AN INTEGRATED HEALTH IMPACT ASSESSMENT USING RS, GIS AND WATER QUALITY ANALYSIS OF THE KODUNGAIYUR DUMPSITE

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Abstract : Rapid urbanization and industrialization are the root causes for increase in solid waste generation in developing countries. The improper disposal of solid waste in landfills results in leachate leakage. This in turn gets infiltrated into groundwater and causes severe health issues. Chennai, the capital city of Tamil Nadu state is the fourth largest metropolitan city in India. Municipal solid waste generation in Chennai city is nearly 4,500 million tonnes per day. There are two major dumpsites in Chennai, the Kodungaiyur dumpsite in North (2,300 million tonnes/day) and the Perungudi dumpsite in South (2,000 million tonnes/day). Kodungaiyur is a residential area and it comes under the Perambur Taluk of Zone IV (Tondiarpet) of the Corporation of Chennai. The study results revealed that the dumpsite area has increased by 37% and there is decrease of 49% in vegetative area, over a period of ten years. The vegetative area got slowly converted into a wasteland due to increase in the area of dumpsite. TDS, Calcium, Nickel, Iron, Copper, Phenol, Manganese, Ammonium and Chloride exceeds the permissible limit of BIS and WHO standards, which signifies the contamination of groundwater due to leachate. Leachate Pollution Index of the dumpsite was found to be 18.15, which is higher than 7.37, which is the permissible limit of leachate disposal of inland water surface. The contamination of groundwater results in severe health issues especially during the rainy season. Skin infection, diarrhea and Malaria are the top diseases, which people face frequently. 16.6% of people were affected by skin infection and diarrhea, 12.1% of people were affected by Malaria. This can be reduced by managing the leachate generated within the open dumps and producing zero waste at household level.

***Index Terms* - Groundwater contamination, Dumpsite, Landfill, Leachate Pollution Index, Landuse/land cover, Water quality, Health Impact Assessment**

I. INTRODUCTION

Water is essential for life, which covers major part of earth's surface. A very small percentage is available as fresh water. The fresh water constitutes of 2.5% of total quantity of water on earth, two-thirds of which is frozen as glaciers and ice caps, leaving only 0.77% of fresh water for human use. Groundwater is the major source for drinking and other domestic purposes, in places where there is no availability of surface water.

Due to urban sprawl, groundwater is being exploited to greater extents. Increase in population and rapid industrialization was found to be one of the root causes for increase in solid waste generation in developing countries.

In India about 52 million tonnes of solid waste are been generated every year (Central Pollution Control Board report, 2016). Landfills are one of the widely used and common methods to dispose municipal solid waste, which is the major reason for groundwater pollution. Chennai is India's sixth largest city and having a population of 4.9 million people (2011 census). Chennai Pollution Control Board (CPCB) with the assistance of the National Environmental Engineering Research Institute (NEERI) has conducted a survey of solid waste management in 59 cities (35 metro cities and 24 state capitals). According to this, Delhi and Mumbai has generated the largest amount of municipal solid waste in 2005, which is 5,922 tons/day for Delhi and 5,320 tons/day for Mumbai, followed by Chennai with 3,036 tons/day and Kolkata with 2,653 tons/day. The largest per capita of solid waste generation is in Chennai, which is about 0.620 kg/day. The lowest per capita waste generation is in Mumbai, which is about 0.45kg/day. (MSW, 2010).

II. NEED FOR STUDY

Due to rapid urbanization and industrialization, there is a change in landuse and land cover pattern. Agricultural and grassland area gets converted into barren lands. The barren lands are used for dumping of huge amount of wastes without any proper management, which has made groundwater increasingly vulnerable to pollution. Landfills has been identified as the major threats to groundwater resources (Fatta, *et.al.*, 1999) especially when they are unlined, as it is common in the developing countries, the leachate which is produced from the waste percolates deep into the soil leading to groundwater pollution.

The surrounding areas of the dumpsite get contaminated and make the groundwater hazardous. This causes severe negative impacts on the health of the people. This study aims at analyzing the groundwater contamination around the Kodungaiyur dumpsite, estimating the leachate pollution index and determining the health impacts caused due to the presence of the dumpsite.

III. STUDY AREA

Chennai is one of the four major metropolitan cities in India with population of about six million. Due to urbanization, increase in population, changes in lifestyle and consumption pattern, the problem of waste management in Chennai has increased. Kodungaiyur is a residential area and it comes under Perambur Taluk of Zone IV (Tondiarpet) of Chennai Corporation. Zone IV consisting of 14 Wards (34 to 48) and Kodungaiyur area comes under Ward number 35 and 37. The Kodungaiyur dumping yard, which is located at the northern part of Chennai city, is in operation since 1980. The location map of the study area is shown in Figure 1. The latitude and longitude of Kodungaiyur is 13^0 80' 02''N and 80^0 16' 09''E. The total area of dumping ground is about 116 ha. The dumpsite lies at about 1.5 to 2.0 km from the western side of the Buckingham canal and 3 km west of the Bay of Bengal coastline. It is situated within a low lying marshy land, 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: Study Area

The Kodungaiyur dumpsite is a non-engineered low-lying open dump, where the wastes are dumped in an irregular fashion. The segregation of waste is rarely done. Wastes such as medical waste, e-waste, industrial waste, organic waste and inorganic waste are all mixed up together and over a period of time. Decomposition takes place and a liquid is generated from the waste which is known as 'leachate'. There are no proper measures to monitor the leachate generated from the dumpsite and it is let into the Kodungaiyur canal without any proper treatment. The water in the canal can be seen as black colour due to the mixing of leachate. The leachate percolates into the groundwater, contaminating it and cause several diseases.

IV. METHODOLOGY

The landuse and land cover maps were prepared by using satellite data of Linear Imaging Self-scanning Sensor (LISSS III). The change detection analysis was done using the Earth Resource Data Analysis System (ERDAS) software. Groundwater samples and leachate samples were collected and tested to analyze the physical, chemical and biological characteristics. Leachate Pollution Index (LPI) was calculated which helped in the analysis of groundwater contamination, which then helped in the study of health impact assessment and providing respective remedial measures.

V. RESULTS AND DISCUSSION

5.1 Landuse and Land Cover change detection using ERDAS

Landuse and land cover change detection of the Kodungaiyur dumpsite were done for a period of 10 years (2006 and 2016) in order to know the expansion of the dumpsite area. Supervised classification was done using ERDAS imagine software. Figures 2 and 3 show the landuse land cover maps of 2006 and 2016 respectively.

The landuse classifications were done for vegetation, dumpsite, waterbody and settelment. The area of vegetation was reduced from 71.15 ha to 15.22 ha over a the period of 10 years. Similarly the dumpsite area got incresed from 65.30 ha to 107.5 ha in the same period.

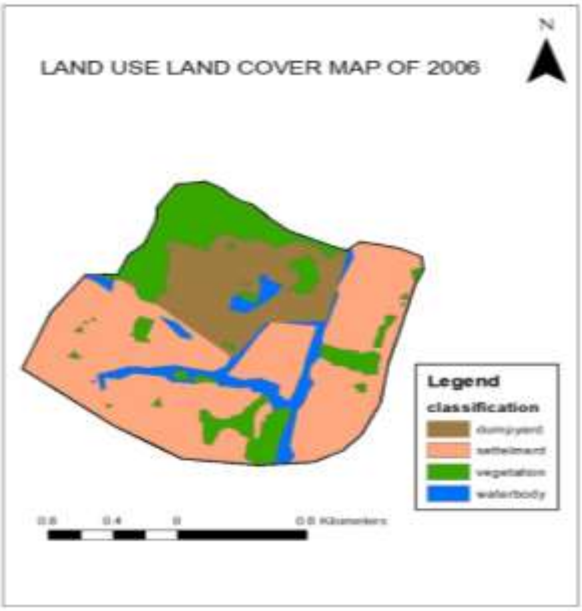

Figure 2 Landuse / Land cover map of 2006

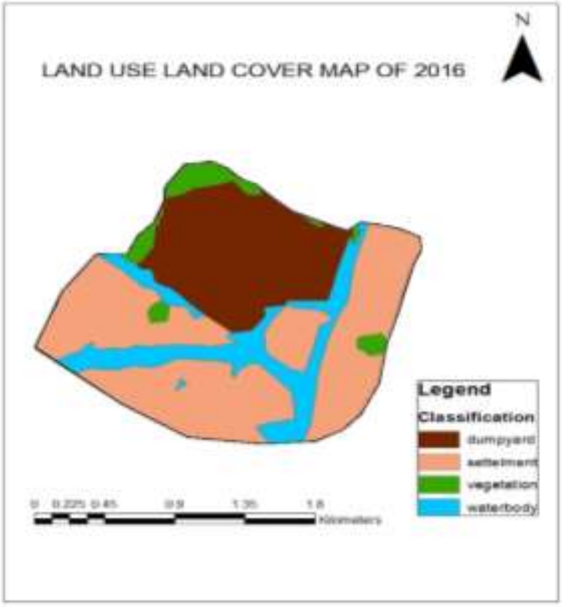

Figure 3 Landuse / Land cover map of 2016

Table 1 shows the land use / land cover change of 2006 and 2016. There is a major decrease of vegetative cover (49%) and increase of dumpsite area (37%) in 10 years.

Table 1 Comparison of Landuse Land Cover Map

Sl.No.	Classification	2006 area (Ha)	2016 area (Ha)	Percentage (%)
1	Dumpsite	65.30	107.5	37 (increase)
2	Vegetation	71.15	15.22	49 (decrease)
3	Settlement	196.93	196.28	1 (decrease)
4	Waterbody	26.83	41.26	13 (increase)
5	**Total**	**360.26**	**360.26**	**100**

5.2 Quality of Groundwater around the Dumpsite

The water samples were collected at a distance of 500 m, 750 m and 1 km from the dumpsite. The location of wells is shown in Figure 4.

Figure 4 Well Locations

The water samples from wells were collected during the months of January and February 2018. Seven bore wells and twelve open wells were identified and samples were collected around the dumpsite. Table 2 shows the concentration of various parameters present in the groundwater samples. All the parameters exceeded the BIS standard.

Table 2 Analysis of Groundwater Quality Parameters

Well location / parameters	O2	O3	O10	B6	BIS Standard
TDS (ppm)	2980	1910	2300	2546	500
Calcium (mg/l)	184	120	30	45	75
Nickel (mg/l)	0.092	0.066	0.044	0.065	0.02
Iron (mg/l)	0.789	0.478	0.815	0.785	0.3
Copper (mg/l)	0.597	0.127	0.725	0.664	0.05
Phenol (mg/l)	0.7942	0.0263	0.1181	0.2463	0.001
Manganese (mg/l)	1.514	1.987	0.031	1.08	0.1
Ammonium (mg/l)	3.273	3.512	4.871	3.432	0.5
Chloride (mg/l)	724.77	537.33	4913.37	5012.63	250

Interpolation of the groundwater samples for Chloride, TDS, Ammonium and Nickel were done using spatial analyst tool of ArcGIS 10.3, using Inverse Distance Weighted method (IDW), which are shown in the Figures 5 (a), (b), (c) and (d). The higher concentration of chemical and biological parameters is due to leachate percolation into groundwater and presence of a public limited company.

Microbiological parameters such as Coliform, Faecal coliform and E-coli, which must be present within the permissible limit of 0 MPN/100, as per National Primary Drinking Water Standard (EPA, 2000). Excess bacteria present in the groundwater results in harmful health impacts to the people. Few samples exceed the permissible limit. It was found to be more than 20 MPN/100. The presence of Coliforms may be due to the intrusion of human fecal matter. The industries near the dumpsite also add pollution to the groundwater. Most of the wells are highly contaminated by the pathogens.

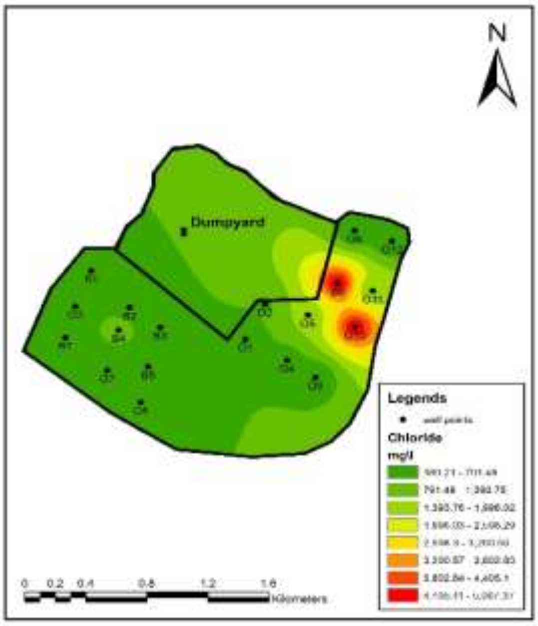

Figure 5 (a) Spatial distribution of chloride in Groundwater

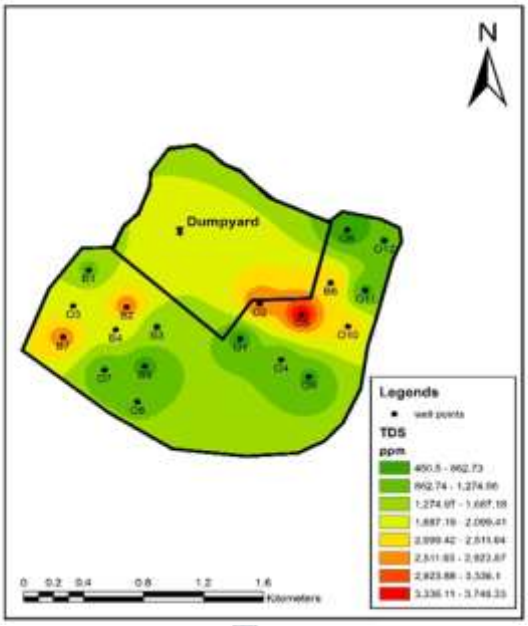

Figure 5 (b) Spatial distribution of TDS in Groundwater

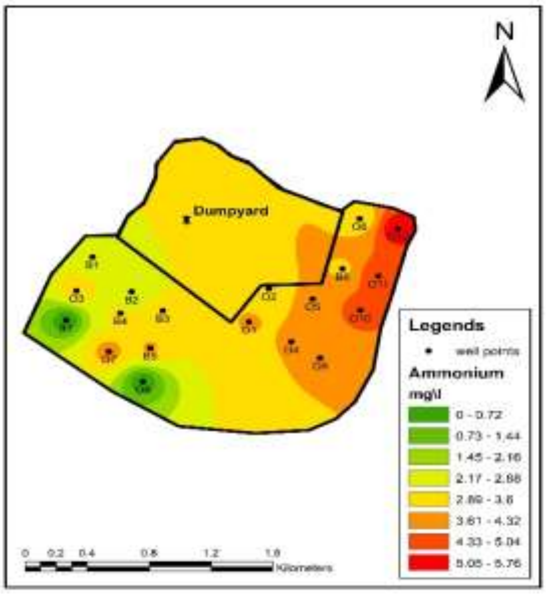

Figure 5 (c) Spatial distribution of Ammonium in Groundwater

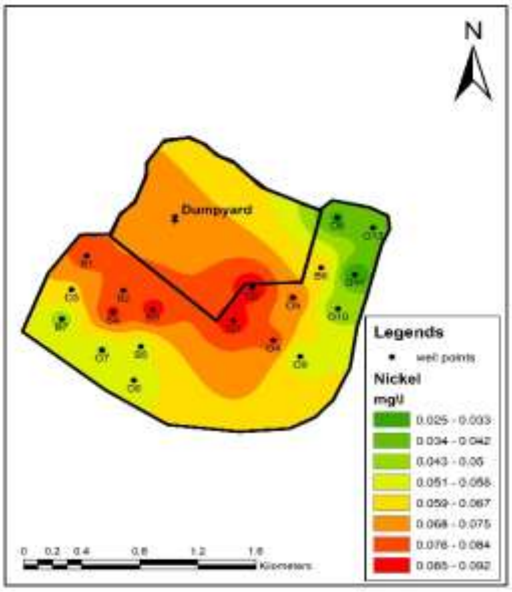

Figure 5 (d) Spatial distribution of Nickel in Groundwater

5.3 Quality of Leachate and Leachate Pollution Index

The physical, chemical and biological characteristics of leachate were collected for the month of January and February. The parameters were compared with the standards of Ministry of Environmental, Forest and Climate Change. TDS, Chloride and Chromium exceed the permissible limit. The high value of TDS (3,965 ppm) shows the presence of organic matter present in solid waste. The chromium in leachate (3.85 mg/l) shows the presence of metal and e-waste in the dumpsite.

The quality of water in Kodungaiyur canal before leachate discharge gave values such as TDS 1,378 ppm, Chloride 986 mg/l and Chromium 2.78 mg/l and the water quality parameter values have increased after the leachate discharge into the canal, which is being substantiated with the values as TDS 1,729 ppm, Chloride 1,960 mg/l and Chromium 3.55 mg/l. Similarly, for all the other parameters too, the values have exceeded the standard values after the leachate got mixed into the canal.

The leachate pollution index was found with the help of pollution concentration, pollution weight and sub-index curve. The weight factor indicates the importance of each pollutant variable to the overall leachate pollutant. The averaged sub index curves for each parameter are drawn to establish a relation between the leachate pollution and strength or concentration of the parameter.

The weighted linear sum aggregation function was used to sum up the behaviour of all the leachate pollutant variables. Pollutant sub index curves for all the parameters were obtained from the graph (Kumar and Alappat, 2004). Leachate pollution index value was calculated as shown in Table 3.

The LPI can be calculated using the equation given below:

$$LPI = \frac{\sum_{i=1}^{n} W_i P_i}{\sum W_i}$$

where,

LPI = Weighted additive leachate pollution index

W_i = Variable weight of the pollutant

P_i = Pollutant sub index value

The high value of leachate pollution index (18.15) which exceeds the leachate disposal for inland water surface (7.37) signifies that the leachate is not treated and stabilized. When this leachate percolates into the groundwater it makes the water contaminated and causes severe health issues, if it is used.

Table 3 Leachate Pollution Index

Sl. No	Leachate pollutant variable	Variable weight (wi)	Pollutant concentration (ci)	Pollutant sub index value (pi)	Aggregation (wipi)
1	Chromium	0.064	3.26	20	1.28
2	Lead	0.063	-	-	-
3	COD	0.062	1878.2	70	4.34
4	Mercury	0.062	-	-	-
5	BOD	0.061	5113	30	1.83
6	Arsenic	0.061	-	-	-
7	cyanide	0.058	-	-	-
8	Phenol	0.057	1.123	5	0.28
9	Zinc	0.056	0.12	5	0.28
10	pH	0.055	8.3	5	0.27
11	Nickel	0.052	0.16	5	0.26
12	Total ammonical nitrogen	0.053	-	-	-
13	Total coliform bacteria	0.052	14.5	25	1.3
14	Ammonium	0.051	2.98	5	0.25
15	TDS	0.05	3651.66	10	0.75
16	Copper	0.05	0.85	5	0.25
17	Chloride	0.048	4041.14	30	1.47
18	Iron	0.045	0.92	5	0.22
	Total	**0.704**			**12.78**
	LPI Value				**18.15**

5.4 Health Impact Assessment

In order to understand the impacts on health of the people due to the presence of dumpsite, questionnaire survey was administered with a sample size of 80. Simple random sampling method was used for the selection of samples. The analysis was done using Statistical Package for Social Sciences (SPSS) software. From the questionnaire one could get a wide knowledge about the perception of people about the dumpsite and its consequences.

From the questionnaire survey it has been understood that 54 % of pollution comes from the dumpsite. Burning of the waste creates air pollution and cause skin allergies and eye irritation to the people. The wastes which are disposed off very close to the waterbodies cause severe waterborne diseases. During the rainy season, 62.5 % of groundwater is highly contaminated and intrusion of sewage water also adds to pollution.

The common illnesses people usually suffer from are: fever, cold, cough and skin allergies. 30.2 % of people suffer from fever, cold and cough. The top three common diseases people face are the skin infection, Diarrhea and Malaria.

Figure 6 shows the vulnerability map for the diseases prevailing around the dumpsite. The diseases considered are Cholera, Malaria, Tuberculosis, Jaundice and Typhoid. Similarly, illness vulnerability map was developed and is shown in the Figure 7.

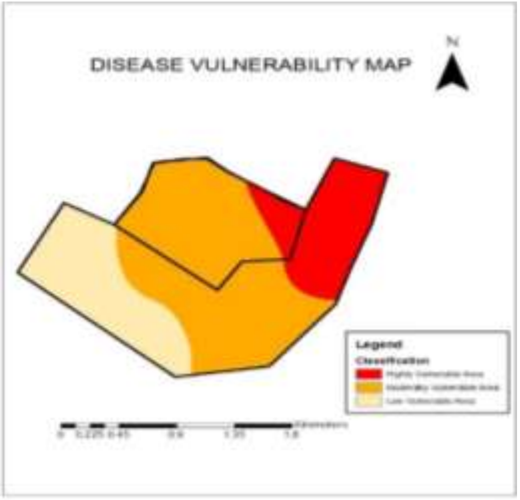

Figure 6 Disease Vulnerability Map

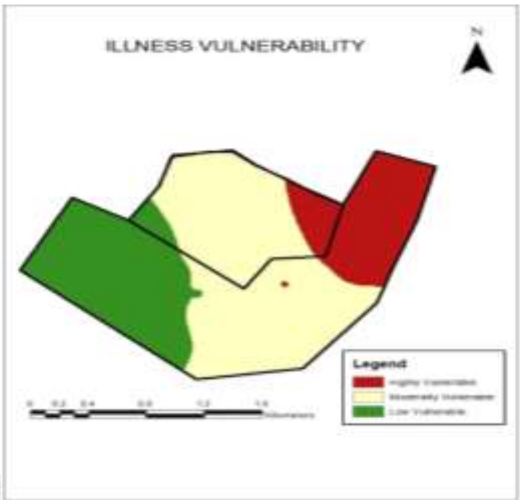

Figure 7 Illness Vulnerability Map

In both cases, high vulnerability of diseases is seen near the southeast direction of the dumpsite. This is due to the movement of leachate in that direction. The presence of oil and petroleum refineries also pollutes the groundwater. The vulnerability of diseases becomes less while moving away from the dumpsite.

VI. CONCLUSIONS AND RECOMMENDATIONS

The analysis of the study revealed that the movement of leachate contamination is more in the southeast direction of the dumpsite. The presence of a Public Sector company and other industries plays a vital role in the contamination of groundwater. According to the Schedule III notification of the Municipal Solid Waste Handling Rules, 2000, the life span of any landfill is 20–25 years, but the Kodungaiyur landfill is more than 30 years old.

In order to overcome the problems, there should be a scientific landfill with proper leachate collection, treatment and disposal system. The landfill site should follow all the criteria said in the Municipal Solid Waste Management Rules, 2000.

LPI value is used as a tool to assess the leachate pollution potential from landfill sites particularly at places where there is a high risk of leachate migration and pollution of groundwater and thus useful for taking necessary decisions. Monitoring should also be done in the industries because they let out their effluents into the waterbodies in open areas directly without any treatment.

Awareness among the people should be created through rallies, media and by the government. Segregation of waste has to be practiced from the household level and the provision of three bin system should be made mandatory for the separation of waste (organic waste, e-waste and recyclable waste, medical waste). Reduce, reuse, recycle and rot (composting) is a better way to reduce the generation of waste in an integrated way.

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