Assessment of Spatial Distribution of Physico-Chemical Parameters of Groundwater around Kodungaiyur Dump yard

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Abstract. Municipal solid waste management has become an acute problem due to enhanced economic activities and rapid urbanisation. In most cities, solid waste is disposed of in open dumps without proper lining which has tremendous health issues and environmental effects. Kodungaiyur dump yard chosen for this study is the major toxic dump yard in Chennai. In recent years there has been a serious concern about the deteriorating groundwater quality due to leachate contamination. Despite posing strict rules on pollution of water bodies, water continues to be consistently underappreciated and undervalued. So, the present study is emphasized on the ill effects of leachate percolation on groundwater quality and is also represented spatially to understand the impact of the landfill in the selected area. For this study water samples are collected from 12 bore wells in and around Kodungaiyur dumpsite and they are tested for various Physico-chemical parameters like total alkalinity, total dissolved solids, hardness, conductivity, pH, sulphate, chloride, potassium, sodium, Magnesium, and nitrate. The water samples are also analysed for BOD, COD and heavy metals include Cd, Cu, Fe, Pb and Ni. The test results are compared with Water quality standards. The spatial distribution of the Physico-chemical parameters is represented in maps prepared using Quantum Geographical Information System (QGIS). The result obtained from testing and spatial representation using GIS helps in monitoring and managing water contamination in the study area.

1. Introduction

The inadequate and unscientific municipal solid waste management practices and the poor state of sanitation in most cities have resulted in the pollution of the environment i.e., contamination of both surface and groundwater. This has created a severe impact on the residents living around the dump yard. According to the Ministry of Environment and Forests (MOEF), 62 million tonnes of waste is generated annually in India. And the per capita waste generation ranges from 200 to 600 grams per day. Kodungaiyur dump-yard which has an area of 250 acres approximately is said to receive 2100 to 2300 metric tonnes per day. A huge amount of disposal without proper treatment causes leachate to percolate deep down. During precipitation, the rainwater collected on the landfill infiltrates into the ground and picks up organic and inorganic compounds. The water gets polluted due to the collected chemical compounds and the resulting contaminated water is called 'leachate’. Municipal landfill leachate which percolates into the soil is highly concentrated with complex effluents. It contains dissolved organic matters; inorganic compounds such as ammonium, calcium, magnesium, sodium, potassium, iron, sulphates, chlorides and heavy metals such as cadmium, chromium, copper, lead, zinc, nickel; and xenobiotic organic substances damaging the potability characteristics of groundwater.

2. Groundwater contamination

Human activities such as dumping of waste in the landfills, spillage of chemicals and littering contribute to the addition of undesirable substances to the groundwater. The spread of contamination in the
groundwater often is far beyond the site of the original site of dumps and spills. The sources of groundwater contamination are difficult to assess and sometimes impossible to clean up. Some examples that contribute to groundwater contamination are on-site septic systems, municipal landfills, leaky sewer lines, runoff of chemicals, graveyard, fertilizer usage in agricultural land, underground injection wells etc. Groundwater contamination also results from excessive presence of naturally occurring substances like iron, manganese, and arsenic. The overabundance of iron and manganese are the most common natural contaminants.

2.1 Effect of Solid waste on Groundwater Quality
Solid waste includes domestic and industrial waste, industrial waste, hospital waste, e-waste and construction rubble. The Corporation of Chennai is the largest generator of solid waste calculable at 3000 tonnes per day. It has a network of transfer stations and two landfill sites at Kodungaiyur and Perungudi. The present system of assortment, transfer and dumping doesn't make any distinction between types of waste aside from domestic and industrial waste and to some extent construction rubble. The disposal of hospital waste and industrial waste is that the responsibility of the generator however a lot of this waste conjointly gets into the Corporation system. A separate system has not been established for e-waste to date. Based on the per capita generation of solid waste that's presently 4248 tonnes, it is estimated that by 2026 around 6590 tonnes of solid waste are going to be generated within the local body areas of CMA including Chennai town. Throughout the refuse disposal practices, gas is released into the atmosphere and the leachate created permeates into the underground. The movement of decomposition products after their formation is inevitable under current refuse disposal practices. The degree of impairment of groundwater depends upon the proximity of the landfill to the groundwater basin, volume and the characteristics of the pollutant generated within the landfill. As organic and inorganic compounds leach into the bottom even before the disposal practices, a lot of leachable material will be discharged into the land throughout the decomposition process. The percolating water also picks up heavy metals and reaches the aquifer system. Heavy metals in water refer to the dense, metallic components that occur in smaller volumes, however, are very harmful and have a tendency to accumulate and are commonly stated as trace metals. The anthropogenic sources of heavy metals are industrial wastes from mining sites, manufacturing and metal finishing plants, domestic sewer water and runoff from roads.

2.2 Role of GIS in water quality analysis
[7] Krishnamoorthy et al. (2015) researched spatial analysis of groundwater quality using GIS. This study demonstrated the utility of GIS as well as the assessment of analytical data. The mapping of groundwater quality from the analytical data obtained was evaluated and explained. Quantum Geographic Information System (QGIS) is an open-source desktop application that provides data viewing, editing, and analysis. This software enables the user to create maps with many layers using different map projections. QGIS allows maps to be composed for raster or vector layers. Interpolation is the most commonly used technique to create a continuous surface from discrete points. A lot of real-world phenomena like elevations, soils, temperature, water quality are continuous. It is impossible to take the measurements throughout the surface for modelling and mapping. Hence the field measurements are taken at various points along the surface and the intermediate values are determined by a process called interpolation. The most commonly used interpolation techniques are Inverse Distance Weighted (IDW), Spline, Kriging etc. IDW interpolation explicitly implements the assumption that things that are close to one another are more alike than those that are farther apart. Spline estimates the value using a mathematical function that minimizes overall surface curvature. Kriging is a geostatistical information technique that considers both the distance and the degree of variation between the known data points when estimating values in the unknown area. Each type of interpolation has varied advantages and disadvantages in different aspects and is used based on their requirements. [3] Chavan. B.L and Zambare. N.S (2014) experimentally conducted the physiochemical Analysis of Groundwater samples in Sholapur City, Maharashtra. The physicochemical properties were experimentally determined by the test conducted according to IS standards. A water sample collected from the field is tested and the results are interpolated by any of the above-explained methods which further contribute
to the spatial distribution of the particular area chosen. [2] The application of GIS in mapping and groundwater quality in Uyo, Nigeria was studied by Magnus Uzoma et al. (2011). The results depict that GIS has a significant application in the analysis of topographic slope, groundwater table variation, soil porosity etc. The maps that are obtained will act as a key source of identification of contamination and their distribution in field area. [1] Abdullah Taheri et al. (2011) formulated the spatial variation of groundwater quality parameters and conducted a case study around semiarid regions of Iran. Thus, the main objective of this study is to make a groundwater quality assessment, based on the determined physicochemical data of various locations in Kodungaiyur.

3. Study area
Chennai is the southeast coast of India and is the capital of Tamil Nadu. Kodungaiyur is a residential neighbourhood in the northernmost parts of Chennai metropolitan city comprising an area of about 350 acres. The latitude and longitude of Kodungaiyur is 13°08’02” N and 80°16’09” E respectively as shown in Figure1. It comes under Perambur taluk of Chennai city. Kodungaiyur is emerging as a developing locality since it is covered by numerous numbers of educational institutions and industrial sectors such as Madras fertilizer limited, Indian oil corporation and madras refinery limited etc. Kodungaiyur dump yard is the largest dump yard in Chennai city maintained by Chennai Corporation since 1987. The total area of the Kodungaiyur dump yard is 250 acres with a dumping rate of about 3600 tons/day. It has many harmful effects on residents in the vicinity in violation of MSW rules framed by the ministry of environment and forests. The corporation Chennai planned to close it by 2015 due to the increasingly harmful effects of contaminants on the residents. The dumpsite is surrounded by the Buckingham canal on the north and the Bay of Bengal on the west sloping towards the terrain. It is an open dump yard that does not possess lining facilities to prevent leachate percolation which adversely affects groundwater. Residents around Kodungaiyur depend on groundwater as well as private water supply based on their priorities. A survey conducted by a questionnaire proves that the majority of the population do not have access to groundwater due to increased contamination.

![Figure 1. Study area](image-url)
4. Groundwater Quality Analysis

To study the groundwater contamination, 12 water samples were collected around the Kodungaiyur dump yard. The samples were collected in plastic bottles of 1-litre capacity. Each bottle was rinsed with lukewarm water. This method is done to ensure that the bottle is sterilized and to avoid contamination. After the collection of water, the nozzle of the bottles was closed with polythene sheets and secured using elastic bands. Later, the bottles were closed using the lids. Each sample was numbered and the latitude and longitude of all sample points were noted down using GPS. After the collection of the samples, various physicochemical characteristics are being studied. The tests which were carried out in this project are pH test, Electrical Conductivity, Total Dissolved Salts, Chlorides, Sulphates, Chemical Oxygen Demand, Biological Oxygen Demand, Total Hardness, Calcium Hardness (Ca\(^{2+}\)), Magnesium Hardness, Total Alkalinity and Nitrate. Also, the samples are tested for the presence of heavy metals Sodium, Potassium, Nickel, Copper, Cadmium, Lead and Iron. The above-mentioned tests were conducted for all 12 samples. The tests were followed as per the Indian Standards (IS3025). The parameters like pH, Electrical Conductivity, Total dissolved salts, Chlorides, Sulphates, COD, BOD, Total Hardness and Total Alkalinity are the common tests that are done for any water sample. It helps in the study of the basic physical parameters. pH and electrical conductivity were tested using EUTECH Instruments (PC-700). The extent to which the water is contaminated is studied by testing the samples for the presence of heavy metals. Water contamination due to leachate is mostly due to the presence of heavy metals. If their content is very high, the water is considered unfit for drinking and other domestic use. The usual method of finding the content of several heavy metals is by Atomic Spectroscopy. It determines the elemental composition by its electromagnetic or mass spectrum. The result of it being less approximate, a more advanced technique is used for the heavy metal study which is ICP-OES (Inductively Coupled Plasma Atomic Emission Spectroscopy). Since this technique uses plasma which is the fourth state of matter, results can arrive at the more accurate Nano range. In this method, the plasma produces the excited atoms that emit electromagnetic radiation at the wavelengths of a particular element. The intensity of this emission is indicative of the concentration of the element within the sample.

| PARAMETERS | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 | S11 | S12 |
|------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|
| pH         | 7.37 | 6.99 | 7.3 | 7.25 | 7.46 | 7.31 | 7.34 | 7.11 | 7.53 | 7.25 | 7.48 | 8.04 |
| Conductivity(μs/cm) | 888 | 16820 | 9120 | 647 | 1350 | 1697 | 609 | 3130 | 2540 | 5410 | 3460 | 2210 |
| TDS(mg/L)  | 425 | 12443 | 6641 | 335 | 811 | 962 | 350 | 1861 | 1556 | 3253 | 2109 | 1467 |
| Chlorides(mg/L) | 260 | 3949 | 1475 | 110 | 180 | 310 | 120 | 550 | 625 | 1225 | 575 | 325 |
| Sulphates(mg/L) | 13 | 16 | 9 | 39 | 19 | 9 | 40 | 216 | 112 | 254 | 372 | 307 |
| COD(mg/L)   | 4 | 236 | 20 | 24 | 24 | 28 | 20 | 12 | 8 | 24 | 12 | 8 |
| BOD(mg/L)   | BDL | 71 | 4 | 5 | 5 | 6 | 4 | BDL | BDL | 5 | BDL | BDL |
| Total hardness(mg/L) | 69 | 2113 | 1375 | 125 | 388 | 344 | 142 | 374 | 718 | 880 | 324 | 596 |
| Calcium(mg/L) | 16 | 324 | 231 | 32 | 133 | 97 | 34 | 101 | 162 | 186 | 65 | 170 |
| Magnesium(mg/L) | 7 | 317 | 194 | 11 | 14 | 25 | 14 | 29 | 76 | 101 | 39 | 42 |
| Alkalinity(mg/L) | 64 | 382 | 509 | 117 | 477 | 456 | 138 | 541 | 254 | 721 | 392 | 329 |
| Nitrate(mg/L) | 3 | 140 | 76 | 4 | 5 | 6 | 2 | 8 | 12 | 13 | 11 | 4 |
| Sodium(mg/L) | 109 | 1631 | 1649 | 59 | 95 | 174 | 50 | 598 | 260 | 898 | 772 | 298 |
| Potassium(mg/L) | 4 | 38 | 51 | 4 | 22 | 28 | 2 | 38 | 19 | 44 | 45 | 19 |
| Nickel(mg/L) | 0.01 | 0.011 | 0.012 | 0.011 | 0.011 | 0.01 | 0.012 | 0.011 | 0.011 | 0.013 | 0.011 | 0.011 |
| Copper(mg/L) | 0.014 | 0.015 | 0.017 | 0.015 | 0.022 | 0.016 | 0.017 | 0.015 | 0.015 | 0.022 | 0.014 | 0.022 |
| Cadmium(mg/L) | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 | 0.015 |
4.1 Spatial distribution

The sampling points are transferred to GIS platform and the parameters of water quality after testing are linked to their attributes to generate various thematic maps. With the help of the Inverse Weight Diagram (IWD) interpolation technique, the variations of physicochemical characteristics and heavy metal content in the area surrounding the Kodungaiyur landfill were presented in the form of thematic maps. The quality of groundwater shows variation from place to place. The spatial variation indicates that there is an increase in the concentration of quality determinants compared to the standards. The leachate percolation results in the decrease of groundwater quality which in turn affects the suitability of groundwater for beneficial purposes. The thematic maps also show that the concentration of the parameters is more towards North-East due to the effect of municipal solid waste disposal at the Kodungaiyur dumpsite. Heavy metal concentration was below the detectable limit in all the samples except Cadmium which is higher than permissible limits in all the samples. The distribution of various physicochemical parameters are discussed as follows:

- **pH** is one of the most vital operational water quality parameters with optimal pH value required within the range from 6.5 – 8.5 as per TNPCB (Tamilnadu Pollution Control Board) and 6 – 8.5 as per BIS (Bureau of Indian Standards). If the pH of the water is greater than 7, it is said to be basic and can form scales. Acidic water has a pH value less than 7 and it can cause corrosion. The value of pH in the groundwater data collected varied from the range of 6.99 to 8.04. The pH value around the Kodungaiyur dump yard is within the permissible limits and is considered for domestic use. The spatial distribution of pH concentration is shown in Figure 2.

- The concentration of mineral composition dissolved in water is known to be dissolved solids. Subsurface water containing TDS more than 1000mg/l is called brackish water. The permissible limit of TDS as per TNPCB is 500. In the Kodungaiyur area, the TDS value ranges from 335 to 12443 mg/l. The concentration of Total Dissolved Solids was found to be the highest in S2. It was observed that TDS content in many parts of Kodungaiyur is higher than the permissible limits. The spatial distribution of TDS is shown in Figure 3.

![Figure 2. pH map of the study area](image1)

![Figure 3. TDS of the groundwater in the study area](image2)

- Sodium is an essential nutrient and principal chemical in body fluids. At normal levels, sodium doesn’t cause any harm when consumed through food and drinking water. It is highly soluble.
that is leached from the terrestrial environment to the groundwater or due to saltwater intrusion from coastal areas and road salt. For good health, the EPA recommends consuming at least 500mg of sodium per day. Also, too much sodium is not recommended for people with heart issues. The maximum permissible limit of sodium in drinking water is 200mg/l as per WHO guidelines. In this study, the concentrations of sodium are heavier than the permissible limits and it ranges from 50 to 1649 mg/l. Sodium concentration is found high in S3. The spatial distribution of sodium is shown in Figure. 4.

- Hardness in water is caused due to the presence of bicarbonates and carbonates of calcium and magnesium. Only 3 sample points show hardness within the limit (300 mg/l according to TNPCB). Very hard water is not suitable for domestic purpose and can cause scaling on the inside of tanks and pipes. The spatial distribution of total hardness is shown in Figure. 5

**Figure 4.** Distribution of Sodium in the Groundwater

**Figure 5.** Total Hardness of the groundwater in the study area

- Chloride is present at a varying concentration in natural water depending upon the geological conditions. Chloride concentrations may occur due to industrial waste, sewage disposal, leaching of saline residues to the soil. The presence of a high concentration of chloride produces a salty taste in drinking water. Water quality data obtained indicates the chloride concentration ranges from 110mg/l to 3949 mg/l. The desired limit is 250mg/l according to TNPCB. Chloride content is very high. Thus, measures are to be taken to reduce its content to the required level. The spatial distribution of chloride is shown in Figure. 6.

- Potassium is an essential element in human and is widely present in the environment including all-natural waters. The potassium content of groundwater obtained from the study area varies gradually from 4mg/l to 50mg/l. Serious health issues may occur if the potassium-based water treatment is done in which the potassium chloride is used for regeneration of ion exchange in water softeners. This process high-risk individuals with kidney dysfunction, coronary artery disease, hypertension etc. The spatial distribution of potassium is shown in Figure. 7
- Sulphates occur naturally in numerous minerals including barite, epsomite and gypsum, these dissolved minerals contribute to the mineral content of many groundwater resources. The sulphate content of water around the Kodungaiyur dump yard ranges from 10mg/l to 350mg/l. The maximum permissible limits for sulphate content as per TNPCB in water are 400 mg/l. Hence the water is within permissible limits. Excess presence of sulphate ions in drinking water results in odours, diarrhoea and gastrointestinal problems. The spatial distribution of sulphates is shown in Figure. 8.

- Alkalinity is the ability of the water to neutralise acidic characteristics, hence it is the most important characteristic of water. As per BIS standards, the desirable limit for total alkalinity is 200mg/l. The water quality standards obtained around the Kodungaiyur dump yard shows the variation of alkalinity content for different samples. It ranges from 64-721 mg/l. Hence the water exceeds the tolerance limit. The high alkalinity content of the water has a major impact on the taste of the water which makes it unfit for drinking. The spatial distribution of total alkalinity is shown in Figure. 9.

- The main source of nitrate in water is from the atmosphere, legumes, plant debris and animal excreta. The presence of nitrate content in the water adds a bitter taste and cause physiological distress in the human brain. Water in shallow wells containing more than 45mg/l causes methemoglobinemia and is called blue baby syndrome in humans. Dumpsites are also one of the major reasons for higher nitrate content. As per TNPCB the permissible limit of nitrate in water is 20mg/l. In the study area, the nitrate content ranges from 2 to 140 mg/lt. Nitrate content is found high in S2.
Figure 8. Distribution of Sulphates in the Groundwater

Figure 9. Total alkalinity of the groundwater in the study area

Figure 10. Distribution of Nitrate concentration in the Groundwater

- Testing of water samples is carried out to determine heavy metal contents like cadmium (Cd), copper (Cu), lead (Pb) and iron (Fe). The permissible heavy metals in water as per TNPCB are 0.01, 1.5, 0.1 and 0.3mg/l respectively. The cadmium content in all the water samples is 0.015 which is higher than the permissible limit. Iron content in S4 is 0.37mg/l which is higher than the desirable limit. This may not cause adverse effects immediately but has to be treated before using for drinking purposes. All other heavy metal content is within the range given by TNPCB. The distribution of heavy metals in the study area is shown in Figure. 11, 12 and 13.
The spatial variation diagrams indicate that the concentration of major ions increased towards North-East due to the effect of municipal solid waste disposal at Kodungaiyur. Heavy metal concentration was below the detectable limit in all the samples except Cadmium which is higher than permissible limits in all the sampling locations.

5. Conclusion
In the current study, an attempt was made to evaluate the groundwater contamination mapping around the Kodungaiyur dump yard. The spatial distribution for the tested water qualities was successfully obtained and mapped using the Inverse distance weighted (IDW) interpolation technique in QGIS. It is inferred that the most affected parameters deviating from the TNPCB standards are Sodium, TDS, Total Hardness, and chloride. These parameters adversely affect health as water is the primary source for human habitat and make the water unfit for drinking. Although the concentration of few contaminants does not exceed the drinking water standards, the groundwater quality still represents a significant threat to public health.
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