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ORIGINAL ARTICLE

Environmental impact of municipal dumpsite leachate on ground-water quality in Jawaharnagar, Rangareddy, Telangana, India

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Abstract The aim of the present work was to study the impact of dumpsite leachate on ground-water quality of Jawaharnagar village. Leachate and ground-water samples were investigated for various physico-chemical parameters viz., pH, total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), carbonates ($CO_3{}^{2-}$), bicarbonates ($HCO_3{}^{-}$), nitrates ($NO_3{}^{-}$), and sulphates ($SO_4{}^{2-}$) during dry and wet seasons in 2015 and were reported. The groundwater was hard to very hard in nature, and the concentrations of total dissolved solids, chlorides, and nitrates were found to be exceeding the permissible levels of WHO drinking water quality standards. Piper plots revealed that the dominant hydrochemical facies of the groundwater were of calcium chloride ($CaCl_2$) type and alkaline earths (Ca^{2+} and Mg^{2+}) exceed the alkali (Na^{+} and $SO_4{}^{2-}$), while the strong acids (Cl^{-} and $SO_4{}^{2-}$) exceed the weak acids ($CO_3{}^{2-}$ and $HCO_3{}^{-}$). According to USSL diagram, all the ground-water samples belong to high salinity and low-sodium type (C3S1). Overall, the ground-water samples collected around the dumpsite were found to be polluted and are unfit for human consumption but can be used for irrigation purpose with heavy drainage and irrigation patterns to control the salinity.

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Keywords Groundwater · Hydrochemical analysis · Piper · Irrigation · Jawaharnagar dumpsite · Rangareddy

Introduction

Groundwater which is in aquifers beneath the earth surface is considered the most important natural resource to mankind. It is the primary source for human consumption, agriculture, and industrial purposes. In the past few decades, due to population growth, rapid urbanization, and industrialization, ground-water quantity and quality has been deteriorated especially in the developing countries, such as India. As the groundwater is an important part of the hydrological cycle, it is more prone to various sources of contamination according to Soujanya (2016). In general, the quality of groundwater varies with the location, geology, type, and quantity of dissolved ions present in it. According to Fatta et al. (1999), landfills have been identified as one of the major threats of ground-water resources. Most importantly, the groundwater located near the landfills or dumpsites is highly polluted due to the leachate produced from it. The toxic leachate rich in organic and inorganic constituents negatively influence the parametric composition of the groundwater making it unsuitable for the human sustenance. Several scientific studies were conducted worldwide to study the impact of leachate on ground-water chemistry (Longe and Balogun 2010; Vasanthi et al. 2008; Sabahi et al. 2009; Jhamnani and Singh 2009). In India, as the groundwater is the main source for drinking and irrigation, regular monitoring of the wells is required to check for various anthropogenic sequences for wellbeing and sustainability. Therefore, in the present study, physico-chemical characteristics of groundwater (dry and wet seasons) located around the municipal open dumpsite of Jawaharnagar village were analyzed for drinking water suitability as per WHO (2011) and various irrigation water quality determining factors, such as sodium adsorption ratio (SAR), sodium percentage (Na%), permeability index (PI), soluble sodium percentage (SSP), and Kelley's ratio (KR) (Fig. 1).

Materials and methods

Study location

Hyderabad is the capital city of Telangana and Andhra Pradesh and is the sixth largest city in India. Currently, 5000 metric tons (MT) of municipal solid waste are generated in the city. This waste is collected by the waste collectors with the help of tricycle cart and dumped into the three major collection points in Hyderabad city which are located in Yousufguda, Imlibun, and Lower Tank bund. Waste from all the three collection points eventually gets collected and dumped into the Municipal Dumpsite of Jawaharnagar village without a proper segregation and recycling process. The percentage composition of the municipal solid waste generated in Hyderabad city according to Gowtham Raj et al. (2015) is shown in Fig. 2.

Municipal dump site is situated in Jawaharnagar Village, Shameerpet Mandal, Rangareddy District of Telangana. It is located just outside the limits of GHMC (Greater Hyderabad Municipal Corporation) and inside the HMDA (New limits of Hyderabad). The site is 35 km from Hyderabad city and 105 km away from the state highway connecting Hyderabad and Nagpur in west direction from

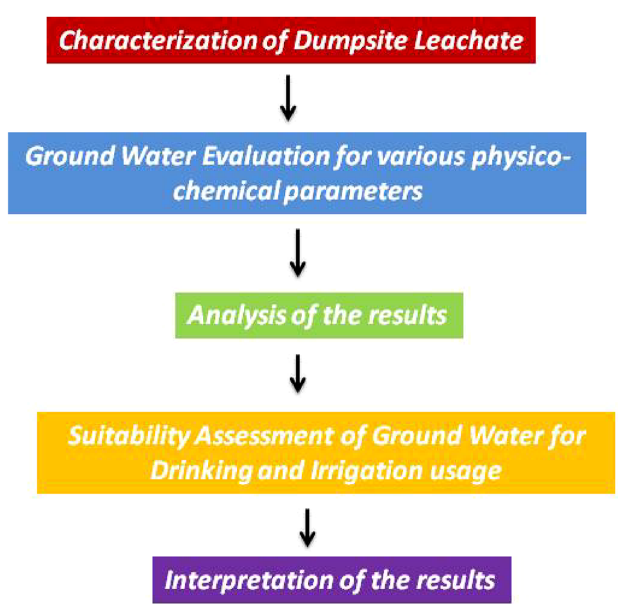

Fig. 1 Conception framework of the study

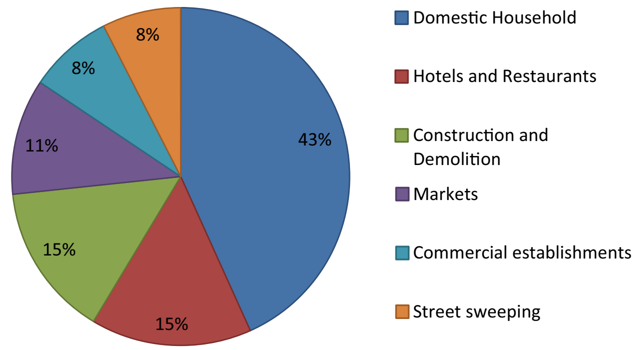

Fig. 2 Percentage composition of municipal solid waste in Hyderabad (after Gowtham Raj et al. 2015)

boundary of project site. It is an open dumpsite which was established in the year 2002. The total area of Jawaharnagar village dumpsite is 350 dekar (da) from which the area occupied by the waste at present is 182 da. It is located between 7030′01″N to 17032′03″N latitude and 78034′13″E to 78037′47″E longitude (Fig. 3). At Jawaharnagar village dumpsite, ground-water table is located at 120 cm below ground level. The annual mean temperature is 26 °C. Summers (March–June) are hot with maximum temperatures of 40 °C. Winter (December–January) has temperatures varying from 14.7 to 28.6 °C. Heavy rain from the south-west summer monsoon falls between June and September, supplying Rangareddy with most of its annual rainfall of 812.5 mm (32 in). Monthly rainfall distribution of the sampling year (2015) in Rangareddy district is presented in Fig. 4.

Sample collection

One leachate sample (from leachate pond) and 15 groundwater samples were collected during dry and wet period (2015) around the dumpsite as per availability. Sampling was done in 1 L pre-cleaned high-density polyethylene bottles (HDPE) with dilute HNO_3 and was stored in the laboratory at 4 °C for 2 days until analyzes. Geographic locations of the sampling points were collected with the help of TRIMBLE GPS. The leachate and ground-water samples were analyzed for 12 parameters viz., pH, total dissolves solids (TDS), total hardness (TH), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chlorides (Cl), carbonates (CO_3), bicarbonates (HCO_3), nitrates (NO_3), and sulphates (SO_4) using the standard procedures recommended by APHA standards (2005).

The pH was measured with digital pH meter (HANNA Inst. Italy) and conductivity with conductivity meter. Total dissolved solids (TDS) were calculated from Electrical Conductivity (EC) using an empirical equation. Total alkalinity, total hardness, calcium, magnesium, and chlorides were estimated by titrimetry using the standard

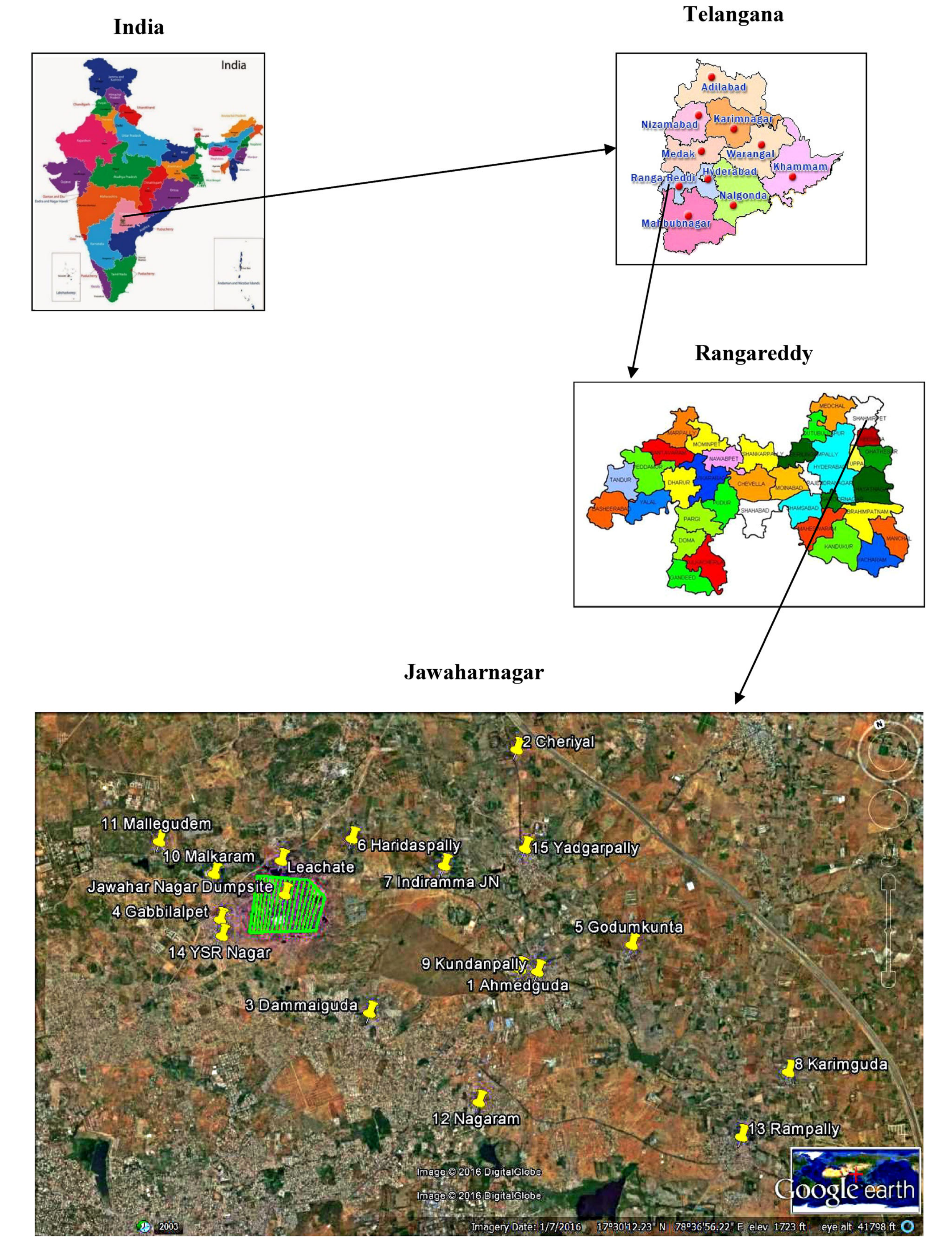

Fig. 3 Location map of study area

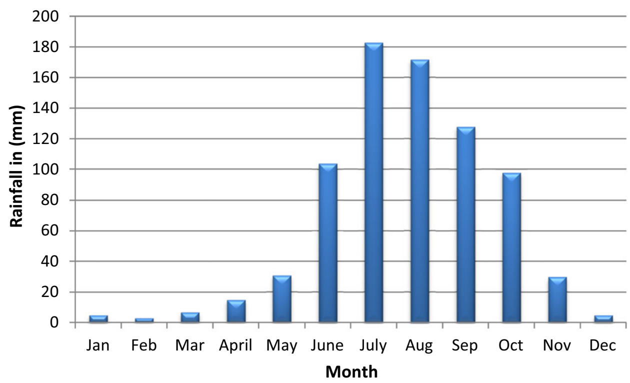

Fig. 4 Monthly rainfall distribution of Ranga reddy District Source: (Ground Water Department, Telangana State (2015)

EDTA. Carbonates and bicarbonates were determined by titration with H_2SO_4. Sodium and potassium were determined by flame photometry. Nitrate determination was carried out using Ion-Selective Electrode (Model-Orion4star). Sulphates were measured by Spectrophotometer (Model-Spectronic 21). The analytical data thus obtained could be used for different classifications for various suitability purposes and decision making.

Results and discussion

Leachate chemistry

The physico-chemical characteristics of collected leachate around the dumpsite during dry and wet seasons were analyzed and presented in Table 1. The color of the leachate was dark brownish which can be mainly attributed to the oxidation of ferrous to ferric form and the formation of ferric hydroxide colloids and complexes with fulvic/humic substance (Chu et al. 1994). Leachate pH is highly alkaline in nature. Alkaline pH is normally encountered at landfills, 10 years after disposal according to El-Fadel et al. (2002). Other analyzed parameters, such as TDS, TH, Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, CO_3^{2-}, HCO_3^-, NO_3^-, and SO_4^{2-}, were found to have higher concentrations in the leachate collected during dry season when compared to wet season leachate sample which could be due to the dilution process of the contaminating ions. However, the high values of EC 55,000 µS/cm and TDS 34,775 mg/l recorded during dry season is mainly contributed by the major ions in larger concentrations indicating the presence of inorganic material.

Table 1 Physico-chemical characteristics of leachate (dry and wet) seasons

Parameters	Dry	Wet
pH	9.6	8.2
EC	55,000	6450
TDS	34,775	3670
Ca^{2+}	12	4.8
Mg^{2+}	394	211
Na^+	484	244
K^+	8700	2100
CO_3^{-2}	231	195
HCO_3^-	1800	812
NO_3^-	460	280
SO_4^{-2}	350	122
Cl^-	45,319	12,266

All parameters are in mg/l, except pH and EC in µS/cm

Major ion chemistry of groundwater

Drinking suitability

Ground-water samples (No. 15) collected from the study area during dry and wet seasons were analyzed using APHA standards (2005) and compared with the drinking water quality standards (WHO 2011), and statistical information, such as minimum, maximum, mean, and standard deviation, was presented in Tables 2 and 3. The pH of groundwater ranged from 7.1 to 7.8 and 6.1 to 7.7 during dry and wet seasons, respectively. The pH results indicate that all the ground-water samples fall within the permissible limits and are in alkaline state according to WHO standards. The EC values of the groundwater ranged from 600 to 2200 and 825 to 2000 µS/cm during dry and wet seasons, respectively. The EC values of all the groundwater samples fall within the permissible levels of WHO standards except for few collected near the dumpsite indicating the impact of leachate on groundwater which may contain more soluble salts. The TDS values of groundwater ranged from 384 to 1408 and 528 to 1280 mg/l during dry and wet seasons indicating that almost all the samples exceeded the permissible levels of WHO standards. The calcium (Ca^{2+}) values of the groundwater ranged from 65 to 335 and 44 to 300 mg/l during dry and wet seasons. All the ground-water samples exceeded the permissible levels of WHO standards except for few magnesium (Mg^{2+}) values of the groundwater ranged from 27 to 115 and 5 to 92 mg/l. Most of the samples fall within the permissible limits of WHO standards except for few. The highest value of magnesium (115 mg/l) was recorded in GW15 collected during dry season. The TH values of the groundwater ranged from 200 to 1000 and 199 to 664 mg/l during dry and wet seasons. All the ground-water samples exceeded the permissible levels of WHO standards. According to Sawyer and McCarthy 1967 classification

Table 2 Physico-chemical parameters, descriptive statistics of analyzed ground-water samples compared with WHO (2011) (dry)

S. No	pH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{-2}	HCO_3^{-}	NO_3^{-}	SO_4^{-2}	Cl^{-}
GW1	7.1	2200	1408	590	335	62	129	4	5	190	70	190	859
GW2	7.1	1000	640	290	175	27	27	4	3	146	162	168	128
GW3	7.1	1500	960	465	250	52	98	3	6	854	196	124	355
GW4	7.2	800	512	275	110	40	56	3	6	112	165	106	138
GW5	7.3	1500	960	306	180	29	87	4	12	128	59	173	263
GW6	7.5	1335	854	410	85	48	116	5	7	160	54	160	1100
GW7	7.3	1200	768	250	135	28	95	3	9	152	13	250	340
GW8	7.4	997	876	344	75	38	147	6	6	102	143	112	351
GW9	7.3	1300	832	465	115	44	142	5	15	85	95	111	319
GW10	7.8	600	384	205	115	28	39	6	6	104	28	110	78
GW11	7.6	1033	661	311	65	36	95	4	4	117	156	120	206
GW12	7.2	1200	768	300	135	40	110	4	6	171	73	130	231
GW13	7.5	1774	991	397	80	48	155	6	7	95	185	160	355
GW14	7.3	1000	640	1000	195	73	38	2	0	116	174	187	128
GW15	7.5	700	448	300	115	115	49	3	12	98	49	111	202
Min	7.1	600	384	205	65	27	27	2	0	85	13	106	78
Max	7.8	2200	1408	1000	335	115	155	6	15	854	196	250	1100
Mean	7.34	1209.27	780.13	393.87	144.33	47.20	92.20	4.13	6.93	175.33	108.13	147.47	336.87
Standard deviation	0.20	418.80	255.46	194.98	73.19	22.84	42.20	1.25	3.79	190.24	62.55	41.34	280.56
WHO (2011)	6.5–8.5	1500.00	500.00	200.00	75.00	50.00	200.00	12.00	NA	NA	45.00	250.00	250.00

All parameters are in mg/l, except pH and EC in µS/cm

based on TH, all the ground-water samples in the study area collected during dry and wet seasons fall under hard to very hard category. The Na^{+} values ranged from 27 to 155 and 15 to 110 mg/l during dry and wet seasons. All the ground-water samples fall within the permissible limits of WHO standards. Potassium values of the groundwater ranged from 2 to 6 and 3 to 10 mg/l during dry and wet seasons. All the samples fall within permissible limits of WHO standards. The nitrate values of the ground-water samples ranged from 13 to 196 and 19 to 204 mg/l during dry and wet seasons. All the ground-water samples exceeded the permissible limits of WHO standards except for few. Major sources for nitrate in groundwater include domestic sewage, runoff from agricultural fields, and leachate from landfill sites. Higher concentration of nitrates (>50 mg/l) in water causes a disease called ''Methaemoglobinaemia'' also known as ''Blue-baby Syndrome''. This disease particularly affects infants that are up to 6-month-old Kapil et al. (2009). The sulphate values of groundwater ranged from 106 to 250 and 49 to 183 mg/l collected during dry and wet seasons. All the samples of the study area fall within the permissible limits of WHO standards. The chloride values of the ground-water samples ranged from 78 to 1100 and 50 to 998 mg/l collected during dry and wet seasons. Most of the ground-water samples exceeded the permissible limits of WHO standards except for few. The highest chloride value was recorded in GW6 in both the seasons, which is located at 1.2 km away from the dumpsite. High concentrations of chlorides are added to the groundwater from the municipal wastes, which clearly indicate the impact of landfill leachate. Other sources include farm drainage and sewage effluents. The abundance of major cations and anions of groundwater collected during dry and wet seasons is as follows: $Ca^{2+} > Na^{+} > Mg^{2+} > K^{+} > Cl^{-} > HCO_3^{-} > SO_4^{2-} > NO_3^{-} > CO_3^{2-}$ and $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+} > HCO_3^{-} > Cl^{-} > NO_3^{-} > SO_4^{2-} > CO_3^{2-}$, respectively.

Hydrochemical facies

The hydrochemical evolution of groundwater can be understood using the analytical data obtained from groundwater samples as a result of plotting the major cations and anions in the piper trilinear diagram (Piper 1944). The piper diagram consists of three distinct fields: cation ternary field (left), anion ternary field (right), and diamond field (centre). Leachate samples and ground-water samples of both seasons (dry and wet) were plotted on the piper diagram so as to understand their relationship, as it reveals the similarities and differences in the quality. Similar studies were carried out (Syafalni et al. 2014; Akudo et al. 2010; Akpoborie et al. 2015). According to the piper diagrams (Fig. 5a, b; Table 4), the leachate samples

Table 3 Physico-chemical parameters, descriptive statistics of analyzed ground-water samples compared with WHO (2011) (wet)

Sl. No	pH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{-2}	HCO_3^{-}	NO_3^{-}	SO_4^{-2}	Cl^{-}
GW1	6.8	1078	690	664	200	40	110	3	5	205	64	155	827
GW2	7.4	825	528	335	76	35	35	3	636	659	180	114	294
GW3	6.8	2000	1280	365	100	28	25	5	546	384	168	135	344
GW4	7.1	1300	832	250	90	6	18	10	0	1208	204	51	266
GW5	7.7	1450	928	400	56	63	28	4	0	1311	40	56	355
GW6	7.5	1058	677	434	89	53	43	5	7	172	25	146	998
GW7	6.7	909	582	408	100	20	54	5	6	70	35	86	295
GW8	7.3	965	618	388	78	47	68	4	8	250	100	131	340
GW9	7.4	1050	672	323	70	36	27	8	180	659	111	65	355
GW10	7.5	950	608	225	140	21	15	9	6	920	19	49	121
GW11	7.1	826	529	348	70	42	29	3	7	125	128	138	196
GW12	7.3	1500	960	285	44	46	25	4	0	1495	77	117	223
GW13	7.3	1095	701	517	105	62	75	5	5	245	167	183	333
GW14	7.2	900	576	199	60	12	16	4	66	61	142	50	202
GW15	7	1050	672	285	92	92	23	8	0	1385	150	115	50
Min	6.7	825	528	199	44	6	15	3	0	61	19	49	50
Max	7.7	2000	1280	664	200	92	110	10	636	1495	204	183	998
Mean	7.21	1130.4	723.53	361.73	91.33	40.2	39.4	5.33	98.13	609.93	107.33	106.07	346.6
Standard deviation	0.29	315.53	201.89	38.09	38.09	22.14	26.71	2.29	206.19	523.16	61.25	43.65	248.59
WHO (2011)	6.5–8.5	1500.00	500.00	200.00	75.00	50.00	200.00	12.00	NA	NA	45.00	250.00	250.00

All parameters are expressed in mg/l, except pH and EC in µS/cm

collected during dry and wet seasons fall in Na^+/K^+ and Cl^- class type which can be observed from anion and cation ternary fields. The majority of the ground-water samples fall in Cl^- class type along with leachate both in dry and wet seasons which can be observed from the anion ternary field and are a clear indication of leachate pollution. According to Panno et al. (2006); Uma (2004); Hanchar (1991); Baedecker and Back (1979), dumpsite, landfill leachate, and sewage are indeed known sources of chloride, bicarbonate, calcium, and magnesium loading to native groundwater. From the plot, alkaline earth (Ca^{2+} and Mg^{2+}) exceed alkalies (Na^+ and K^+), while the strong acids (Cl^- and ${SO_4}^{2-}$) exceed the weak acids (${CO_3}^{2-}$ and ${HCO_3}^-$). Therefore, the dominant ground-water type of the study area can be observed as $CaCl_2$ type.

Irrigation suitability

The suitability assessment of groundwater for irrigation purpose is essential to provide good quality water for a proper growth of crop plants. The classification systems used to evaluate the suitability of groundwater for irrigation purpose can be determined through the indices, such as percentage sodium (Na%), sodium adsorption ratio (SAR), Kelley's ratio (KR), and permeability index (PI), sodium soluble percentage (SSP) and USSL classification.

Salinity

Electrical conductivity (EC) is a measure of the dissolved ionic salts present in the groundwater. EC is a good measure of salinity hazard to crops, as it reflects the TDS in groundwater (Subramani et al. 2005). During dry season, 80 % of the ground-water samples fall under "permissible" category, 13 % fall under "good" category, and 7 % fall in "doubtful" category for irrigation purpose. During wet season, 100 % of ground-water samples fall in "permissible" category for irrigation purpose (Table 5). Excessive high salinity can affect the plants causing specific toxicity of sodium and higher osmotic pressure around the roots, thus preventing an efficient water absorption by the plants.

According to Wilcox (1955), in all natural waters, Na% is a common parameter to assess its suitability for irrigational purposes. The sodium in irrigation water in usually denoted as % Na and can be determined using the formula:

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

From Table 6, it can be observed that the ground-water samples of the study area collected during dry and wet seasons fall under ''excellent" to "permissible'' limits for irrigation.

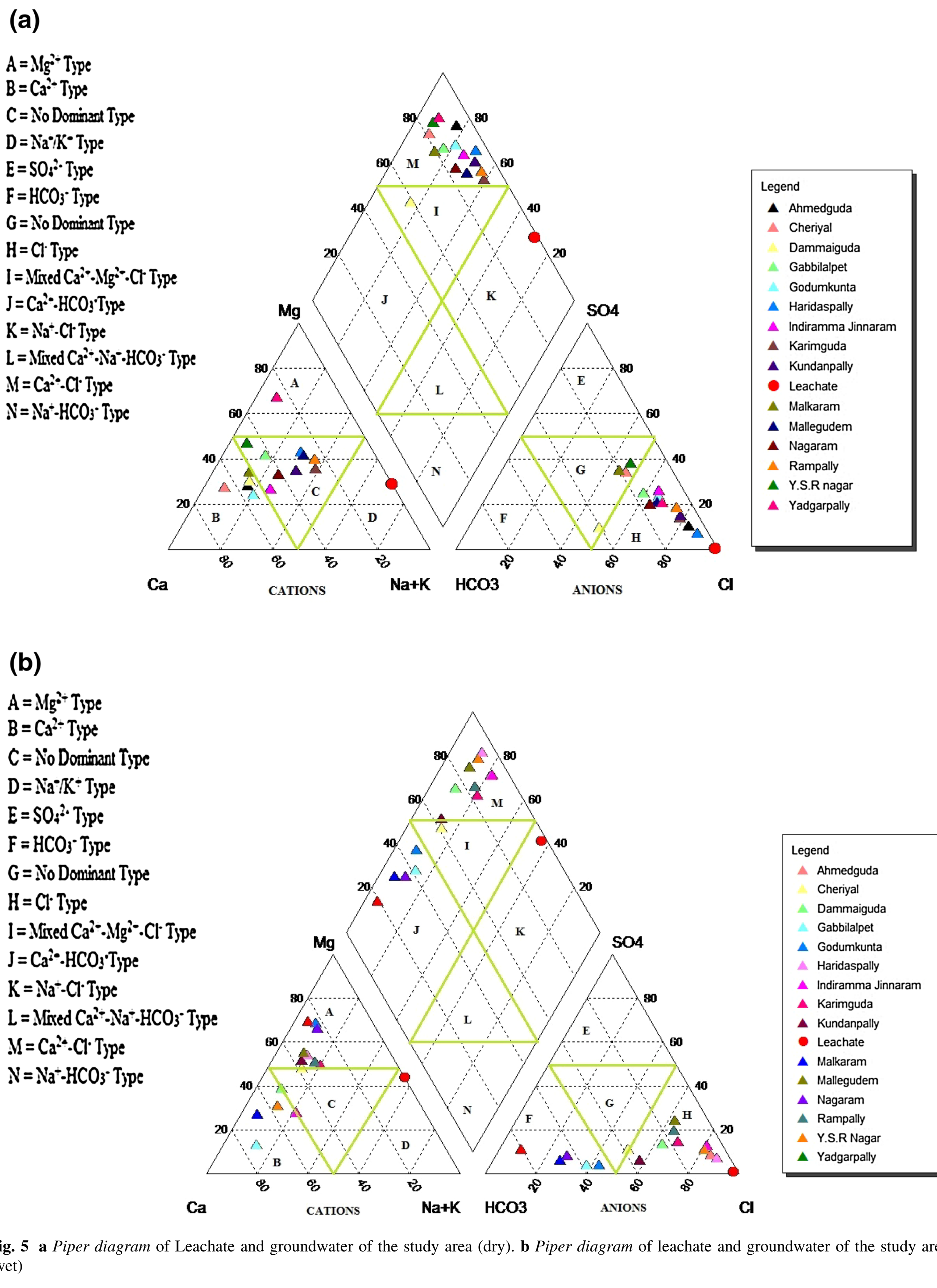

Fig. 5 **a** *Piper diagram* of Leachate and groundwater of the study area (dry). **b** *Piper diagram* of leachate and groundwater of the study area (wet)

Table 4 Ground-water type based on piper diagram for Jawaharnagar dumpsite

	Dry	Wet	Class type
Cation ternary field			
Groundwater	1	9	(A) Magnesium (Mg^{2+}) type
	5	5	(B) Calcium (Ca^{2+}) type
	9	–	(C) No dominant type
Leachate	Leachate (dry)	Leachate (wet)	(D) Na^+/K^+ type
Anion ternary field			
Groundwater	4	1	(E) No dominant type
	0	5	(F) Bicarbonate (HCO_3^-) type
	11	10	(G) Chloride (Cl^-) type
Leachate	Leachate (dry)	Leachate (wet)	(H) Chloride (Cl^-) type
Central diamond field			
Groundwater	1	1	(I) Mixed Ca^{2+}–Mg^{2+}–Cl^- type
	0	5	(J) Ca^{2+}–HCO_3^- type
	14	8	(K) Ca^{2+}–Cl^- type
Leachate	Leachate (dry)	Leachate (wet)	(L) Na^+Cl^- Type

Table 5 Irrigation water quality based on EC values

Water class	EC values	% compliance	
		Dry	Wet
Excellent	<250	–	–
Good	250–750	13 %	–
Permissible	750–2000	80 %	100 %
Doubtful	2000–3000	7 %	–
Unsuitable	>3000	–	–

Table 6 Irrigation water quality based on % Na

Water class	% Na	% compliance	
		Dry	Wet
Excellent	<20	26 %	73 %
Good	20–40	67 %	20 %
Permissible	40–60	7 %	7 %
Doubtful	60–80	–	–
Unsuitable	>80	–	–

Sodium adsorption ratio (SAR)

The SAR is the most useful parameter for determining the suitability of groundwater for irrigation purposes, because it measures the alkali/sodium hazard to crops (Subrahmanyam and Yadaiah 2000). It can be determined using the following formula introduced by Karanth (1987) (Table 7):

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

where sodium, calcium, and magnesium are in meq/L.The results of the SAR values indicated that all the ground-water

Table 7 Irrigation water quality based on SAR (after Karanth 1987)

Water class	SAR values	% compliance	
		Dry	Wet
Excellent	<10	100 %	100 %
Good	10–18	–	–
Doubtful	18–26	–	–
Unsuitable	>26	–	–

samples of the study area collected during dry and wet seasons fall in "excellent" category for irrigation. US Salinity diagram was also used to determine irrigation water suitability by plotting SAR against EC. The USSL (1954) plot indicated that 86 % of the ground-water samples collected during dry season fall in C3S1 field, which indicates high salinity and low-sodium type and 14 % of the samples fall in C2S1 field which indicates medium salinity and low-sodium type, whereas 100 % of the samples collected during wet season fall in C3S1 category indicating high salinity and low-sodium type (Fig. 6a, b). High salinity water can be used only on the soils with adequate drainage and salt tolerant plants must be selected. Low-sodium-type water can be used for irrigation purpose on almost all the types of soils with little danger of exchangeable sodium (Hem 1989).

Sodium Soluble Percentage (SSP)

It is also to evaluate the sodium hazard. The SSP is calculated as follows (Todd 1995):

$$\mathrm{SSP} = \frac{(\mathrm{Na}^+ + \mathrm{K}^+) \times 100}{(\mathrm{Na}^+ + \mathrm{K}^+ + \mathrm{Ca}^{2+} + \mathrm{Mg}^{2+})}.$$

All ions are expressed in meq/L. Based on the calculated values (Table 8), all the ground-water samples of the study

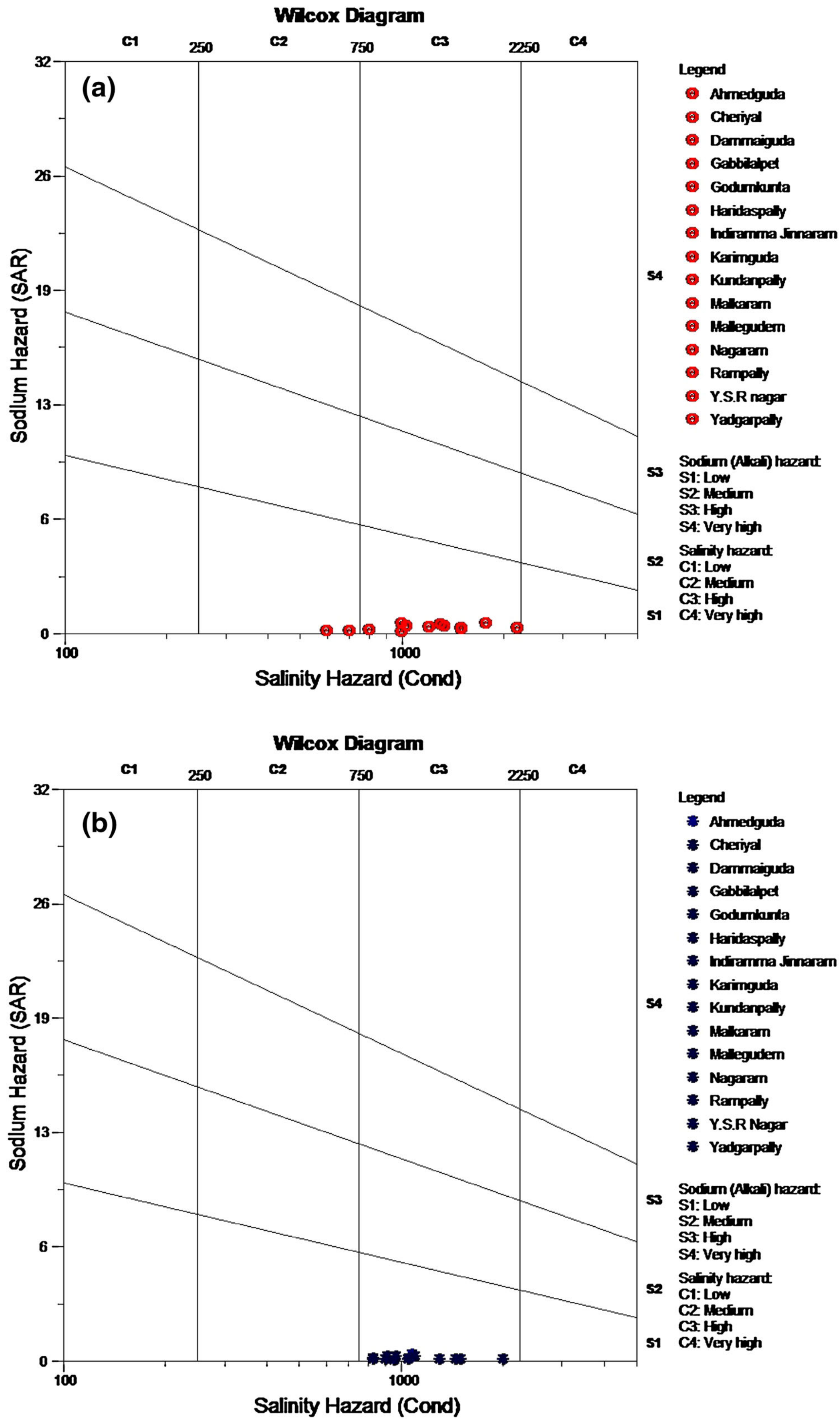

Fig. 6 **a** USSL classification of groundwater of the study area (dry). **b** USSL classification of groundwater of the study area (wet)

Table 8 Irrigation water quality based on SSP (after Todd 1995)

Water class	SSP values	% compliance	
		Dry	Wet
Excellent	<60	100 %	100 %
Good to permissible	60–75	–	–
Doubtful to unsuitable	>75	–	–

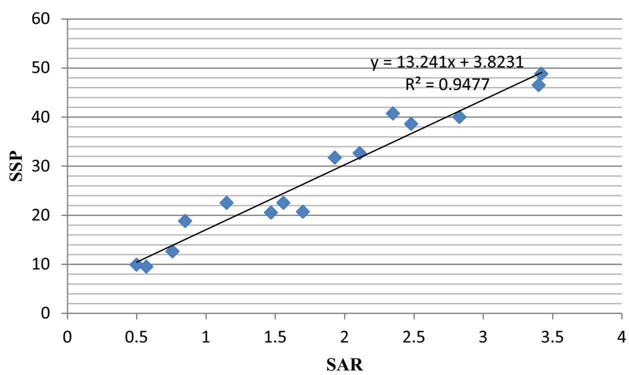

Fig. 7 SAR vs SSP for irrigation water

Table 9 Irrigation water quality based on KR (after Kelly 1963)

Water class	KR values	% compliance	
		Dry	Wet
Good	<1 or 1	100 %	100 %
Unsuitable	>1	–	–

area fall in "excellent" class suitable for irrigation. Positive correlation between SAR and SSP ($R^2 = 0.9477$) is shown in Fig. 7.

Kelley's Ratio (KR)

The KR values are calculated by the formula given by Kelly (1963):

$$KR = \frac{(Na^{+})}{(Ca^{2+} + Mg^{2+})}.$$

KR values of 1 or <1 indicate suitability, while KR values of >1 indicate unsuitability for irrigation purpose. Based on this classification, all the ground-water samples collected during dry and wet seasons fall in "good" category for irrigation purpose, i.e., below (<1 or 1) (Table 9).

Permeability Index (PI)

The PI values also indicate the suitability of groundwater for irrigation. This index is used to evaluate the effects of water quality on the physical properties of the soil. It is calculated by the following equation which was developed by Doneen (1964):

$$PI = \frac{(Na^{+} + \sqrt{HCO_3^{-}}) \times 100}{(Ca^{2+} + Mg^{2+} + Na^{+})},$$

where all ions are expressed in meq/L. During dry season, the majority of the samples (80 %) fall in "good to permissible" category and 20 % of the samples fall in "doubtful to unsuitable" category. During wet season, most of the samples (87 %) fall in "good to permissible" and 13 % of the samples fall in "excellent" category for irrigation purpose (Table 10).

Table 10 Irrigation water quality based on PI (after Doneens 1964)

Water class	PI values	% compliance	
		Dry	Wet
Excellent	>75	–	13 %
Good to permissible	75–25	80 %	87 %
Doubtful to unsuitable	<25	20 %	–

Conclusion

The leachate characteristics studied reveal that almost all the parameters carried out were found to have higher concentrations during dry season with slight dilutions in wet season. The interpretations of the hydrochemical analyses of the groundwater collected in both the seasons reveal the unsuitability for drinking purpose considering drinking water quality standards. Hydrochemical facies studies reveal that most of the ground-water samples fall in the Cl type along with the leachate which can be witnessed from piper diagram plotted for both the seasons. It can be observed that the groundwater having higher concentrations of Ca^{+2}, Cl^{-}, and NO_3^{-} can be used as an indication of leachate percolation into the groundwater which can have deleterious effects to humans if consumed. According to the irrigation water quality classification limits, most of the ground-water samples of the study area are suitable for various irrigation needs. However, salt tolerant plants/crops are appropriate, as the water is highly saline in nature which can be witnessed from the USSL diagram. Finally, it can be concluded that leachate emanating from the dumpsite is causing an environmental risk which has to curb immediately, as it is highly dangerous in every aspect of the life.

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