Assessment of Groundwater Quality in and around the Jawaharnagar Municipal Solid Waste Dumping Site at Greater Hyderabad, Southern India

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Abstract

Rapid urbanization and population growth are largely responsible for exponentially increasing rate of solid waste in the urban areas. The proper management and recycling is a major problem of Municipal Corporation which is great concern of human health and environment. The purpose of this study is to assess groundwater contamination in and around of Jawaharnagar Municipal Solid Waste (MSW) dumping site due to heavy metals and its relationship between hydrochemical data. Groundwater samples were collected from the wells located in the vicinity of the dumping site and its surrounds in a watershed. The samples were analyzed for physicochemical properties as well as for major ion concentrations such as Ca\(^{2+}\), Mg\(^{2+}\), Na\(^{+}\), K\(^{+}\), CO\(_3^{2-}\), HCO\(_3^{-}\), Cl\(^{-}\), NO\(_3^{-}\), F\(^{-}\) and SO\(_4^{2-}\) using ion chromatograph. Results suggest the high concentrations of major ions such as Ca\(^{2+}\), Mg\(^{2+}\), and F\(^{-}\) is observed in groundwater indicating differential weathering of minerals present in granite rocks in the study area. A good number of samples are showing higher values for NO\(_3^{-}\) than that of World Health Organization (WHO) drinking water guideline values. This demonstrates the oxidation of ammonia and similar sources from leachates originating from municipal solid waste of the study area. Further, heavy metals such as Cd, Cr, Cu, Fe, Mn, Pb and Zn are analyzed using Inductively Coupled Plasma-Mass Spectrometer. The data revealed elevated concentrations of Arsenic (0.04-0.36 ppb), Cadmium (0.00-0.09 ppb), Chromium (24.0–28.0 ppb), Copper (0.61–2.9 ppb), Iron (11.99-35.26 ppb), Manganese (1.04-107.2 ppb), Lead (0.19-1.32 ppb) and Zinc (1.49–49.59 ppb). The present study demands proper management of landfill site and municipal solid waste to reduce further groundwater contamination via percolation of toxic substances.

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Peer-review under responsibility of the organizing committee of 5IconSWM 2015
1. Introduction

The generation of solid waste has become an increasing environmental and public health problem everywhere in the world, particularly in the developing countries. The rapid expansions of urban, industrial and commercial activities prompted by rapid population growth are the major cause for producing huge amounts of solid wastes. The quality of the municipal solid waste (MSW) depends on various factors such change in the life style, food habit, standard of living and cultural tradition of inhabitants and climate. The quantities of MSW generation rate both in terms of per day and per capita basis for the seven most important metros cities as shown in Fig.1 in accordance with CPCB report [1]. Further, Indian Ministry of Urban Development has estimated waste generation is about 100,000 MT in its manual on solid waste management. It is observed in most of the Indian cities dispose off their waste simply by open dumping and only few (94) landfill sites have been constructed/operational in the country out of which 34 new landfills have been constructed during 2014 that exhibits the threat on environment [2]. Lack of appropriate MSW management leads to significant soil, water, air and aesthetic pollution which is associated human health problems, as well as an increase in greenhouse gas emissions [3]. Further, if the solid waste disposal facilities are not properly designed these landfill sites has further contributed to environmental degradation especially the groundwater resources. Landfills have been identified as one of the major threats to groundwater resources areas near landfills have a greater possibility of groundwater contamination because of the potential pollution source of leachates originating from nearby sites [4-7]. It has been observed few studies reported impact of landfill on groundwater quality and no detailed report on the present site to the best of our knowledge. The present study made an attempt to evaluate impact of groundwater contamination due to heavy metals and its relationship between hydrochemical data in and around of Jawaharnagar Municipal Solid Waste (MSW) dumping site.

![Fig. 1.MSW generation rate per day for the seven major metro cities of India](image)

2. Materials and methods

2.1 Study area:

2.1.1 Description of the study area

The Jawaharnagar municipal solid waste dumping site and its surroundings is under urban local body called
Greater Hyderabad Municipal Corporation (GHMC), Hyderabad. The area under investigation belongs to Ranga Reddy district of Telangana with coordinates between 17°26' N to 17°34' N latitude and 78°32.5' E to 78° 40' E longitude. The area falls in the Survey of India (SoI) topographic map number 56K/10 to a scale of 1:50,000 in order to understand the extent of groundwater contamination (Figure 2).

The Jawaharnagar dumping yard utilizes an “Integrated Municipal Solid Waste Management Scheme” started in 2010 by GHMC to manage the waste disposal in the city. The city produces around 4,500 metric tonnes of solid waste everyday, which is transported from three collection units located in Imlibun, Youusufguda and lower Tank Bund to the garbage dumping site of Jawaharnagar. The site is 35 km away from Hyderabad city, 10.5 km away from the state Highway connecting Hyderabad- Nagpur in West direction from the boundary of the project site. The various processes such as rag picking and incineration are practicing at dumping sites as shown Figure 3.

2.1.2 Total Waste Generation

The average daily waste generation from GHMC is around 5454 TPD, with a per capita generation of about 648 g per day as on year 2011 and it is expected that the daily waste should be 9201 TPD, with a per capita generation of about 739 g per day by 2021 [8]. The solid waste management project at the Jawaharnagar dump yard on the city outskirts is runs by RamkyEnviro Engineers Ltd. Hyderabad has multiple violations of environmental laws and causing health hazards. For example, the foul smell emanating from the dumping yard has been taking a toll on the health of over 1 lakh residents of the nearby colonies. The stench is distinctly noticeable even in the residential areas about 7-8 km from the dumping yard [9].

2.1.3 Sampling and analytical methodology

The sampling locations were selected for comprehensive analysis to cover the entire study area. Water samples were collected from bore wells in the study area during November 2012. Total 12 groundwater samples were collected in polythene bottles from various wells in the study area. The locations of water samples were recorded using handheld Garmin GPS in the study area and shown in Figure 2. The samples were analyzed for various parameters according to the standard methods [10]. The pH, EC and TDS of water samples were measured in-situ using portable meters (Eutech Instruments, model: pHTester10, ECTester11+ and TDSTester11+ respectively). Bicarbonate and carbonate were analyzed by classical volumetric method. Major cations such as calcium, magnesium, sodium, potassium [11] and anions like chloride, nitrate, sulphate, fluoride [12] were analyzed by Ion chromatography (Metrohm, Model: 882 Compact IC plus).

3. Results and discussion

3.1 Hydrochemistry of groundwater:

The groundwater hydrogeochemistry is primarily controlled by water-rock interactions as well as anthropogenic pollution. Thus, the various indices were evaluated to understand the hydrogeochemistry of groundwater in the study area and summary of analytical results of are presented in Table 1. Physicochemical parameters such as pH, EC, TDS, major anions, cations and toxic metals were included for discussion. Results showed that the pH value is with an average of 7.04 exceeding from the standards prescribed for compost in Municipal Solid Waste (Management and Control) Rules 2000. This may be due some basic contents in the waste. However, its higher range accelerates the scale formations in water heating apparatus either in industrial or domestic purposes. The average EC value is 897 µS/cm while average TDS value 1589 mg/L is observed.

From the data of alkalis (Na+ and K+) and alkaline earths (Ca2+ and Mg2+), reveal that high concentration of Ca2+ than others with following order Ca2+>Na+>Mg2+>K+. In contrast, the increased Na+ concentration and decreased Ca2+ and Mg2+ values can be explained by the probability of the loss of Ca2+ and Mg2+ and gain of Na+ by the cation exchange process [13]. Among the various anions (Table 1) determined in groundwater samples, HCO3-, Cl-, SO42- are the major anions identified in the groundwater (Cl-> HCO3->SO4). This could be due to available carbonates in
the rocks might have been dissolved and added to the groundwater system during irrigation, rainfall infiltration and groundwater movement increases the bicarbonate [14]. Further, an increased chloride concentration may be due to the process of the removal of other ions from the system as sampling done during post monsoon, either by precipitation or by adsorption. The high content of chloride in water causes salinity related problems.

Fig. 2. Location map of study area with groundwater sampling locations
Fig. 3. Overview of Jawaharnagar dump yard near Hyderabad under Greater Hyderabad Municipal Corporation (GHMC)

Table 1: Summary statistics of the analytical data

| Water quality Parameter | Concentration | Min | Max | Average |
|-------------------------|---------------|-----|-----|---------|
| Physicochemical parameters |               |     |     |         |
| pH                      |               | 6.7 | 7.4 | 7.04    |
| Ec (μS/cm)              |               | 196 | 1930| 897     |
| TDS (mg/L)              |               | 778 | 3070| 1589    |
| Cations (mg/L)          |               |     |     |         |
| Ca^{2+}                 |               | 53.78| 191.97| 107.85 |
| Mg^{2+}                 |               | 18.01| 93.79 | 47.27  |
| Na^{+}                  |               | 65.41| 164.99| 95.90  |
| K^{+}                   |               | 0.12 | 14.54| 3.07   |
### Table 1: Water quality Parameter

| Anions (mg/L) | Min     | Max     | Average |
|---------------|---------|---------|---------|
| HCO₃⁻         | 143.80  | 451.40  | 270.80  |
| Cl⁻           | 53.28   | 665.90  | 288.90  |
| NO₃⁻          | 0.25    | 439.21  | 133.01  |
| SO₄²⁻         | 13.64   | 167.15  | 78.19   |
| F⁻            | 0.37    | 2.64    | 1.25    |

| Heavy metals (µg/L) | As | Cd | Cr | Cu | Fe | Mn | Pb | Zn |
|---------------------|----|----|----|----|----|----|----|----|
|         | 0.04 | 0.00 | 24.0 | 0.61 | 0.37 | 1.04 | 0.19 | 1.49 |
|         | 0.36 | 0.09 | 28.0 | 167.15 | 2.9 | 107.2 | 1.32 | 49.59 |
|         | 0.10 | 0.03 | 25.70 | 78.19 | 1.28 | 22.74 | 0.58 | 13.10 |

### 3.2 Water quality assessment:

According to the notification issued by Ministry of Environment, Forests and Climate Change (MoEF&CC) on 25th September, 2000, usage of groundwater in and around landfill sites for any purpose both drinking and irrigation is to be considered after ensuring its quality.

Accordingly, the analytical results of groundwater samples (Table 2) were compared with the Bureau of Indian Standards (BIS) drinking water specifications [15] to assess the groundwater quality. The various key parameters are considered and discussed in detail below in order to assess the suitability of the groundwater for use either for drinking or irrigation purpose.

The prescribed limit of pH for drinking purpose given by Bureau of Indian Standards is 6.5-8.5. In the study area, most of the groundwater has pH value within the prescribed limits indicating its suitability for drinking. Classifications of electrical conductivity of groundwater in study area are given in Table 3. It is found that 33.33% of the samples are within the permissible limits and 58.33% samples fall in not permissible limit but they are marginally poor in quality and only 8.33% of the sample location can be classified as hazardous according to the WHO guideline values [16]. The groundwater is classified depending upon their TDS values [17,18] and the data are presented in Table 4 representing that 100% of the sample are exceeding 500 mg/L of TDS [17] which cannot be used for drinking. The results further demonstrated that the groundwater of the area is fresh water type for 16.66% as well as the 83.33% of the samples represent brackish water in accordance with Freeze and Cherry classification [18] (Table 5).

Total hardness (TH) of groundwater samples in the present study exhibited minimum content of 120 to a maximum of 525 mg/L with an average of 290 mg/L. Please note that the maximum allowable limit of TH for drinking purpose is 500 mg/L and the most desirable limit is 100 mg/L as per the WHO standard. The spatial distribution of hardness shows higher concentrations were observed in the central part of the study area (i.e. Kampally and surroundings). According to the Sawyer and McMacartly [19] classification, 16.66% of samples fall in the hard category, on the other hand 41.66% of the samples falls in very hard category (Table 6) are not suitable for drinking.
Table 2. Groundwater samples of the study area exceeding the permissible limits prescribed by Bureau of Indian Standards (BIS)

| Parameter      | Units   | No. of samples exceeding Acceptable Limits | % of samples exceeding Acceptable Limits | BIS* Ref [15] Drinking Water Specification IS:10500:2012 |
|----------------|---------|--------------------------------------------|------------------------------------------|-------------------------------------------------------|
|                |         |                                            |                                          | Requirement (Acceptable Limit) Permissible Limit in the absence of alternate source |
| pH             | --      | --                                         | --                                       | 6.5-8.5 No relaxation                                 |
| EC             | µS/cm   | --                                         | --                                       | --                                                   |
| TDS            | mg/L    | 12                                         | 100.00                                  | 500 2000                                             |
| Calcium        | mg/L    | 10                                         | 83.33                                   | --                                                   |
| Magnesium      | mg/L    | 9                                          | 75.00                                   | --                                                   |
| Sodium         | mg/L    | --                                         | --                                      | --                                                   |
| Potassium      | mg/L    | --                                         | --                                      | --                                                   |
| Total Hardness (as CaCO₃) | mg/L | 6                                          | 50.00                                   | 200 600                                              |
| Fluoride (as F⁻) | mg/L | 8                                          | 66.66                                   | 1.0 1.5                                              |
| Chloride (as Cl⁻) | mg/L | 9                                          | 75.00                                   | 250 1000                                             |
| Sulphate (as SO₄) | mg/L | --                                         | --                                      | 200 400                                              |
| Nitrate (as NO₃) | mg/L | 7                                          | 58.33                                   | 45 No relaxation                                     |
| Arsenic        | µg/L    | --                                         | --                                      | --                                                   |
| Cadmium        | µg/L    | --                                         | --                                      | 0.003 No relaxation                                  |
| Chromium       | µg/L    | --                                         | --                                      | --                                                   |
| Copper         | µg/L    | --                                         | --                                      | 0.05 1.5                                             |
| Nickel         | µg/L    | --                                         | --                                      | 0.02 No relaxation                                   |
| Manganese      | µg/L    | 1                                          | 8.33                                    | --                                                   |
| Lead           | µg/L    | --                                         | --                                      | 0.01 No relaxation                                   |
| Zinc           | µg/L    | --                                         | --                                      | 5 15                                                 |

b.d.l: below detection limit

Table 3. Groundwater classification based on electrical conductivity

| EC us/cm | Classification | Sample No.         | No. of samples | % of samples |
|----------|----------------|--------------------|----------------|--------------|
| <1500    | Permissible    | 1,3,6, and 10      | 4              | 33.33        |
| 1500-3000| Not permissible| 2,4,5,7,9,11,12    | 7              | 58.33        |
| >3000    | Hazardous      | 10                 | 1              | 8.33         |
| Total    |                |                    | 12             | 100          |
Table 4. Groundwater classification based on TDS (Davis and De Wiest 1966)

| TDS (mg/l) | Classification       | Samples | No. of samples | % of samples |
|------------|----------------------|---------|----------------|--------------|
| <500       | Desirables for drinking | Nil     | Nil            | Nil          |
| 500-1000   | Permissible for drinking | 1 and 10 | 2              | 16.66        |
| 1000-3000  | Useful for irrigation  | 2,3,4,5,6,7 and 9 | 9              | 75.00        |
| >3000      | Unfit for drinking and irrigation | 8      | 1              | 8.33%        |
| Total      | -----                 | ----    | 12             | 100          |

Table 5. Groundwater classification of all groundwater based on TDS (Freeze and Cherry 1979)

| TDS (mg/l) | Classification       | Sample No. | No. of samples | % of samples |
|------------|----------------------|------------|----------------|--------------|
| <1000      | Fresh water type     | 1 and 10   | 2              | 16.66        |
| 1000-10000 | Brackish water type  | 2,3,4,5,6,7,8, and 9 | 10 | 83.33 |
| 10000-100,000 | Saline water type | Nil       | Nil            | Nil          |
| >100,000   | Brine water type     | Nil       | Nil            | Nil          |
| Total      |                      | 12        | 100            |

Table 6. Groundwater classification based on hardness (Sawyer and McMCartly 1967)

| Total Hardness as COCO3 (mg/l) | Classification | Sample No. | No. of samples | % of samples |
|--------------------------------|----------------|------------|----------------|--------------|
| <75                            | Soft           | Nil        | Nil            | Nil          |
| 75-150                         | Moderately High| 2,4,8,10,11| 5              | 41.66        |
| 150-300                        | Hard           | 3,9        | 2              | 16.66        |
| >300                           | Very hard      | 1,5,6,7,12 | 5              | 41.66        |
| Total                          |                | 33         | 100            |

The analytical data on cations demonstrated that 83.33% and 75% of the samples with Ca$^{2+}$ and Mg$^{2+}$ concentration are exceeding the BIS limits, whereas Na$^+$ and K$^+$ concentrations is within permissible limits. This may be due to the ion exchange process occurring in the aquifer. The permissible limit for bicarbonate (i.e. 300 mg/l) is exceeded in majority of the samples which confirm that all carbonate minerals are dissolved in the groundwater. This is further evidence that no carbonate is detected in all the groundwater samples investigated. Fifty eight percent of groundwater samples are showing higher values for nitrate than that of the WHO permissible limit of drinking water [16]. The common sources of nitrate in water are the leachates from the landfill sites whether in use or abandoned, local agricultural field, domestic sewage etc. Fluoride concentration varies between 0.37 to 2.64 mg/l with average 1.25 mg/l which is slightly higher concentration in some samples. However, the average concentration falls within permissible limit of 1.5 mg/l according to BIS limits. Chloride content in groundwater varies between 53.28 mg/l and 665.90 mg/l with an average of 288.90 mg/l indicating 75% of the samples are exceeding acceptable limits. Sulfate in the study area is found to be within the acceptable limit of 200 mg/l as per BIS standards.
Heavy metal are the major indicator of anthropogenic impact which having various sources like dry deposition from incineration plants, industrial effluents, traffic activities and landfill leachate etc. Therefore monitoring of heavy metals which are toxic in nature are concern to assess the landfill impact on groundwater quality. The results of metal analysis of groundwater reveal that all the toxic metals are nearly fall within the prescribed standard except Mn in few samples. The low concentration is perhaps due to its requirement for several microbial enzymatic activities. It appears that there is no indicator compound(s) that is unique to landfill leachate which is not presented in uncontaminated water.

Conclusions

Groundwater quality assessment studies around Jawaharnagar municipal solid waste dumping site indicating that the pollution source is dominated over natural process in the vicinity of studied area. However the excess nitrate contamination is expected due landfill activities. Heavy metals in all the samples are found within the permissible limits of drinking water guideline values. This study further suggested that the leachate, soil and sediments from surrounding water bodies needs to be monitored to evaluate the vulnerability of groundwater contamination in the study area.

Acknowledgement

The authors are grateful to Director, CSIR-National Geophysical Research Institute, Hyderabad for his kind permission for publishing this work and financial support from the CSIR-NGRI (Project code: MLP-6601-28(KRM). We are thankful for the support rendered from the project staff namely Mr.PeriasamyVenkatasalam and Mr.Manohar Kata in fieldwork and data processing.

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