Article

An assessment of groundwater quality for agricultural use: a case study from solid waste disposal site SE of Pune, India

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Abstract

Groundwater pollution around the improperly constructed landfill areas of the growing cities has always been in the rising trend and hence its effects on the environment warrant a thorough monitoring. The seasonal variations in the quality of groundwater from the dug wells surrounding the solid waste disposal site from the SE of Pune city (India) has been assessed by calculating the sodium adsorption ratio (SAR). The results indicate that the groundwater from the wells nearing the waste disposal site show consistent increase in the pollution from monsoon to summer through winter. The study further demonstrates that the wells near the site are severely polluted and the source is mainly the leachates emerging out of the decaying solid wastes. The recurrent addition of the solid waste in the dump site in the coming years would result in further exponential deterioration of the groundwater quality of the dug wells from the area and hence adequate steps are urgently needed to prevent further aggravation of the problem. Based upon the SAR values it is evident that most of the wells from the Hadapsar area have excellent groundwater for irrigation throughout the year; from Manjari area it is excellent to good; the Fursungi area has sub-equal proportions of excellent, good and fair groundwater, while in Mantarwadi, although most of the wells have excellent to good water, few wells have fair to poor quality water for irrigation purpose. In Uruli-Devachi about 50% wells have poor quality of water and hence can not be used for irrigation. Hence this study strongly suggests that most of the abstracted groundwater samples from the study area were suitable for irrigation except from Uruli Devachi area.

Keywords sodium adsorption ratio (SAR); groundwater pollution; solid waste disposal.

1 Introduction

Pune city has been experiencing urbanization due to rapid economical development resulting in dramatic changes in the land-use pattern imposing a negative impact on the groundwater quality. Quality of water for the human consumption is of vital importance as the natural waters are contaminated by many natural as well as anthropogenic factors**.** Hence continuous monitoring of water quality is of paramount importance in view of the insufficiency of potable water in both urban and rural areas. The unplanned deposal of solid waste on land surface leads to downward movement of pollutants from the surface causing degradation of groundwater quality. Water is indispensable and one of the precious natural resources (next to air) of the earth and when its quality or composition is changed (directly or indirectly due to waste disposal and other human activity) is said to be unsuitable for drinking and domestic purposes. While fresh water has become a scarce commodity, due to over exploitation and pollution of water, an increasing population and its necessities have lead to the deterioration of surface and sub-surface water and hence an assessment of water quality using various methods should be an important mission. The quality of groundwater is the resultant of all the processes and reactions that act on the water from the moment it condenses in the atmosphere to the time it is discharged by a well or spring and varies from place to place and with the depth of the water table (Ackah et al., 2011). As groundwater is the major source of drinking water, in both urban and rural areas, the importance of groundwater for the existence of human society cannot be overemphasized because it is an important source of water for the agricultural and industrial sector.

2 Study Area

Pune, the seventh largest city in India by population, lies between latitudes 18^0 31' N & 22^0 45' N and longitudes 73^0 52' E & 32^0 9'E (Fig. 1) with an altitude of 559m above the mean sea level and covering approximately 243.84 km^2 area. The waste disposal site is a non-engineered open dump looking like a huge heap of waste up to a height of 20m. The soilid waste disposal site (73^o 55' to 74^o 00' N and 18^o 25' to 18^o 32' E) is situated at elevation ranging between 550 to 660m above mean sea level on the eastern slopes of a small topographic high.

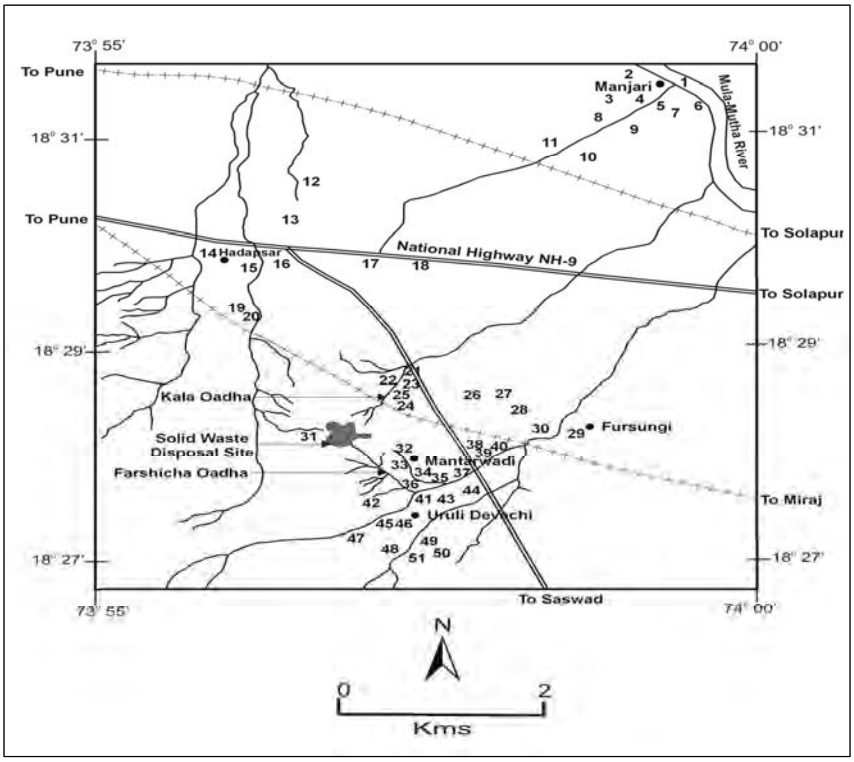

Fig. 1 Location map of study area

3 Methods

Sodium adsorption ratio (SAR): Sodium is a unique cation because of its effect on soil (when present in exchangeable form) as it causes adverse physico-chemical changes in the soil, particularly to the soil structure. A high salt concentration in the water leads to the formation of saline soil and the higher concentration of sodium leads to development of alkali soil. Irrigation water could be a source of excess sodium in the soil solution and hence it should be evaluated for this hazard. The sodium or alkali hazards (in using water for irrigation) is calculated by determining the absolute and relative concentrations of cations and is expressed in terms of Sodium adsorption ratio (SAR) which is a simple method to evaluate the danger of high-sodium water (Richards, 1954). If the proportion of sodium is high the alkali hazard is high and if calcium and magnesium predominate the hazard is less. There is a significant relationship between SAR values of irrigation water and extent to which sodium is absorbed by the soil. If water used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium which can destroy the soil structure owing to dispersion of clay particles. It has an ability to disperse soil, when present above certain threshold value, relative to the concentration of total dissolved salts. Dispersion of soils results in reduced infiltration rates of water and air into the soil. When dried, dispersed soil forms crusts which are hard to till and interfere with germination and seedling emergence.

Usually SAR less than 3.0 will not be a threat to vegetation while SAR greater than 12.0 is considered sodic and threatens the survival of vegetation by increasing soil swelling (dispersion) and reducing soil permeability (Kuipers et al., 2004). The compounding effects of discharging water with high SAR is that it produces soils that are unsuitable for agriculture, grazing and it creates hazards such as fugitive dust from wind and increased sediment loading of local streams and rivers from surface runoff and damages the stream channel integrity (Kuipers et al., 2004). The suitability of the groundwater for irrigation from the present area of study was judged by determining the SAR value and they were categorized under different classes. Sodium adsorption ratio (SAR) was computed by using the following formula:

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

4 Results and Discussion

In the present study it has been found that the SAR values varied from 1.05 to 53.91 (Table 1 and Fig. 3) and the data revealed that in the rainy season 49% wells have excellent groundwater (SAR<10.0) which in winter and summer seasons are 43% and 49% respectively (Table 1). Richards (1954) categorized the groundwater on the basis of SAR values (<10 as excellent; between 10-18 as good; 18-26 as fair; and < 26 as of poor quality). The details of the number of wells categorized in terms of groundwater quality based on SAR values and their percentages are tabulated (Table 1) and compared (Fig. 2).

It is evident that most of the wells from the Hadapsar area have excellent groundwater for irrigation throughout the year while from Manjari area it is excellent to good. Fursungi area, however, has sub-equal proportions of excellent, good and fair groundwater, while in Mantarwadi, although most of the wells have excellent to good water few wells have fair to poor quality water. In Uruli-Devachi about 50% wells have poor quality of water and hence can not be used for irrigation. Hence this study strongly suggests that most of the abstracted groundwater samples from the study area were suitable for irrigation except from Uruli Devachi area. On the basis of SAR it is evident that most of the water from the wells of study area was suitable for irrigation except from Uruli-Devachi area.

Table 1 Classification of the wells in terms of ground water quality (based on SAR)

A) Rainy season

Location	Excellent SAR < 10		Good SAR 10-18		Fair SAR 18-26		Poor SAR > 26	
	Wells	%	Wells	%	Wells	%	Wells	%
Manjri	6	55	5	45	0	0	0	0
Hadapsar	8	89	1	11	0	0	0	0
Fursungi	4	44	3	33	2	22	0	0
Mantarwadi	5	56	3	33	0	0	1	11
Uruli-Devachi	1	9	2	18	3	27	5	45
Total	24	49	14	29	5	10	6	12

B) Winter season

Location	Excellent SAR < 10		Good SAR 10-18		Fair SAR 18-26		Poor SAR > 26	
	Wells	%	Wells	%	Wells	%	Wells	%
Manjri	6	55	5	45	0	0	0	0
Hadapsar	7	78	2	22	0	0	0	0
Fursungi	3	33	3	33	0	0	3	33
Mantarwadi	4	44	3	33	1	11	1	11
Uruli-Devachi	1	9	2	18	1	9	7	64
Total	21	43	15	31	2	4	11	22

C) Summer season

Location	Excellent SAR < 10		Good SAR 10-18		Fair SAR 18-26		Poor SAR > 26	
	Wells	%	Wells	%	Wells	%	Wells	%
Manjri	6	55	5	45	0	0	0	0
Hadapsar	8	89	1	11	0	0	0	0
Fursungi	4	44	3	33	2	22	0	0
Mantarwadi	5	56	3	33	0	0	1	11
Uruli-Devachi	1	9	2	18	3	27	5	45
Total	24	49	14	29	5	10	6	12

5 Conclusions

Groundwater is particularly important as it accounts for about 88% safe drinking water in the rural areas, where population is widely dispersed and the infrastructure needed for treatment and transportation of surface water does not exist. Although the quality of groundwater is controlled by various factors like evaporation, dissolution, precipitation, oxidation-reduction, sorption, exchange reaction, transformation of organic matter, mixing process the relative importance of these factors varies according to flow scale dimension and geological setting. Conventional water quality monitoring programmes involve periodic sampling of ground and surface waters surrounding a landfill for chemical indicators of contamination, such as elevated levels of ammonium, chloride and heavy metals (Sayyed and Sayadi, 2011). Although the water required for the domestic consumption should possess a high degree of purity, in the municipal cities improper way of effluents and solid waste disposal is largely responsible for the groundwater pollution.

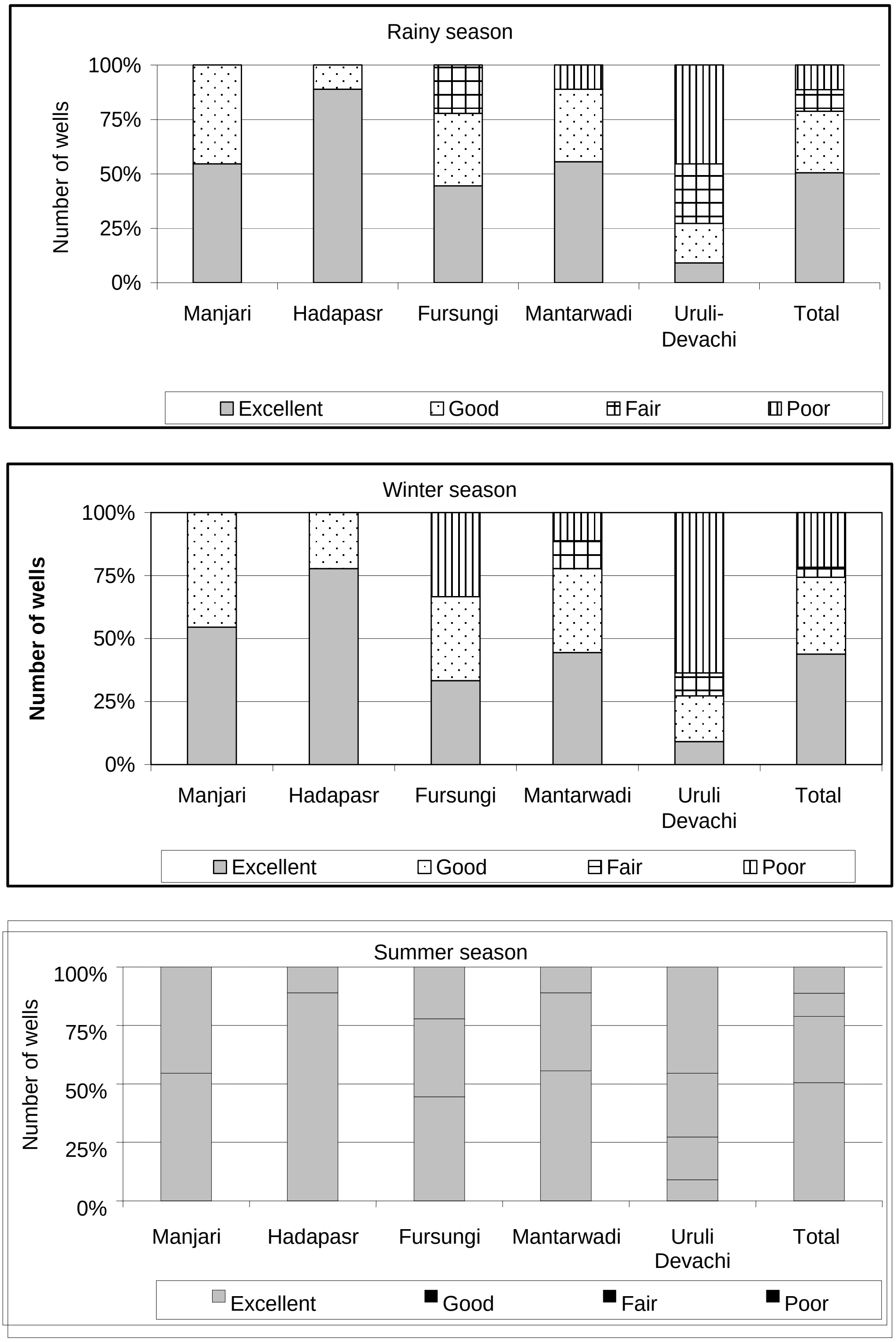

Fig. 2 Classification of wells in terms of groundwater quality on the basis of SAR

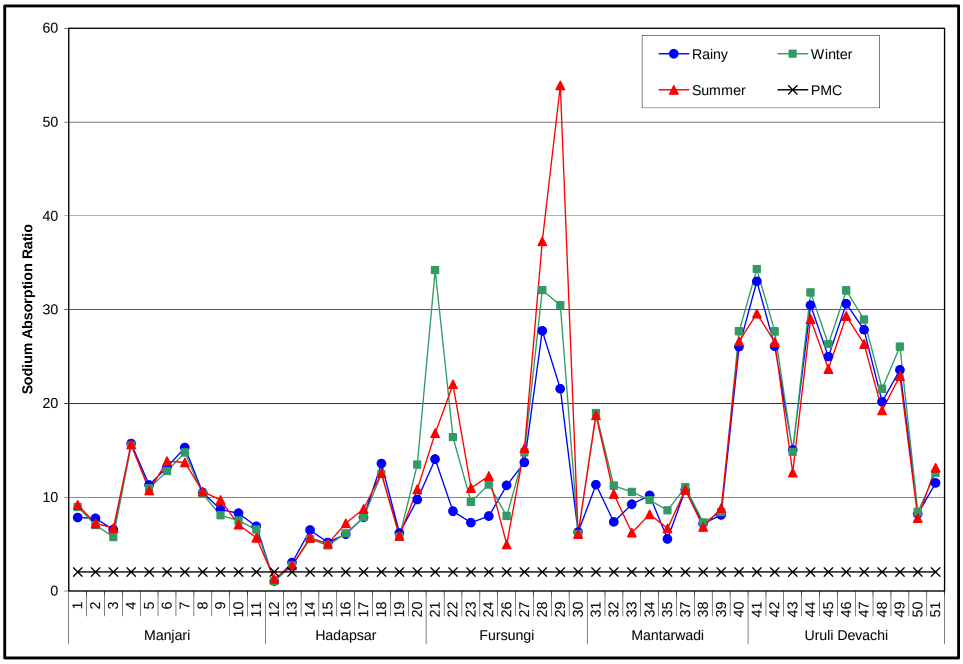

Fig. 3 Seasonal variations in SAR in different sampling stations

Table 2 Seasonal variation of SAR for different sampling station

Sampling station		Rainy	Winter	Summer	PMC
Manjari	1	7.83	8.95	9.17	2.03
	2	7.75	7.02	7.19	2.03
	3	6.55	5.75	6.71	2.03
	4	15.72	15.51	15.64	2.03
	5	11.29	10.96	10.72	2.03
	6	13.21	12.79	13.83	2.03
	7	15.29	14.76	13.70	2.03
	8	10.50	10.36	10.60	2.03
	9	8.68	8.07	9.70	2.03
	10	8.29	7.51	7.08	2.03
	11	6.88	6.55	5.67	2.03
Hadapsar	12	1.05	1.06	1.30	2.03
	13	3.03	2.72	2.75	2.03
	14	6.50	5.54	5.68	2.03
	15	5.17	4.85	5.03	2.03
	16	6.05	6.15	7.22	2.03
	17	7.86	7.86	8.76	2.03
	18	13.59	12.47	12.56	2.03
	19	6.17	5.79	5.90	2.03
	20	9.74	13.46	10.85	2.03
Fursungi	21	14.06	34.20	16.82	2.03
	22	8.51	16.41	22.03	2.03
	23	7.28	9.49	11.00	2.03
	24	7.98	11.35	12.26	2.03
	26	11.26	8.00	4.97	2.03

	Rainy	Winter	Summer	PMC	Rainy
	27	13.71	14.78	15.23	2.03
	28	27.74	32.07	37.28	2.03
	29	21.55	30.47	53.91	2.03
	30	6.28	6.07	6.07	2.03
Mantarwadi	31	11.32	18.99	18.73	2.03
	32	7.36	11.23	10.36	2.03
	33	9.25	10.57	6.22	2.03
	34	10.19	9.71	8.18	2.03
	35	5.55	8.60	6.67	2.03
	37	10.79	11.08	10.80	2.03
	38	7.19	7.30	6.84	2.03
	39	8.10	8.41	8.84	2.03
	40	26.04	27.69	26.61	2.03
Uruli Devachi	41	33.02	34.32	29.58	2.03
	42	26.09	27.67	26.54	2.03
	43	15.04	14.83	12.62	2.03
	44	30.46	31.82	28.99	2.03
	45	24.98	26.30	23.68	2.03
	46	30.62	32.04	29.32	2.03
	47	27.85	28.94	26.35	2.03
	48	20.17	21.55	19.26	2.03
	49	23.58	26.06	22.95	2.03
	50	8.21	8.43	7.77	2.03
	51	11.51	12.58	13.15	2.03

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