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Comprehensive characterisation of groundwater quality in and around a landfill area for agricultural suitability

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Abstract. Groundwater contamination has become so alarming that the existing valuable freshwater resources are at stake. Landfilling of solid refuse without pre-emptive measures, over the years, leads to the utter depletion of the groundwater quality in its vicinity. The Kodungaiyur landfill at the Perambur taluk located in the northernmost region of the Chennai metropolitan, is such a poorly managed landfill. This research article is intended to exhibit a detailed study report on the physicochemical and bacteriological parametric analyses of the currently available subsurface water in and around the landfill area. Besides being evident from the faecal coliform test that the water is not potable, the chief objective was to investigate the suitability of groundwater for irrigation. Representative samples of groundwater were collected from inside the landfill site, and the residential areas located within 2 km from the site and analysed using standard methods. The test results were interpreted by employing exhaustive statistical approaches. It is evident to the interpretations that, out of the nine sampled locations, seven were found to be endowed with a groundwater quality fit enough for irrigation.

Introduction

Water, which is one of the five basic elements of nature forms the basis for human existence. A recent study by UNICEF shows that 1 in 10 people lacks access to secure water ^[6]. A safe water is acknowledged by its quality. When it comes to quality, the physical, chemical and biological parameters of the water constitute its degree of reliability. However, the actuality is that the existing freshwater resources are being challenged by the activities that are anthropogenic in nature.

One such activity is landfilling of solid refuse. Unlike hazardous waste landfills, solid waste landfills are monitored and regulated differently. Such landfills may receive a melange of solid, semi-solid and small quantities of liquid wastes. Landfills are supposed to be given liners in order to prevent the leaching of wastes into the water table in their vicinity. Unfortunately, a number of landfills in India are not engineered landfills, which lead to leachate percolation into the surrounding groundwater table.

The landfill that receives precipitation accompanied by any disposed liquid waste, results in the release of water-soluble compounds and particulate matter from the waste, and the successive generation of leachate. The composition of leachate varies with respect to the quantum of precipitation, and the amount and variety of wastes disposed ^[7].

Review of previous work

Mufeed et al. (2007) reviews the MSW management in the Indian cities. It shows that more than 90% of MSW in cities and towns are directly disposed on land in an unsatisfactory manner. Due to the absence of waste segregation at the source all types of wastes including infectious wastes from hospitals as well as industrial wastes are deposited at the sites meant for MSW disposal^[14].

Umesh et al. (2008) indicates the existence of an empirical relationship between specific indicator parameters such as heavy metals among the MSW, leachate and groundwater. Factor analysis indicated that pollution source was dominated over natural process such dispersion in the vicinity of the landfill site^[16].

Al-Wabel et al. (2011) describes the various characteristics of a landfill leachate collected in Riyadh city, Saudi Arabia. It was found that the pH value of leachate was low due to its acidic nature as well as the organic and inorganic acids formed during the decomposition of municipal wastes^[5].

Jayanthi et al. (2012) states that the extent of contamination of groundwater quality due to landfill waste depends upon a number of factors such as rainfall, leachate composition, depth and distance of wells from the pollution source etc. In the case of unprotected landfills natural phenomenon such as dilution will have very little or no effect on reducing the contaminant concentrations^[8].

Parameswari et al. (2012) analysed the groundwater quality around the Perungudi landfill area in the Chennai city, India. With the identified concentrations of contaminants, they modelled the contaminant transport from the landfill to find their influence on the surrounding wells in the locality^[2].

Study Area

Kodungaiyur (13.140961 N, 80.248175 E) is a residential setting situated in the northernmost part of Chennai. Fig.1 shows the Kodungaiyur landfill site on the Indian Map.

The extent of the landfill area is about 200 acres. This site has been in use for the past 30 years receiving 2100 to 2300 metric tons of solid waste every day^[6]. Fig.3 shows the average distribution of wastes being brought to the landfill.

The state government plans to close the landfill operations and convert the area into park soon. Thenceforth, the site will require characterization of the existing soil and other geological conditions that will aid in deciding whether gardening or agricultural activities will be feasible on the restored landfill site. However, the scope of this research is limited only to ascertaining the suitability of the groundwater in and around the site for irrigation. The chosen sampling stations are listed in Table 1.

Methodology

Fig.2 depicts the sampling locations in and around the landfill site. Five bore well samples (including one sample inside the site) from the surrounding residential units situated within a distance of 2 km and four samples from observatory wells (nine samples in total) were collected radially. The wells other than observatory wells are currently used for domestic utilization (except for drinking) by the residents.

For sample collection, white PET containers of 2 liter capacity were used. pH and conductivity were measured on field using digital meters. Each sample was labelled with unique identifying code and other essentials, transported to lab and preserved.

Water samples were tested following IS 10500: 2012 procedures. Physical parameters viz. Turbidity (IS 3025, Part 10) and Total dissolved solids (IS 3025, Part 16) were measured. Chemical parameters viz. Total Hardness (IS 3025, Part 21), Calcium (IS 3025, Part 40), Magnesium (IS 3025, Part 46), Chlorides (IS 3025, Part 36) were determined. Sodium and potassium were analyzed using flame photometry (IS 3025, Part 45). Microbiological analysis was carried out using the standard method 9221B. Results are shown in Table 2.

Results and Discussion

Nowadays, software is being used widely for analysis. For this work, the following parametric studies were preferred, and results were interpreted statistically to exhibit the suitability of groundwater samples for irrigation.

- i. **Electrical conductivity (EC)**
- ii. Sodium absorption ratio (SAR)
- iii. Sodium percentage
- iv. Magnesium ratio
- v. Kelly's ratio
- vi. Salinity index
- i. *Electrical conductivity (EC)*

Electrical conductivity serves as an effective tool to quantify the hazards to crops caused by salinity. The EC of the sample is compared with the EC classification guidelines (Table 3), and it was arrived that three samples fall under doubtful class and one sample fall under good category, and the other five samples fall under the unsuitable category.



Fig.1. Kodungaiyur landfill on the Indian map

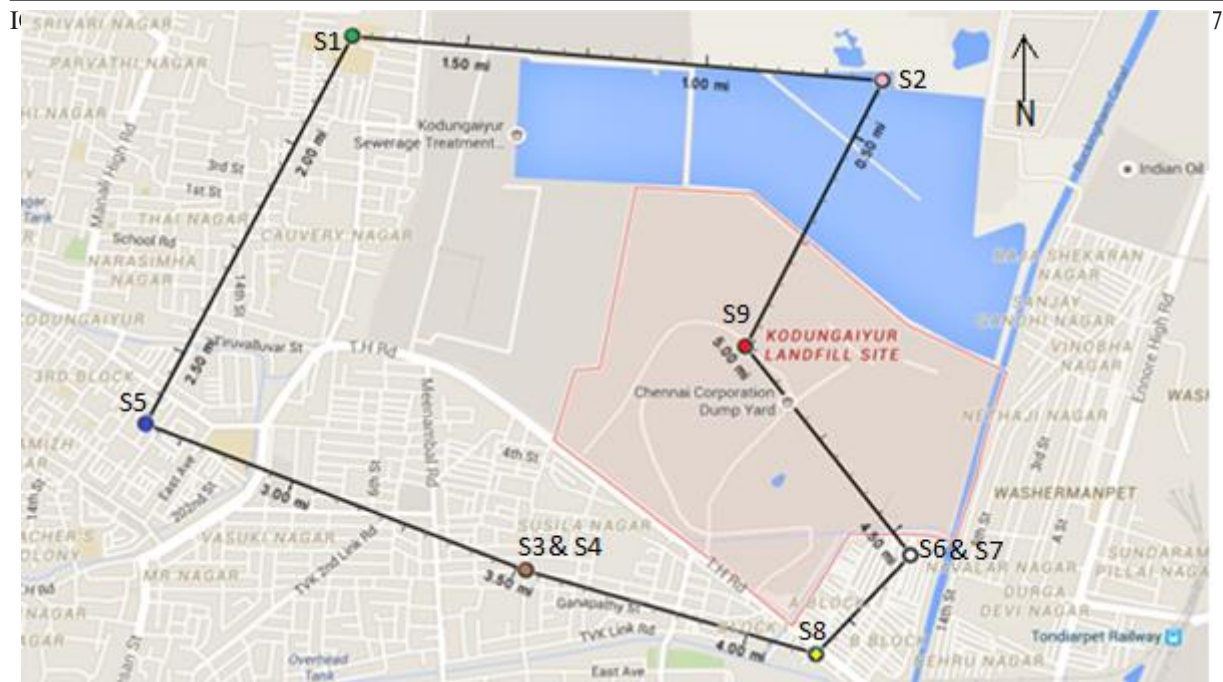


Fig.2. Sampling locations in and around the site

ii. *Sodium Absorption Ratio (SAR)*

The U.S. Salinity Laboratory (1954) defines SAR. The ion concentrations are expressed in milliequivalents per litre. SAR sensibly estimates the degree to which irrigation water tends to invade cation–exchange reaction in soil. For irrigation, the cation-exchange complex may become saturated with sodium if the groundwater exhibits high sodium and low calcium concentrations. This can affect the structure of soil due to dispersion of clay particles. Table 4 represents the SAR based observations. The following equation governs the SAR determination (*Ragunath et al, 1987*).

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \quad [1]$$

iii. *Sodium percentage*

The tendency of water to invade cation– exchange reaction is generally computed by the “sodium percentage.” It is a measure of the percentage of total cations that sodium makes up. Sodium percentage is a vital entity in stratifying water for irrigation.

The permeability of the soil is reduced by the accumulation of sodium in the pore spaces. Sodium content is indicated by soluble sodium percentage.

$$\text{Sodium percentage} = \frac{Na + K}{Ca + Mg + Na + K} \quad [2]$$

A maximum of 60% sodium is permissible as per the Indian standards. Out of the nine samples, sodium percent of seven samples (34%-56%) are found to fall below 60% which makes them fit for irrigation.

iv. *Magnesium ratio*

Generally, Ca and Mg concentrations in water are found within equilibrium state. The existence of magnesium in excess quantities poses detrimental effects on the soil quality. It makes the soil alkaline eventually diminishing the crop yield. It is expressed as

$$\text{Magnesium ratio} = \frac{Mg \times 100}{Ca + Mg} \quad [3]$$

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 Magnesium ratio exceeding 50% make the water noxious to plants. The magnesium ratio for the nine samples ranges between 31 to 37 percent. Hence, all the samples fall under the safe category which qualifies the water for irrigation.

v. *Kelly's ratio*

Kelly's ratio is another potential criterion for deciding the appropriateness of water for irrigation. It is nothing but the ratio of sodium versus calcium and of sodium versus magnesium. The following equation is used to compute the ratio.

$$\text{Kelly's ratio} = \frac{\text{Na}}{(\text{Ca}) + (\text{Mg})} \tag{4}$$

A ratio of more than unity declares the water unfavourable for irrigation. Kelly's ratio of the analysed groundwater samples ranges between 0.42 and 2.3. Out of the nine samples, seven samples are found to be suitable for irrigation.

vi. *Salinity index*

It is one of the important considerations while inspecting the water for irrigation. If the salinity index falls below 2 ppt (parts per thousand), it is suitable for irrigational activities. Salinity index is provided by the following equation.

$$\text{Salinity index (ppt)} = 0.0018066 \times \text{chloride concentration (mg/L)} \tag{5}$$

Out of the nine samples, seven samples fall between the limit of 0.17 -1.5, except two samples, exceed the limit, making seven samples suitable for irrigation.

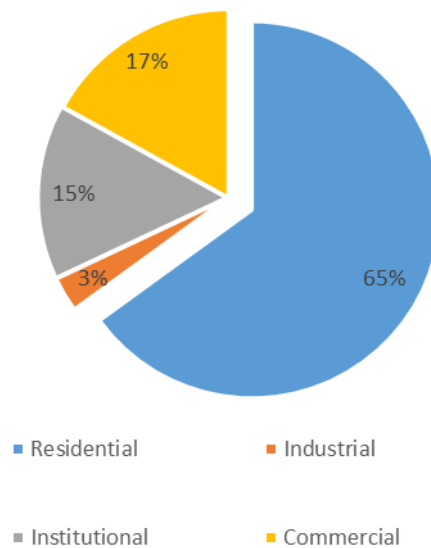


Fig.3. Solid wastes from different sources

Table 1 Sampling stations and their locations (B_i– Bore well; W_i – Open well)

Sample Station	Source	Location	Distance from landfill site (km)
S1	B _i	Aishwarya nagar	1.60
S2	W _i	Around Sewage Treatment Plant (STP) of Chennai Metro Water	1.45
S3	B _i	Krishnamurthy nagar	1.86
S4	W _i	Krishnamurthy nagar	1.84

S	W_i	Location	EC
S5	W_i	Muthamizh nagar	1.89
S6	W_i	Ezhil Nagar, A block	1.56
S7	B_i	Ezhil Nagar, A block	1.58
S8	B_i	Chandrasekar nagar	1.74
S9	B_i	Inside landfill site	Nil

Conclusion

It is evident to the findings that seven out of the nine samples possess appropriate quality for irrigation. From the interpretations made, those samples belonging to sites S2 and site S9 proved to be unfit. This condition with these samples may be attributed to their locations. That is, S2 and S9 constitute the samples taken nearby the STP of Chennai metro water and inside the landfill site respectively.

Since sampling and analyses were carried out during pre-monsoon season, the contamination rates may vary due to dry conditions. For future work, the same procedure can be adopted during post-monsoon season to compare and validate the results.

Further, soil profile surveys and other geological surveys can be made once the landfill site gets ready with restoration for after-use such as irrigation.

Groundwater flow and migration of contaminant plume around the landfill site can be simulated using tools like MODFLOW.

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