Hydro Chemical Analysis and Suitability Determination for Irrigation for Ground Water near Solid Waste Dump Site at Pune

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Abstract

Over exploitation and pollution of groundwater resources is considered to one of the major pollution problems these days. Even pollution of air, surface water or land may have a significant effect on pollution and contamination of ground water. Industries, human activities, agriculture, etc generate waste in various forms like solid, liquid and gas. If all this waste is not treated properly, it shall result polluting the environment and further affecting the quality of ground water due to its hydraulic connectivity with the hydrological cycle. In addition, leachate resulting from municipal or industrial solid waste dump site as well agricultural run-off also leads to ground water pollution. It has been estimated that around 45 million people globally are affected by water pollution resulting from excess iron, fluoride, arsenic, or sea water intrusion. The current study deals with physico-chemical analysis of ground water samples and suitability determination of water by using water quality index and Piper diagram for solid waste dump site near Pune. Water samples were collected from open wells as well as bore wells for pre-monsoon and post monsoon season and results were evaluated using residual sodium carbonate, sodium hazard, sodium adsorption ratio, and piper diagram. It can be inferred that, Ca-Cl type of water predominates the study area for both pre-monsoon as well as post-monsoon season.

1. Introduction

Ground water is one of the major sources for drinking, agricultural and other uses. The sub-surface hydrology influence on groundwater movement and hence contaminants migrate to the subsurface water. The increasing rate of urbanization, agricultural activity and industrialization are mainly responsible for pollution (Sarala and Babu, 2012). Pollutants observed at a single location may be resulting from an individual source or combination of multiple sources. This study involved physico-chemical analysis of various parameters at different locations around solid waste dump site at Pune, Maharashtra, which is facing many problems related to solid waste disposal and management. Due to unscientific solid waste disposal, large heaps of wastes are accumulated at the dumpsite. Further decomposition of this waste leads to various environmental problems like bad odour, grazing of cows, rodent and mosquito nuisance (Longe and Balogun, 2010). The leachate resulting from this dumpsite flows and percolates in the soil, resulting in groundwater pollution in nearby areas (Nilo, N. S., et al, 2013). For efficient management of ground water resources, it is necessary to do the progressive groundwater quality mapping of the entire area using GIS. The present study objective is to assess the major physicochemical parameter concentration at various samples around Pune dumpsite, identification of root causes of such pollutants, and determining ground water suitability for drinking or irrigation purpose using piper diagram.

Ground water quality assessment around the dump site shall help in finding the contaminants, determine water suitability for domestic or irrigation purpose and suggest treatment solution for the same. Moreover it becomes important if the groundwater resources are situated in the close vicinity of solid waste dump site (Sasane and Lohote 2013). Considering the concentration of individual and paired ions in ground water, various indices are used to determine various alkali hazards. Piper diagram is generally used to predict the hydro-geochemical facies. A piper diagram generally shows the relative concentrations of six

to seven ions in a solution or water sample. The cations considered for this study are Ca, Mg, Na, and K, and the anions considered are Cl, SO₄, HCO₃, and CO₃. In most of the natural waters, these cations and anions make up almost 95 to 100 percentages of the total ions present in the solution. For determining the water suitability for agriculture or irrigation purpose, Department of Agriculture for US Salinity Lab has approved various techniques like sodium hazards, Sodium absorption ratio Residual sodium carbonate.

2. Study Area And Sampling Locations

Pune, the seventh largest city in India by population, covering approximately 333.56 km² area, lies between latitudes 18° 22' N and 18° 35' N and longitudes 73° 44' E and 73° 57' E with an average altitude of 559 m above the mean sea level. The solid waste disposal site at Pune is located at Mantarwadi at Uruli Devachi in Haveli Taluka, 20 km away from Pune City between latitude 18° 28' N and Longitude 73° 57' E. Pune city comprises of commercial complexes, industries, hospitals, hotels, residential buildings as well as highly urban population. As a result, the solid waste generated from municipal areas is found to be heterogeneous in nature and chiefly consists of papers, plastics, metals, glasses as well as biodegradable waste (Mane and Hingan, 2012). Pune generates about 1200-1300 metric tons of solid waste daily that is disposed off at Mantarwadi dumpsite. The organic matter is estimated to be around 45 to 50 percent and recyclable material contributes about 35 to 40 percent, where as the inert material contributes about 10 to 15%. The waste has calorific value above 900 Kcal/kg. Studies have revealed various problems associated with air and groundwater pollution resulting from unscientific solid waste disposal at Uruli-Devachi village (Dhere, A M., et al, 2008).

Sampling stations were selected randomly within 3 km radial distance from dumping site by grab sampling methods. Water samples were collected from seven open wells and two bore wells around the solid waste dumpsite (Raman and Sathiyarayanan, 2011). The sampling was carried out manually, and the samples were kept in opaque polythene bottles. The collected samples were analyzed within 24 hours using standard methods. The sampling locations around the dumping site are shown in Figure 1. The details of sampling locations are mentioned in Table 1 below.

Table 1
Latitude and Longitude of the Sampling station

Sampling Points	Latitude	Longitude	Dist. from dumping yard	Elevation from MSL
OW1	18° 27' 57.76" N	73° 57' 27.20" E	699.38 m	598 m
OW2	18° 27' 58.09" N	73° 57' 48.31" E	1167.53 m	582 m
OW3	18° 28' 00.89" N	73° 57' 49.38" E	1161.14 m	582 m
OW4	18° 28' 1.06" N	73° 57' 55.01" E	1305.07 m	580 m
OW5	18° 28' 7.74" N	73° 57' 54.58" E	1236.57 m	578 m
OW6	18° 28' 18.65" N	73° 58' 07.69" E	1373.73 m	575 m
OW7	18° 28' 13.73" N	73° 58' 0.23" E	1589.26 m	576 m
BW1	18° 27' 43.24" N	73° 57' 13.49" E	1022.49 m	600 m
BW2	18° 27' 51.77" N	73° 57' 32.91" E	949.05 m	591 m
Dumping yard centre	18° 28' 16.50" N	73° 57' 13.50" E	00 m	602 m

3. Sodium Hazards, Sodium Adsorption Ratio, Residual Sodium Carbonate, And Piper Diagram

3.1 Sodium Hazards

In Irrigation waters, the amount of sodium present is generally represented in terms of per cent sodium and is calculated by the equation-1 shown below:

$$\% \text{ Na} = \frac{(\text{Na}^+) \times 100}{(\text{Ca}^{+2} + \text{Mg}^{+2} + \text{Na}^+ + \text{K}^+)}$$

Where, Ca^{+2} , Mg^{+2} , Na^+ and K^+ are expressed in milli equivalents per litre. The following Table 2 shows the water classification on the basis of Sodium percent water class for irrigation purpose.

Table 2
Sodium percent water class

Sodium (%)	Water class
<20	Excellent
20-40	Good
40-60	Permissible
60-80	Doubtful
>80	Unsuitable

3.2 Sodium Adsorption Ratio (SAR)

Sodium Adsorption Ratio (SAR) is a measure for determining water suitability for agricultural or [irrigation](#) use. It is generally, ascertained by finding the concentration of dissolved solids in water (Rajkumar, N., et al, 2010). If SAR value is found to be high, water is termed to be less suitable for irrigation purpose. Water having high SAR when used for irrigation purpose, shall require soil treatment to prevent long-term damage to the soil. The water classification for irrigation can be found when the SAR and specific conductance are known. SAR is calculated using equation-2 shown below:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

The following Table 3 shows the water classification on the basis of Sodium Hazard class for irrigation purpose.

Table 3
Sodium hazard classes based on USSL classification

Sodium Hazard Class	SAR in Equivalents per mole	Remark on Quality
S1	10	Excellent
S2	10-18	Good
S3	18-26	Doubtful
S4 and S5	>26	Unsuitable

3.3 Residual sodium carbonate (RSC)

The Residual sodium carbonate (RSC) establishes whether excess Ca and Mg ions remain in the irrigation water after reaction with carbonate, or all the Ca and Mg ions are precipitated from the irrigation

water. When water having residual sodium carbonate values greater than 2.5 meq/l is used for a long period it causes salt build up, and further clogs the soil pores preventing air and water movement and resulting in physical degradation of soil. A negative RSC value signifies that more Ca and Mg ions are present in water as compared to Carbonate ions. The excess Ca and Mg ions will act as counter ions to displace Na. A positive RSC indicates that all the Ca and Mg ions have undergone precipitation, so the excess bicarbonate or carbonate ions shall react with the Ca added, in the form of gypsum, dolomite, or lime. RSC is calculated using equation-3 shown below,

$$RSC = (HCO_3^- + CO_3^{-2}) - (Ca^{+2} + Mg^{+2})$$

The following Table-4 shows the water classification on the basis of Residual Sodium carbonate for irrigation purpose.

Table 4
Groundwater quality based on
RSC (Residual Sodium
carbonate)

Table 4:	
RSC	Remark on quality
<0	None
0-1.25	Good
1.25-2.5	Doubtful
>2.5	Unsuitable

3.4 Piper Diagram

A Piper diagram comprises of two trilinear diagrams, one for anions which is shown on the lower right corner and one for cations shown on the lower left corner. For each sample, the detail from each trilinear diagram is projected up in the central quadrilateral. As a result, each sample will be plotted in the Piper diagram, one representing cations, one representing anions, and one representing the combination. As shown in figure-2 below the diamond shape is divided into various parts, where each part has significance, based on the cations and anions present.

3.5 Steps to be followed to plot Piper Diagram

Step 1: Convert concentrations from mg/lit to milli equivalent/lit by using following equation-4 shown below

$$\text{Milliequivalent/lit} = \frac{\text{mg/lit}}{\text{Equivalent weight}}$$

The equivalent weights of various elements are mentioned in Table 5.

Table 5
Equivalent weights of elements

Sr. No.	Element	Equivalent weight
1	CO ₃	30.004
2	H-CO ₃	61.016
3	Chlorides	35.453
4	Sulphate	48.03
5	Calcium	20.04
6	Magnesium	12.156
7	Sodium	22.991
8	Potassium	39.12

Step 2: Use major cations and anions concentrations-

Cations - Ca, Mg, Na, and K and Anions - SO₄, Cl, HCO₃, and CO₃ (Alkalinity)

Step 3: Calculate percentage of each element.

$$\% \text{ Ca} = \text{Ca} / (\text{Ca} + \text{Mg} + \text{Na} + \text{K}) * 100$$

$$\% \text{ Mg} = \text{Mg} / (\text{Ca} + \text{Mg} + \text{Na} + \text{K}) * 100$$

$$\% (\text{Na} + \text{K}) = (\text{Na} + \text{K}) / (\text{Ca} + \text{Mg} + \text{Na} + \text{K}) * 100$$

$$\% \text{ SO}_4 = \text{SO}_4 / (\text{SO}_4 + \text{Cl} + \text{HCO}_3 + \text{CO}_3) * 100$$

$$\% \text{ Cl} = \text{Cl} / (\text{SO}_4 + \text{Cl} + \text{HCO}_3 + \text{CO}_3) * 100$$

$$\% (\text{HCO}_3 + \text{CO}_3) = (\text{HCO}_3 + \text{CO}_3) / (\text{SO}_4 + \text{Cl} + \text{HCO}_3 + \text{CO}_3) * 100$$

Step 4: Plot percentage of each element on Cation and Anion triangle respectively.

Step 5: Project each percent on diamond diagrams.

4. Results And Discussion

4.1 Sodium Hazards

From the calculations, the sampling stations are checked for Sodium hazards. The results obtained are shown in figure-3.0. The percent sodium for 8 samples is between 7.26-19.46 during pre-monsoon for 8 samples and between 6.58-16.71 for 7 samples during post monsoon, which are less than 20 percent indicating excellent water quality, whereas sodium percent of 1 sample is 22.39 during pre-monsoon and that of 2 samples is between 20.46 – 22.15, which falls in the standard range of 20-40 percent classifying the samples as good quality water. When the sodium range is high, Na will be absorbed by clay particles and displace Mg^{+2} and Ca^{+2} ions (Anandakumar, S., et al 2009). When Na^{+} in water is displaced with Mg^{+2} and Ca^{+2} ions in soil, it shall reduce the soil permeability and further result in poor internal drainage of the soil. This shall restrict the movement of air and water in the soils and such soils generally become hard when dry (Saleh A., et al, 1999).

4.2 Sodium Absorption Ratio

From the calculations, the sampling stations are checked for SAR. The results obtained are shown in figure-4. SAR values fall in the range of 0.59-1.58 for pre-monsoon season for all nine samples and were found to be in the range of 0.49-1.49 during post monsoon for all the nine samples, which indicate sodium hazard class to be S1 and water quality to be excellent. Water with SAR values greater than 6, are observed to have permeability problems (Saleh A., et al, 1999).

4.3 Residual Sodium Carbonate

From the calculations, the sampling stations are checked for RSC. The results obtained are shown in figure-5.0. All the samples were found to have negative RSC values. A negative RSC indicates that more concentration of Ca and Mg ions in water as compared to carbonates. Percentage of each element at various sampling points for pre monsoon and post monsoon are shown in the figure 6 and 7 below.

4.4 Piper diagram

The Piper Diagram is plotted for both the seasons by using Groundwater chart software. The piper plots for post- monsoon and pre-monsoon season are shown in figure 8 and 9 and the characteristics of diamond shaped fields are depicted in figure-10. The piper diagram plotted clearly demonstrates the variations in the concentrations of cations and anions during pre-monsoon and post-monsoon. On the basis of piper diagram it can be inferred that the water type is predominantly of Ca-Cl type for both pre-monsoon and post-monsoon seasons (Tomar V., et al, 2012). No significant change was observed in the hydro-chemical facies for both the seasons.

5. Conclusions

The current study indicates that the solid waste disposal Urali Devachi causes various environmental and health problems in the nearby areas. Open dumping of solid waste results in bad odour, anaesthetic view as well as leachate problems during decomposition of solid waste. The leachate emanating from the dumpsite contains various contaminants like organic compounds, soluble salts and even heavy metals which combine with the ground water, polluting it. The Piper diagram helped to evaluate the hydro-chemical facies in the study area, which clearly revealed the water is predominantly of Ca-Cl type for pre-monsoon as well as and post-monsoon season. The suitability of water for irrigation for the study area is evaluated based on SAR, Percent sodium, and RSC (Sadashivaiah, C., et al, 2008). Since all groundwater sampling stations are falling in excellent and good category for SAR and % Na, it can be concluded that all the ground water sources are safe for the irrigation use. However, all the RSC values obtained are negative, which implies that more Ca^{+2} and Mg^{+2} ions are present in the samples than carbonates ions.

Declarations

Availability of data and materials

All the relevant data generated or analysed during the study is incorporated in the manuscript.

Competing interests

The authors declare they have no competing interests.

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Authors' contributions

SAN has done literature survey to identify research gaps for this study. She also provided technical support in writing the manuscript along with comments and revisions in the manuscript.

SNB collected samples, conducted all the experiments, along with data interpretation and statistical analysis during the study.

ARM provided support for writing the manuscript along with critical comments and revisions in the manuscript. All the authors have read and approved the final manuscript.

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Figures

Figure 1

Location of sampling locations

Hydrochemical facies of groundwater

Figure 2

Hydrochemical facies of groundwater

Figure 3

Percentage of sodium at sampling stations

Figure 4

SAR at sampling stations

Figure 5

RSC values at sampling stations

Figure 6

Percentage of various elements at sampling stations

Figure 7

Percentage of SO₄ and CO₃+HCO₃ at sampling stations

Figure 8

Piper Diagram for Post Monsoon Season

Figure 9

Piper Diagram for Pre Monsoon Season

Figure 10

Characteristics of diamond shaped fields