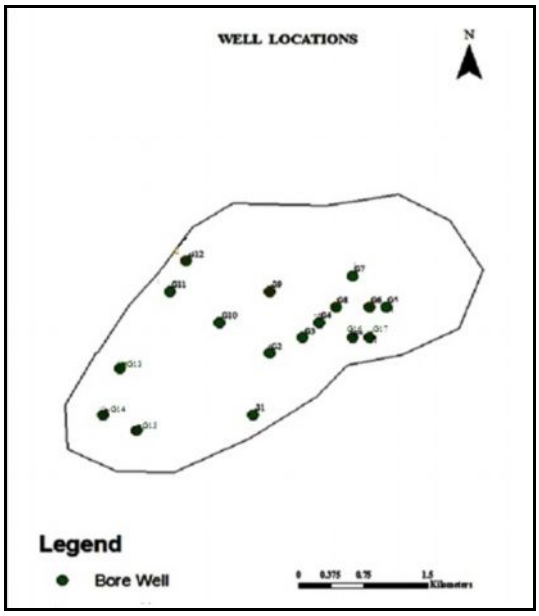

Figure 2.Samples collected from site

Surface Leachate Chracterization

Chemical characteristics of the leachate depend primarily upon the waste composition and water content in total waste. The characteristics of the leachate samples collected from the dumpsite has been presented in Table 1. Variation in the conductivity was very high (2360µmhos/cm) and is the main indicator of dissolved inorganic species or total concentration of ions. Though the pH values were within the stipulated standards, the levels can be used to explain the nature of the leachate. Higher pH (> 8) value indicates the alkaline nature of leachate. This shows that the biochemical activity in the landfill was in its final stage and the organic load was biologically stabilized.[6] During the initial stage or acetogenic stage, the pH values are quite low (<7).The maximum pH value of leachate at dumpsite is 6.98. The presence of high BOD (18439 mg/l) and COD (25110 mg/l) indicates high organic strength of leachate. In all three leachate sample sample 1 shows the high value of ammonia nitrogen (2047 mg/l) indicates the decomposition of organic matter. The high TDS value of 25920 mg/l shows presence of inorganic material in the leachate sample.

Table 1. Physico-chemical characteristics of leachate at landfill sites

Parameters	Samlpe1	Sample 2	Sample 3
pH	6.98	6.6	6.7
EC	2360	2256	2283
TDS	25920	2247	23186
COD	25110	24860	23748
BOD	18439	16385	1657
Na^+	674	553	539
k^+	1267	1153	1126
NH_4^+	2047	1749	1942
NO_3^-	394	341	373
Phenol	0.01	0.98	0.02
Fe	78	65	61
Pb	1.21	1.28	1.3
Zn	2	1.67	1.7
Cu	0.78	0.63	0.69
Cd	0.04	0.03	0.03
Cr	0.38	0.35	0.33

The high concentration of Fe (78 mg/l) and Zn (2.0 mg/l) indicates the presence of Iron and batteries in the leachate.[7] The leachate samples also having small amount of Pb,Cr,Cd and Cu and maximum value of those heavy metals are Pb (1.28 mg/l),Cr(0.38 mg/l),Cd(0.04 mg/l) and Cu (0.78 mg/l).

Contamination of Water

Initially the well inventory survey has been conducted which reveals that shallow wells for a depth of 8 - 10.5 m exist for a radius of 1.5 km around the dumping site. During reconnaissance survey the inhabitants stated that the deep wells excavated are of no use as the water is black in colour. From the observations and the survey it is inferred that mostly shallow wells are located in the vicinity of the dumpsite. The present research aims to understand the behavior of shallow unconfined aquifer which is majorily under use by the community. The dumpsite is located inside the marsh and the groundwater in the marsh is having high TDS since water gets stagnated for many years. Also reconnaissance survey in the study area reveals the groundwater for a distance of 100 - 200 m at the fringes of the marsh is of bad quality for more than 25 years and the groundwater at a distance of 200 m is deteriorated for the past 5 - 8 years.

To study the groundwater contamination due to migration of leachate from the dumpsite a detailed investigation on groundwater quality, general groundwater flow pattern has been assessed by selecting 17 representative wells in the study area. Table 2 shows chemical parameters of water samples. The test results were compared with Bureau of Indian Standards[8] and World Health Organization standard[9] which are presented in Table 3.

Table 2. Physiochemical parameters of ground water Samples

Parameters	Sampling Sites																
	G1	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**	**G9**	**G10**	**G11**	**G12**	**G13**	**G14**	**G15**	**G16**	**G17**
pH	6.52	6.71	6.92	6.9	6.85	6.74	6.54	6.77	6.81	6.79	6.28	6.37	6.48	6.63	6.2	6.86	6.76
EC	1539	2273	2146	2574	1754	1960	1584	2027	1985	1845	1820	1584	1283	1429	1483	1382	1380
TDS	1080	1378	1839	2225	1538	1203	1029	1782	1629	1372	1300	1219	1015	1038	1270	1198	1374
Ca^{2+}	62	112	160	140	48	106	48	84	54	60	36	40	63	52	39	74	47
Mg^{2+}	32	109	94	112	61	71	135	108	72	56	134	91	89	84	51	78	126
TH	290	738	793	820	376	560	685	660	437	385	649	483	538	483	310	510	644
K^{+}	30	29	69	12	18	46	15	57	83	27	17	38	7	16	27	17	14
Cl^{2-}	121	277	447	121	280	638	82	532	50	156	326	186	454	138	79	372	152
SO_4^{2-}	91	113	86	147	95	169	101	194	86	129	144	274	158	128	107	94	89
Na^{+}	195	208	122	192	291	542	167	424	228	112	251	73	459	98	133	261	139
No_3^{2-}	0.31	1.22	0.96	0.69	0.52	0.49	0.18	0.29	0.75	0.64	0.33	0.41	0.38	0.37	0.16	0.53	0.49
F^{-}	0.67	0.34	0.85	0.72	0.13	0.39	0.46	0.49	0.26	0.47	0.76	0.97	0.5	0.38	0.16	0.27	0.37

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

Table 3 Comparision of grounwater quality parameters with Indian (BIS) and International (WHO)standards

Parameters	Minimum	Maximum	Average±SD	BIS standards		WHO standards	No of sapmles exceeds permissible Limits		Undesirable Effect
				Desirable Limit	Permissible Limit	Permissible Limit	BIS	WHO	
pH	6.2	6.92	6.65±0.221	6.6-8.5	No relaxation	7-8.5	Nil	Nil	Taste
EC	1283	2574	1767.53±358.68	-	-	1000	-	All	
TDS	1015	2225	1381.71±330.30	500	2000	500-1500	G4	G3,G4,G8,G9	Gastro- intestinal irritation
Ca^{2+}	36	160	72.06±330.302	75	200	75	Nil	G2,G3,G4,G6,G8	Scale formation
Mg^{2+}	32	135	88.41±29.736	30	50	50	All saples except G1	All samples except G1	Scale formation
TH	290	820	550.65±162.508	300	600	500	G2,G3,G4,G7,G8,G11,G17	G2,G3,G4,G6,G7,G8,G11,G13,G16,G17	Scale formation
K^{+}	7	83	30.71±21.508	-	-	-	-	-	
Cl^{2-}	50	638	259.47±176.261	250	1000	200	Nil	G2,G3,G5,G6,G8,G11,G13,G16	
SO_4^{2-}	86	274	129.71±49.295	200	400	200	Nil	G12	Laxative effect
Na^{+}	73	542	229.12±133.465	-	-	200	-	G2,G5,G6,G8,G9,G11,G13,G16	
No_3^{2-}	0.16	1.22	0.51±0.275	45	100	45	Nil	Nil	Blue bby
F^{-}	0.13	0.97	0.48±0.239	1	1.5	1.5	Nil	Nil	Fluorosis

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

Physiochemical Characteristics

The pH value of the study area lies between 6.2 to 6.92 which was within the desirable limit suggested by BIS. The highest value of pH found at G3 and the minimum value of pH was found at G15. The EC value in the study area ranged between 1283 mg/l to 2574 mg/l and the maximum value was observed at site G4. The EC values of all the samples were permissible limit of WHO. It was noted that the groundwater samples collected near the landfill sites contains more soluble salts. The TDS value of the sample water was high at site G4 (2225 mg/l) and low at site G13 (1015 mg/l) and all the samples were exceeding the permissible limit given by BIS standards. The TDS generally represent the amount of suspended and dissolved particles present in water.

The high value of Total Hardness (820 mg/l) was recorded at the sampling site G4 and the minimum value of (290 mg/l) was recorded at sampling site G1. The Calcium and Magnesium was in the range of 36 to 160 mg/l and 32 to 135 mg/l. The maximum value of Calcium was observed at G1 and maximum value of Magnesium was found at G7. The calcium values of all the samples are below the permissible limit of BIS. The concentration of Chloride in the study area has the maximum value of 638 mg/l at G6 and the minimum value of 50 mg/l at G9 and all the sampling sites were showing the Chloride value within the permissible limits by BIS. An excess of Chlorides in water sample usually taken as the index of pollution and considered as tracer for groundwater contamination.[10]

Sulphate concentration of samples ranged from 86 to 274 mg/l. The maximum value of sulphate was found at site G12 and the minimum value was found at G3. Except the sample from the site G12 all other samples were within the permissible limits of BIS and WHO. The value of Nitrate was in the range of 0.16 to 1.22 mg/l and it was found that all the samples having their nitrate value well below the permissible limits (45 mg/l) of BIS and the highest value of nitrate was found at G2. The concentration of fluorides was in the ranges between 0.13 to 0.97 mg/l. The maximum and minimum value of sodium was in the range of 73 to 542 mg/l and it was found at G12 and G6.

Heavy Metals

All the collected samples were analyzed for heavy metals such as Cu, Fe and Zn. The permissible limits of these metals in drinking water respectively 1, 0.3 and 5 mg/l (WHO) .The maximum values of Fe and Zn in the water samples are 0.41 and 0.90 mg/l. The concentration of Cu was within the permissible limits for all water samples.

Conclusion

The concentration of EC, TDS,TH,Cl^-,SO_4^{2-} and NO_3^- was high in the sampling site near to the dumping yard. The high concentration of these parameters shows that there is a ground water contamination from leachate percolation in the study area.[11,12,13] As the lithology is changed to sandy soil after 1.5 km along the eastern and south eastern part of the dump site, the leachate movement will take place at a faster rate and the concentration will get increased significantly in the sandy aquifer after 10 years.

It can be concluded that kodungaiyur dumpsite is non-engineered landfill. It is neither having any bottom liner nor any leachate collection and treatment system. Therefore, the leachate generated finds its own path into the surrounding environment. Moreover un-segregated waste dumped in unlined landfill had severely affected the groundwater quality. As the dumpsite is located in the marshy area, water stagnated throughout the year around the dumpsite facilitates the generation and movement of leachate at higher rate. Moreover according to MSWM rules[14] the dumping yard should not be located near the water bodies. As the dumpsite is in operation for more than 25 years, further dumping may damage the aquifer to unrecoverable condition. It is necessary to the upgrade the Landfill site and scientific management to prevent future contamination of groundwater [12,13] and treatment of water for domestic supply.[15,16,17] If the dumping is stopped immediately, the analysis shows that the groundwater quality will get improved after a period of 10 years by natural attenuation.

Recommendations for Reducing the Level of Contamination Have Been Given Below.

- Spatial and temporal variation of leachate quality and quantity has to be properly monitored in and around the dumpsite.
- Groundwater should also be monitored by increasing the observation wells in the hot spots.
- Strict measures have to be adopted to prevent the dumping of the un-segregated waste in order to avoid the further deterioration.
- Usage of non-biodegradable materials has to be reduced to minimize the level of contamination in the groundwater.

The important structural measure that has to be adopted to remediate the groundwater is by selecting appropriate in-situ techniques which are available to clean up the groundwater. Treatment techniques such as natural attenuation and cut off wall constructed along the groundwater flow direction may provide a viable solution for the treatment of contaminated groundwater in kodungaiyur.

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