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RESEARCH ARTICLE

IMPACT OF MUNICIPAL SOLID WASTE DISPOSAL ON GROUNDWATER IN MYSURU CITY, INDIA USING GEOGRAPHICAL INFORMATION SYSTEM

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ABSTRACT

Mysuru city is among those cities that have been witnessing a drastic increase in urban areas and an inflow of population from its surrounding rural areas. The city has several well-known tourist attractions, which adds a good revenue to the city's economy. These urbanization and tourism not only brings in prosperity to the city, but also the crisis of municipal solid waste management. The Mysuru City Corporation works hard to retain the title of the Cleanest City in India. The Land Use and Land Cover were assessed that clearly showed the development of settlement around the existing landfill site causing health hazards to the residents. To study the effects of the landfill site and several unauthorized disposal sites around the city on the groundwater resources, tools of Geographical Information System and Water Quality Index were used. The leachate formed from the MSW disposal sites drains down the soil, polluting both the soil and the groundwater. Groundwater quality were assessed based on certain chemical parameters & the standards prescribed by the Bureau of Indian Standards. The Inverse Distance Weighted method of spatial interpolation was applied to derive the groundwater quality for the study area based on the locations of the samples. To assess the quality of soil, samples were collected from in and around the landfill site. The environmental impact of the existing municipal solid waste landfill was found alarming and requires a new landfill site away from the inhabited areas.

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INTRODUCTION

The rapid increase in urban population led to the creation of several land-use related problems, including solid-waste management. Solid materials produced by human activities and disposed once they become worthless are called solid waste. Collecting, processing, transporting and disposing municipal solid waste (MSW) is the responsibility of the urban local bodies in India (NIUA, 2015). Most local bodies are struggling to provide efficient waste management services to citizens. The coverage and efficiency of waste collection is still low; waste is collected in open trucks in an unsafe and insanitary manner; have limited waste recovery and processing; and the waste is often dumped indiscriminately at the open dump sites without leachate treatment (HPEC, 2011). The improper management of the landfills would result in the contamination of air, land and water, which are considered the most important aspects sustaining the life on earth. Leachate poses a threat to local surface and ground water systems (Alam and Ahmade, 2013).

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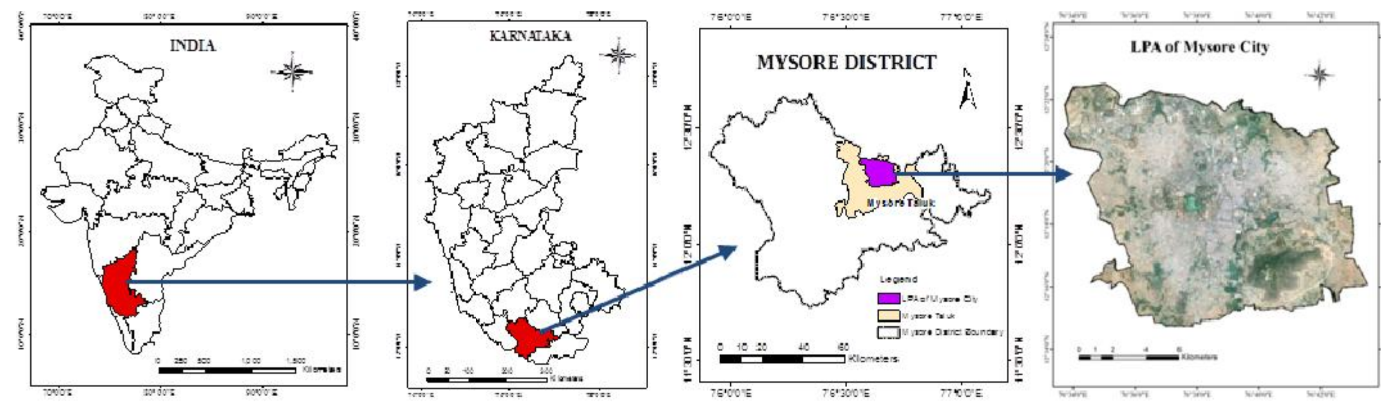
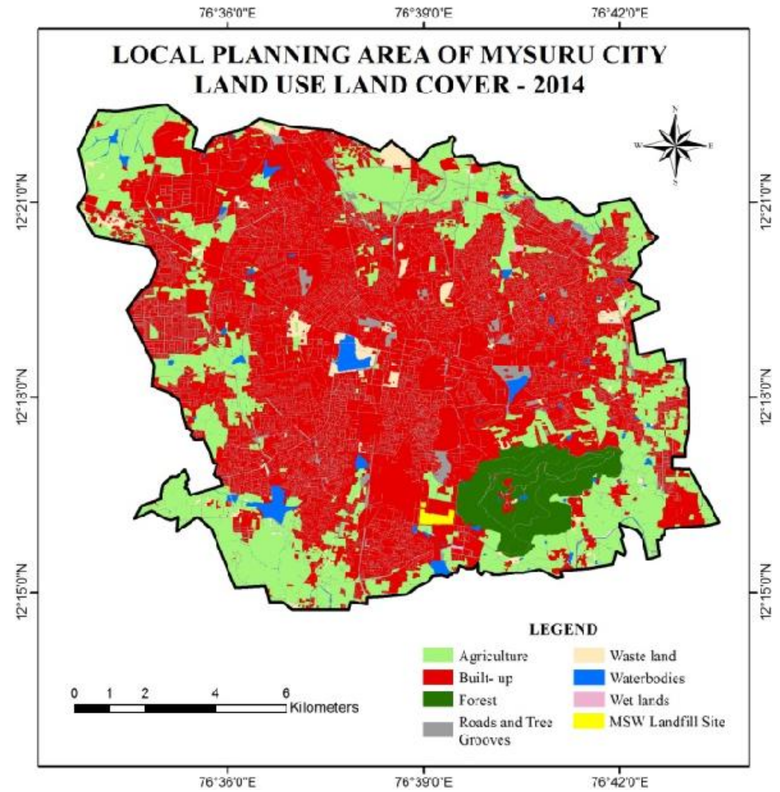
Based on the research by Sankoh *et al*. (2013), households living less than fifty metres from the dumpsite are most affected causing malaria, chest pains, diarrhea, cholera, irritation of the skin, nose and eyes. Tests performed by Şchiopu *et al*. (2009) on the old landfill in Iasi County has shown that the organic components and heavy metals present in the leachate that penetrates through infiltrations in soil induce impacts and risks in environment. According to the United States EPA (2002), uncontrolled dumping of waste can contaminate groundwater and soil, attract disease carrying rats and insects, and even cause fires. Properly designed, constructed, and managed landfills provide a safe alternative to uncontrolled dumping. To protect groundwater from the liquid that collects in landfills (leachate), a properly designed landfill has an earthen or synthetic liner.

MATERIALS AND METHODS

The study area selected for the research was the Local Planning Area of Mysuru City that extends from 12º 22' North to 12º 15' North latitude and 76º 34' East to 76º 44' East longitude covering an area of 178 kms^2 (Map 1). A land use land cover map was initially prepared using images from Landsat 8 and



Map 1. Location Map of the study area

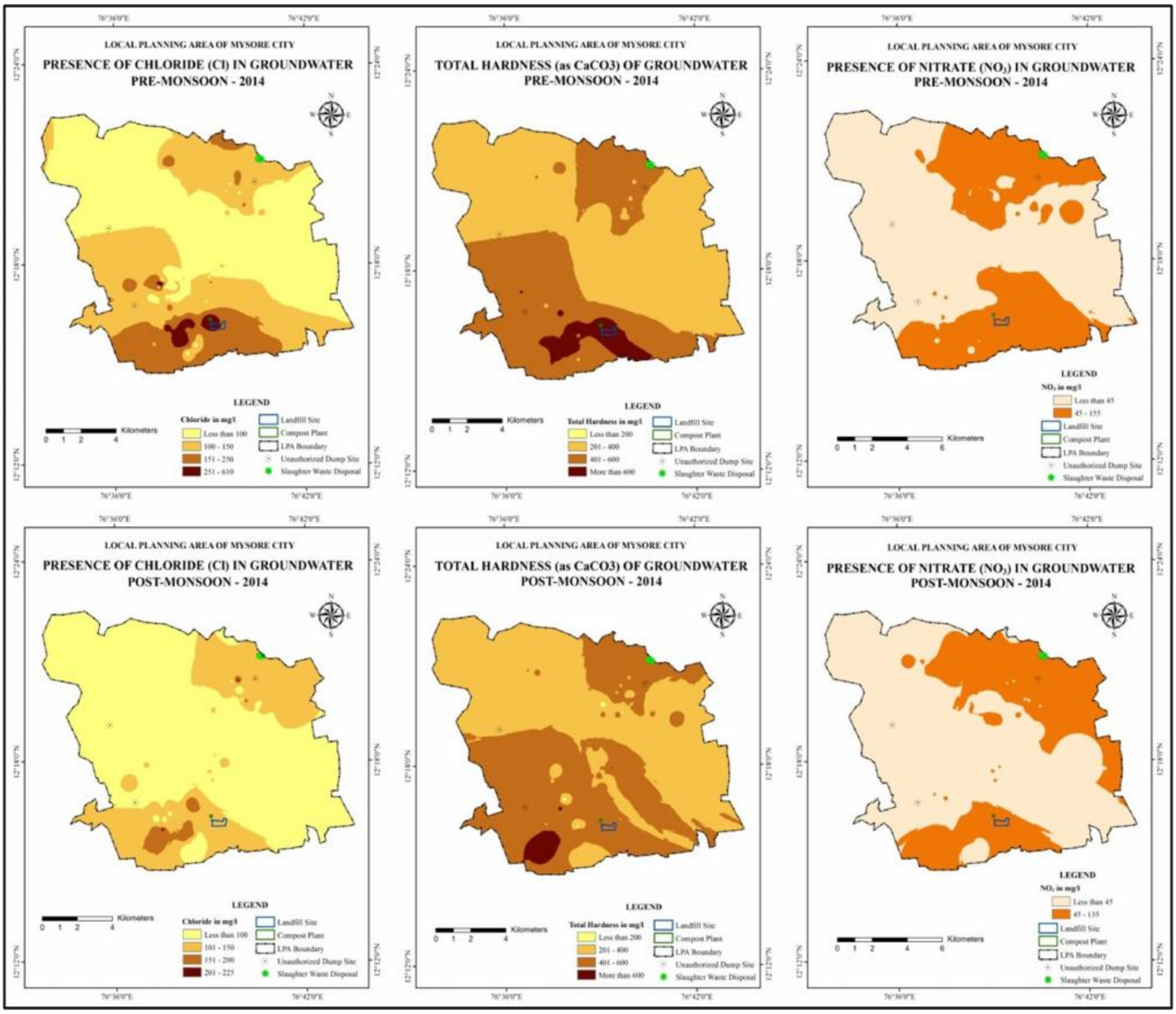


Map 2. Land Use Land Cover Map of Mysuru City LPA

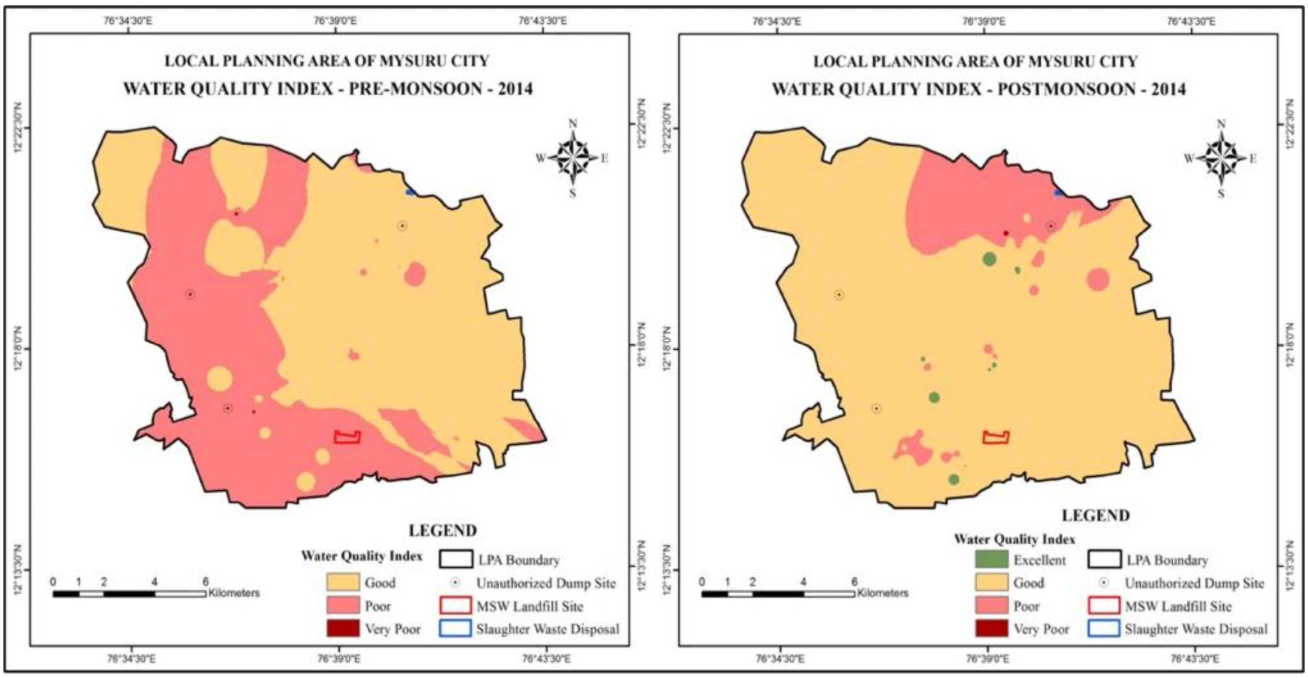
Google Earth within the ArcGIS Desktop v.10.3 software. Seven major land use and land cover classification were identified and compared with the location and proximity of Municipal Solid Waste Compost and Landfill site with other land uses. The groundwater quality data obtained from the Department of Mines and Geology, Mysuru was used to assess the impact of Municipal Solid Waste disposal on the groundwater resources. Parameters like pH, Total Hardness, Chloride, Fluoride, Nitrate and Iron were selected for both pre-monsoon season (April to June) and post-monsoon season (October to December) and the spatial variations in groundwater quality were mapped using ArcGIS Desktop v.10.3. The standards for the requirement of water quality were calculated as per IS 10500-2012 prescribed by the Bureau of Indian Standards for the selected parameters. Water Quality Index was also ascertained and mapped to understand the impact of MSW. Soil samples were collected from within and outside the landfill site and tested for major quality parameters to substantiate that improper waste disposal was the major reason for the variations in the groundwater quality.

RESULTS AND DISCUSSION

The total estimated quantity of Municipal Solid waste generated per day in Mysore City is 402MT. Area used for waste dumping is 41.47 acres. Three acres of land is developed for sanitary landfill and is operational since July 2012. The Municipal Solid Waste Landfill Site is located amidst the built-up lands in Mysuru City as shown in the Map 2. The expansion of settlement has engulfed the landfill site within its proximity. As per the MSW management rules laid down by the government, it is mandatory for a landfill site to be located



Map 3: Presence of Hardness, Nitrate and Chloride for the Pre and Post Monsoon in 2014



Map 4: Water Quality Index for Pre-monsoon and Post-monsoon season of 2014

away from the specified buffer zones of built-up, agriculture, forest, lakes and rivers, etc. At present, the sudden expansion of the residential and commercial development around the landfill site has made it vulnerable to a lot of environmental pollution and impacted the health of the local people. The need for good quality groundwater around the landfill has thus become very essential. Though the practice of Sanitary Landfill has been started, the earlier disposals are a potential threat to the quality of groundwater.

Impact on Groundwater

Emissions to water could take place in a number of ways, mostly from landfill. Water already in the wastes, or rainwater falling onto a landfill, acquires (“leaches”) contaminants from the wastes and is known as “leachate”. Leachate is to be collected and treated on-site or at a sewage treatment works, before being released to a river or the sea. Some of the leachate seeps slowly from the landfill, and mixes with water in the soils surrounding the site. Parameters like Iron, pH, and Fluoride were found well within the standards. Map 3 shows the spatial distribution of Chloride, Total Hardness and Nitrate for both pre-monsoon and post monsoon seasons. The total hardness in the pre-monsoon season near the landfill site was above the maximum prescribed limit of 600mg/l. The values of Nitrates were above the maximum prescribed standards of 45mg/l in the pre-monsoon and post-monsoon seasons. The values of other parameters near the landfill site were within the permissible limits. Chloride was found comparatively higher near landfill sites. Iron, pH and Fluoride were found well within the standards. Map 3 shows the spatial distribution of Chloride, Total Hardness and Nitrate within the city for both pre-monsoon and post-monsoon season.

Chloride in shallow groundwater is a useful indicator of contamination. Chloride concentrations are typically high in landfill leachate or in groundwater beneath or downgradient from landfills. A pattern of increasing Chloride concentrations during pre-monsoon and decreasing Chloride concentrations during post-monsoon was observed in groundwater beneath the landfill. This pattern of changing Chloride concentrations in response to wet and dry periods indicates that the landfill retains or absorbs leachate during dry periods (Jason R. Masoner, 2015). Leachate in landfill gets diluted during monsoon and migrates from the landfill.

Water Quality Index (WQI)

A water quality index provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters. Each of the selected six parameters was assigned a weight (wi) based on its relative significance in the overall quality of drinking water as shown in Table 1. The maximum weight of five for the parameter of nitrate has been assigned due to its major magnitude in water quality evaluation. The relative weight (Wi) was then computed for each parameters from the following equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (i)$$

where, W_i refers to the relative weight, w_i refers to the weight of each parameter and n refers to the number of parameters.

Table 1. Relative weight of chemical parameters

Parameters	Standards	Weight	Relative weight
pH	6.5-8.5	4	0.18182
Total Hardness	300 - 600	2	0.09091
Chloride (Cl)	250 - 1000	3	0.13636
Iron (Fe)	0.3 - 1.0	4	0.18182
Nitrate (No_3)	45 - 100	5	0.22727
Fluoride (F)	1 - 1.5	4	0.18182
		$\sum w_i = 22$	**$\sum W_i = 1.00000$**

The quality rating (q_i) scale for every parameter is calculated from the following equation:

$$q_i = (C_i / S_i) \times 100 \qquad (ii)$$

where q_i refers to the quality rating, C_i refers to the concentration of individual chemical parameter in every water sample measured in mg/L, and S_i is the standard prescribed for every chemical parameter measured in mg/L according to the guidelines of the IS 10500-2012 issued by the Bureau of Indian Standards. For computing WQI, a subindex value (SI) is initially determined for every chemical parameter and it is used to determine the WQI as per the following equations:

$$SI_i = W_i \times q_i \qquad (iii)$$

$$WQI = \sum SI_i \qquad (iv)$$

SI_i refers to the subindex value of i^{th} parameter; q_i refers to the quality rating based on the concentration of i^{th} parameter and n refers to the number of parameters. The six selected parameters for the ninety five samples of groundwater within the study area were used to assess the Water Quality Index. The WQI were analyzed for both the pre-monsoon and post-monsoon seasons of the year 2014. The percentage of samples falling under the different WQI values were calculated, which is depicted in the Table 2. The water quality was found in portable conditions throughout the city with the variations in the quality as shown in Map 4. The worst quality of groundwater was found in the southern part of the study area, which is due to the presence of the municipal solid waste landfill site. The quality of water is found to be improving in the post-monsoon season compared to the pre-monsoon period. The 9.5 percent samples of water was found to be excellent in quality in the post-monsoon season whereas in per-monsoon season, no samples were in excellent quality.

Table 2. Water Quality Classification based on WQI

WQI Value	Water Quality	Pre-Monsoon % of Samples	Post-Monsoon % of Samples
< 50	Excellent	0.0	9.5
50 - 100	Good	74.4	64.2
100 - 200	Poor	22.2	25.3
200 - 300	Very Poor	3.3	1.1
> 300	Unsuitable for Drinking	0.0	0.0

Figure 1. Snapshot of Google Earth view of the locations of the collected soil samples

Table 3. Soil Quality for the samples from the MSW landfill site

Sample	pH	Electrical Conductivity (dSm^{-1})	Organic Carbon (%)	Total Nitrogen (Kg/acre)	Available Phosphorous (Kg/acre)	Available Potassium (Kg/acre)
A	6.6	0.72	0.70	167.0	23.0	358.0
B	6.9	0.99	0.90	246.0	104.0	175.0
C	8.5	2.38	0.42	87.6	28.0	8.8
D	7.3	0.23	0.18	46.4	51.0	82.0
E	7.3	0.54	0.45	96.0	31.8	35.0
F	8.6	1.55	0.49	107.0	37.0	84.0
G	8.0	0.06	0.49	107.0	13.0	43.0

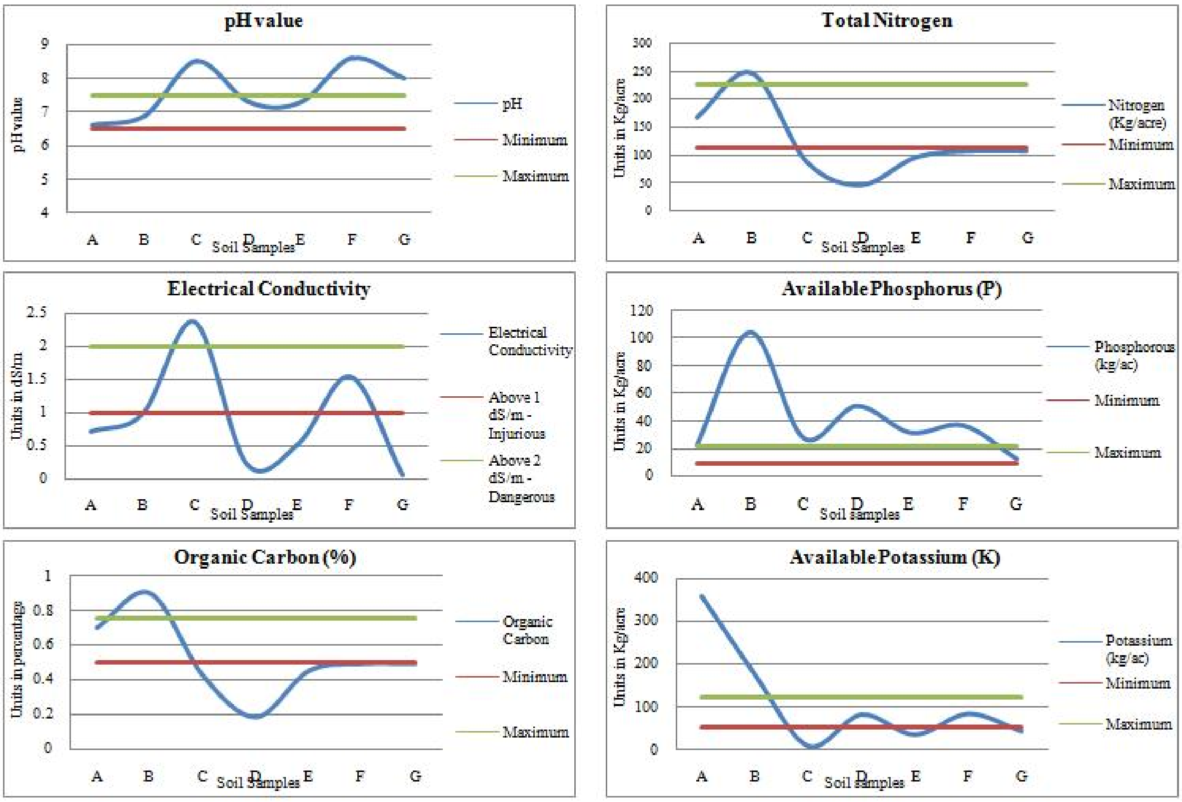


Figure 2. Level of each chemical parameters in the soil samples

Soil Quality Assessment

Six soil samples were collected from different locations within the municipal solid waste landfill site and one sample was collected from outside the landfill site as a control sample to facilitate comparison. The snapshot of Google Earth image with the location of the samples collected is shown in Figure 1. Samples A, B, C, D and E are collected from the landfill site and Sample F is collected from within the MSW compost plant. The Sample G was collected 300 metres away from the landfill site. The results of the soil quality test are portrayed in Table 3. Sample A & B are close to sanitary landfill areas which showing a lower contamination as a result of protective layers of HDPE sheets and geo-synthetic layers beneath it. All other samples within landfill site were highly contaminated. Sample C was the worst contaminated due to the downward slope towards the south. Sample C had a high value of pH and Electrical Conductivity (EC). EC value above 2 dS/m is considered very dangerous for the health of plants or crops. Sample F from the compost plant showed an injurious level of EC value.

Conclusion

The Sanitary landfill has helped to reduce the contamination of soil due to the HDPE sheets and geo-synthetic layers are laid below the landfill to protect it. But the area under Sanitary Landfill is less compared to the other parts of the landfill. Using GIS, it has been found that the areas of improper disposal has a direct impact on the quality of groundwater and soil. Leachates have to be treated well before it is drained out of the landfill. Water Quality Index has helped in understanding the extend of impact of contamination in the portability of groundwater both in pre-monsoon and post-monsoon seasons. Since the general slope is towards the south, much of contamination will not affect the northern part, whereas the affect will be more on the southern and eastern part of the landfill. There is an urgent need of a new and safer landfill site away from residential areas. Depending on landfill site alone for disposal will not be an efficient practice. The concept of Zero Waste Management (ZWM) will help in reducing the burden on the landfill site. The ZWM will allow the collection, segregation and composting within each ward and the non-recyclable waste can be sent to the landfill. It will help in handling these waste at landfill much easier and will reduce the impact on soil and groundwater. Though the city has begun the ZWM plants in selected wards, only a few are functional. If every household can dispose their degradable waste within the own premises, they can generate bio-fuels as well as reduce the crisis of disposal. Households and the civic authorities must ensure the segregation of waste before disposal as hazardous waste at the landfill site will lead to severe environmental and health hazards. Areas of unauthorized disposal have to be cleared and monitored and the secondary bins have to be placed away from sensitive areas, especially water bodies. GIS can further be utilized for the identification of new landfill site as well for finding the cost effective routes for the primary and secondary collection of municipal solid waste and its disposal.

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