Original Research

Suitability of Water Sources for Domestic and Irrigation Purpose around Corporate Dumpsite

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Abstract

Water is an important resource for domestic, agriculture, and industrial purpose. The urban population requires a wide range of urban services including water supply, sewerage, and solid waste management. In most cities, the solid waste is dumped in open dumps without proper lining which affects the environmental media such as water and land. So the present study was focused on the impact of leachate on water quality. Water samples were collected from the Ramayanpatti dump site and the surrounding area. The water samples were tested for various physiochemical parameters and also predict the various effective irrigation indices such as Sodium Absorption Ratio, Residual Sodium Carbonate, Soluble Sodium Percent, Magnesium Absorption Ratio and Chloro-Alkaline Indices. Based on the Water Quality Index and irrigation indices most of the samples were not suitable for domestic as well as irrigation purposes. This indicates that the water is contaminated by leachate.

Introduction

Water is the most essential substance for the survival of life on earth. The fresh water resource available for usage is decreasing now a day due to various human activities. Groundwater is one of the most relied freshwater resources for domestic, agricultural and industrial purposes as it is available throughout the year and is polluted lesser than surface water [1, 2]. About 50% of the demand in municipal, domestic, and agricultural water supply is met using groundwater. In recent years much groundwater pollution have been noted because of increased usage due to rapid urbanization, industrialisation and population growth [3]. The engineered landfill disposal of solid waste protects the groundwater sources. However, the developing countries like India more than 90% of solid waste disposed in open dump in an unsatisfactory manner [4]. Open dump is one of the major polluting sources of ground water [5]. Municipal Solid Waste (MSW) contains combination of various organic and inorganic substances. Food waste, paper waste, coconut shells, husks and yard waste constitute a major portion of organic waste, and the inorganic wastes consists

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Fig. 1. An overview of Ramayanpatti dumpsite in Tirunelveli.

of mainly thin plastic food wraps, drinking water bottles, soft drink bottles, milk packaging cover, grocery bags and disposable cups [6]. Due to the waste disposal in open dump and infiltration from precipitation over waste generate landfill leachate which contaminates the water sources [7]. The pollutant from the waste materials of the landfill gets transferred to the percolating water there by forming strong leachate. This transfer of pollutants happens through various physical, chemical and biological processes [8]. The leachate contains lot of harmful compounds which pollute water sources and affect best usage of water. Hence it is essential to analyze the quality of water around dumpsite before usage.

Materials and Methods

Study Area

Tirunelveli municipality was upgraded into a corporation in the year 1994. It has got a population of about 474838 covering an area of 108.65 km². It ranges between latitude 8°45'20" and longitude 77°40'29". The solid waste generated from Tirunelveli city was dumped in the Ramayanpatti municipal dumpsite (Fig. 1). The dumping site spread across 118 acres of land having an elevation of 54 m. Tirunelveli Corporation disposes nearly of 10 tons of garbage every day in which the per capita waste is around 379 g. The average rainfall is 879 mm.

Geological formation of the study area consists of horn blended biotite gneissic overlying by weathered rock followed by thin soil. The general rock formation is striking in east-west direction and dipping towards south with an angle of 75°S. It is found that limestone flanked by Kankar followed by quartzite on the northern side and in the southern side magnesium, limestone, calcareous quartzite and calcgneiss were found. The study area falls under pediment geomorphic unit with the absence of lineaments. In general the Pediments are hard rock terrains forming outcrops with or without soil cover.

Due to improper maintenance of the dumping site; the surrounding boreholes have been contaminated. The Ramayanpatti dumpsite was chosen as the study area to assess the degradation of groundwater quality in and around it. The study area includes residential zone, agricultural farm lands and fresh-water ponds.
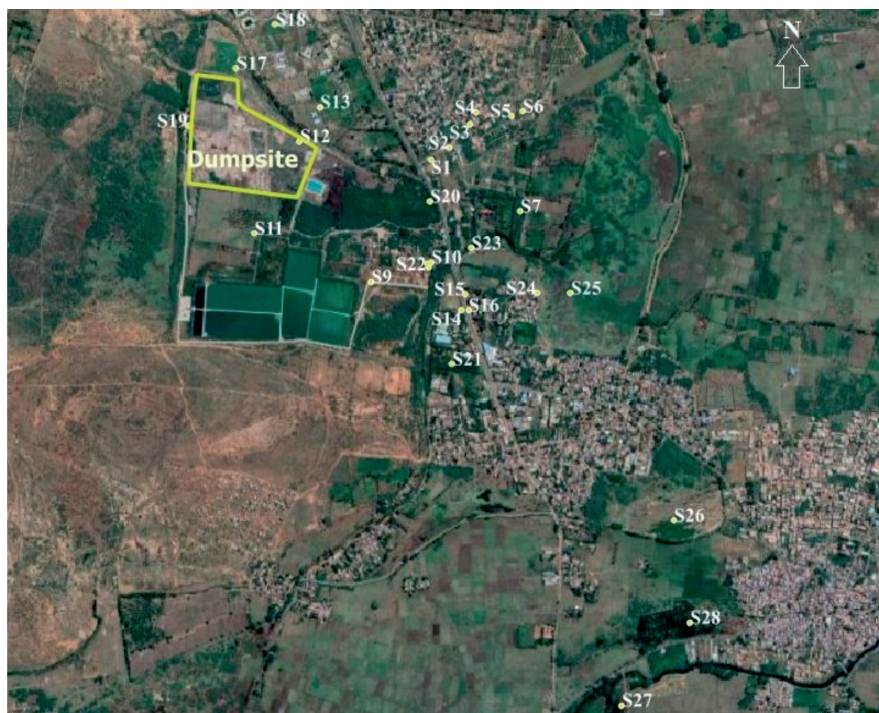

Fig. 2. Location of sampling sites in the study area.

Field Sampling

Water samples were identified and collected from twenty two groundwater sampling sites and six surface water sampling sites (Fig. 2). The groundwater sampling sites includes bore wells, hand pumps and open wells. For quality analysis, water samples were collected in 5 litre plastic containers and prior to collection, as a part of quality control measures, all the containers were washed with non-ionic detergent and rinsed with de-ionised water. Before the final water sampling, the containers were labelled and transported to the laboratory.

Analytical Techniques and Laboratory Analysis

The adopted methods of analyses for the examination of parameters such as pH, alkalinity, hardness, TDS, chloride, sulphate, calcium, magnesium, sodium and potassium were in accordance with IS 3025 standard recommendation. The impact on several parameter of water quality is characterised by single rating scale of WQI. It is a significant indicator for the assessment of groundwater. Weighted arithmetic method was used to arrive the Water Quality Index (WQI). Parameters such as pH, alkalinity, hardness, chloride, sulphate and TDS were considered to find out WQI Value. WQI value represents the drinking water quality of the sample (Table 1).

Methods used for analysis of quality parameters for water samples:

PARAMETERS   -   METHOD
pH   -   pH Meter
TDS   -   TDS meter (TDS3TM)
Alkalinity   -   Titration Method
Chloride   -   Titration Method
Total hardness   -   Titration Method
Sulphate   -   Turbid metric method
Sodium   -   Flame photometer
Potassium   -   Flame photometer
Calcium   -   Titration Method

Irrigation Purpose

Water quality is affected by the dissolution of minerals from the soil, leachate from open dumpsites

Table 1. Permissible Limits as Per IS and WHO Standards.

Parameters	IS 10500:2012	WHO	Weight
pH	6.5-8.5	6.5-8.5	4
TDS	500	1,000	4
TH	300	100	3
Cl	250	250	3
Sulphate	200	250	4
Alkalinity	0.3	0.1	2

etc. Hence it becomes essential to assess its quality before using it for irrigation. The yield of the crop and the texture of soil are mainly influenced by the presence of excess chemical components and salt content in water [9]. The parameters such as sodium adsorption ratio (SAR), residual sodium carbonate (RSC), soluble sodium percentage (%Na), Kelly's ratio (KR), and magnesium adsorption ratio (MAR) were determined to find out the irrigation water quality.

Sodium Adsorption Ratio: $\text{SAR} = \dfrac{Na^+}{\sqrt{(Ca^{2+}+Mg^{2+})/2}}$ (1)

Residual Sodium Carbonate:
$$\text{RSC} = \left(HCO_3^- + CO_3^{2-}\right) - \left(Ca^{2+} + Mg^{2+}\right) \quad (2)$$

Permeability Index: $\text{PI} = \dfrac{Na^+ + \sqrt{HCO_3^-}}{Na^+ + Mg^{2+} + Ca^{2+}}$ (3)

Kelly Ratio: $\text{KR} = \dfrac{Na^+}{\left(Ca^{2+} + Mg^{2+}\right)}$ (4)

Soluble Sodium Percentage:
$$\text{SSP} = \dfrac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100 \quad (5)$$

Magnesium Adsorption Ratio:
$$\text{MAR} = \dfrac{Mg^{2+}}{\left(Ca^{2+} + Mg^{2+}\right)} \times 100 \quad (6)$$

Results and Discussion

Domestic Water Suitability

pH

pH is the measure of hydrogen ion concentration in water. It helps in finding the nature of water whether acidic or alkaline. In drinking water quality, pH is not of a health concern because, most of the groundwater sample has value varied from 6.4 to 8.2. However, high pH values (10-12.5) may cause gastrointestinal irritation, similarly very low pH can cause irritation to the skin, eyes and mucous membrane [10] The highest pH value of 8.2 was found at the sampling site S21 while the lowest pH value of 6.4 was found at the sampling sites S4 and S20. Except for the sampling site S4 and S20, all other sampling sites had their pH values within permissible limits of 6.5-8.5 as per IS-10500:2012 and WHO standards and are suitable for drinking [11, 12].

Alkalinity

Alkalinity is the measure of the ability of substances in water to neutralize acids [13]. Majorly the calcareous

and limestone formation impart the higher alkalinity [14]. The alkalinity value was found to be maximum at the site S23 with a value of 625 mg/L as $CaCO_3$ and the minimum value of alkalinity was found to be 215 mg/L as $CaCO_3$ at the sampling site S5. Almost all the samples shad their alkalinity values within maximum permissible limit of 600 mg/L.

Total Hardness

Total Hardness may be defined as the total concentration of magnesium and calcium in mg/L equivalent of $CaCO_3$. Hardness in water prevents it

from forming lather when added with soap. Though hardness doesn't have adverse effects below permissible value but when hardness rises above 300 mg/L, it may cause kidney related ailments [15] The highest value of total hardness was found to be 2160 mg/L as $CaCO_3$ at the sampling site S3 while the lowest value of total hardness was found as 600 mg/L as $CaCO_3$ in S25 and S27 site.

Chloride

All natural waters contain chloride but comparatively of smaller amount, however, it also can be derived from

Table 2. Physicochemical characteristics of water from sampling sites.

Sampling site	pH	Total Alkalinity in mg/L as $CaCO_3$	Total Hardness as mg/L as $CaCO_3$	Cl^- in mg/L	Ca^{2+} in mg/L	Mg^{2+} in mg/L	SO_4^{2-} in mg/L	Na^+ in mg/L	K^+ in mg/L	TDS in mg/L
S1	7.3	475.0	1880.0	2149.0	416.0	201.6	417.0	420.0	9.5	2440.0
S2	7.4	415.0	1600.0	1949.0	320.0	192.0	388.0	487.0	9.2	2500.0
S3	6.6	255.0	2160.0	2698.0	512.0	211.2	528.0	537.0	12.8	3070.0
S4	6.4	300.0	1240.0	1499.0	288.0	124.8	198.0	316.0	8.7	1650.0
S5	7.9	215.0	1200.0	1299.0	224.0	153.6	123.0	278.0	12.6	1670.0
S6	6.9	500.0	960.0	699.0	176.0	124.8	214.0	298.0	6.5	1190.0
S7	7.2	475.0	1120.0	949.0	332.0	69.6	260.0	250.0	6.2	1300.0
S8	7.6	465.0	1400.0	1099.0	224.0	201.6	186.0	286.0	8.9	1510.0
S9	6.8	535.0	1120.0	1099.0	304.0	86.4	226.0	304.0	2.9	1540.0
S10	7.1	375.0	1280.0	1199.0	240.0	163.2	32.0	427.0	11.3	1740.0
S11	6.8	435.0	720.0	699.0	80.0	124.8	40.0	214.0	5.9	852.0
S12	6.6	325.0	1680.0	1999.0	480.0	115.2	295.0	407.0	11.7	2550.0
S13	7.5	335.0	680.0	3048.0	128.0	86.4	608.0	549.0	13.5	3280.0
S14	6.6	565.0	760.0	599.0	112.0	115.2	60.0	213.0	8.8	910.0
S15	8.0	540.0	680.0	649.0	96.0	105.6	82.0	260.0	16.1	982.0
S16	7.4	560.0	720.0	699.0	176.0	67.2	98.0	301.0	9.6	1070.0
S17	7.5	485.0	690.0	449.0	128.0	88.8	82.0	38.0	77.8	623.0
S18	7.5	495.0	705.0	349.0	128.0	92.4	90.0	38.0	77.5	644.0
S19	6.7	310.0	800.0	299.0	192.0	76.8	96.0	55.0	12.2	485.0
S20	6.4	490.0	1000.0	849.0	256.0	86.4	251.0	263.0	13.8	1150.0
S21	8.2	400.0	900.0	280.0	212.0	88.8	138.0	133.0	33.2	583.0
S22	7.4	560.0	1320.0	1380.0	224.0	182.4	127.0	294.0	17.0	1720.0
S23	6.8	625.0	820.0	500.0	192.0	81.6	150.0	134.0	33.2	603.0
S24	6.5	500.0	1000.0	350.0	268.0	79.2	104.0	27.0	5.6	615.0
S25	7.3	500.0	600.0	350.0	128.0	67.2	50.0	15.0	4.8	595
S26	7.1	300.0	900.0	300.0	204.0	93.6	82.0	11.0	1.9	510
S27	6.8	400.0	600.0	250.0	136.0	62.4	78.0	25.0	8.2	565
S28	7.8	520.0	860.0	400.0	192.0	91.2	90.0	51.0	6.1	580.0

human activities [16]. The highest value of chloride was found as 3048 mg/L at the sampling site S13 while the lowest value was found as 250 mg/L at the sampling site S25 which is a surface water source, located in the west direction of dumping site. The higher concentration of chloride shows the contamination of water by leachate from landfill [17].

Calcium

Calcium is one of the most common elements found in water and it contributes to hardness [18]. The maximum permissible limit for calcium for drinking purposes according to Indian Standards is 200 mg/L.

The highest and lowest values of calcium were found as 512 mg/L and 80 mg/L at the sampling sites S3 and S11 respectively. Nearly 54% of the samples exceeded permissible limits and are unsuitable for drinking.

Magnesium

Magnesium is an important drinking water quality parameter as it imparts hardness to water. Excess Magnesium concentration affects the quality of soil resulting in poor crop yield [19]. The maximum and minimum values of magnesium were found as 211.2 mg/L and 62.4 mg/L at the sampling sites S3 and S25 respectively. These high values of magnesium present

Table 3. Water Quality Index of sampling sites.

S. No	LOCATION	Latitude	Longitude	Elevation	WQI	Water Quality
S1	4/627, Balaji Nagar	8.76288	77.68608	47.5	381.65	Water unsuitable for drinking
S2	4/591, Balaji Nagar	8.76332	77.6868	48	354.06	Water unsuitable for drinking
S3	4/573, Sivaji Nagar	8.76422	77.6876	48	463.67	Water unsuitable for drinking
S4	Plot no:114, Sivaji Nagar	8.76467	77.6878	49	272.78	Very poor water
S5	Sivaji Nagar	8.76454	77.68916	49.5	237.33	Very poor water
S6	Sivaji Nagar	8.76472	77.68959	49.5	183.66	Very water
S7	UGS Nagar	8.7609	77.6895	51.5	212.16	Very poor water
S8	Annai Velankani Nagar	8.75874	77.68598	51	242.47	Very poor water
S9	Vinayagar Temple, Annai Velankani Nagar	8.7582	77.6838	51.5	236.37	Very poor water
S10	Annai Velankani Nagar	8.75895	77.68609	51.5	228.18	Very poor water
S11	Sakthi Thoppu	8.76005	77.67933	54	144.97	Poor water
S12	Dump site	8.763575	77.68107	54	361.79	Water unsuitable for drinking
S13	Veterinary college field	8.764877	77.68184	52.5	420.14	Water unsuitable for drinking
S14	10/375, Ramayanpatti	8.757099	77.68728	48	159.39	Poor water
S15	5B, Ramayanpatti	8.757731	77.68739	49	159.11	Poor water
S16	5/65, Ramayanpatti	8.757118	77.68752	49	161.91	Poor water
S17	Corporation park	8.766357	77.67865	54.5	123.84	Poor water
S18	Veterinary college	8.768016	77.68013	53	120.57	Poor water
S19	Sasthakovil	8.764163	77.6768	55	112.52	Poor water
S20	Annai Velankani Nagar Field	8.761278	77.68604	51.5	215.52	Very poor water
S21	Ramayanpatti farm land	8.755056	77.68689	49.5	132.16	Poor water
S22	10/200, Annai Velankani Nagar	8.758907	77.68594	50.5	261.09	Very poor water
S23	Kodagan Canal	8.759486	77.68762	51	146.37	Poor water
S24	Thenirkulam	8.75777	77.69013	50	148.92	Poor water
S25	Megamudaiyarkulam	8.757769	77.69143	54	106.33	Poor water
S26	Illanthaikulam	8.74909	77.69537	51	105.70	Poor water
S27	Nainarkulam	8.742028	77.69338	46	100.58	Poor water
S28	Seeniyappankulam	8.745188	77.69599	49	134.07	Poor water

in the groundwater samples are due to the infiltration of toxic material from the open dumpsite [20].

Sulphate

It is a major mineral present in water. According to Indian standards, the acceptable limit for sulphate in drinking water is 200 mg/L and the maximum permissible limit is 400 mg/L. Excess sulphate in water causes laxative effect and irritation of gastro- intestinal tract [21]. In our study area, the highest value of Sulphate was found as 608 mg/L at the sampling site S13 while the minimum value of Sulphate was found to be 32 mg/L at the sampling site S10.

Sodium

Generally sodium is present in water due to the dissolution of the weathered rock materials However higher concentrations are attributed due to the pollution from industrial wastes which is disposed in dumpsites [22]. The concentration of sodium was found to be highest, that is 549 mg/L at the sampling site S13 while the lowest concentration of 11 mg/L was observed in the sampling site S26.

Potassium

The maximum potassium concentration was found as 77.8 mg/L at the sampling site S17 while the minimum concentration was found to be 1.9 mg/L at the sampling site S26. The higher potassium ion concentration in the water samples may be from the leachate of the nearby dumpsite [23].

TDS

The highest concentration of TDS was found to be 3280 mg/L at the sampling site S13 while the minimum TDS concentration was found as 485 mg/L at the sampling site S19. (Table 2). Of the 28 sampling stations, 13 sampling sites have their TDS values above 1000mg/L. This shows that water in such sampling sites are brackish and are unsuitable for drinking [24].

WQI

The WQI has been used to identify the quality of water for drinking purposes [25] Maximum WQI value was found as 463.67 in sampling site S3 and minimum WQI value was 100.58 in sampling site S27. The WQI values indicate that water samples around dumpsites were not suitable for drinking purposes. Mostly the groundwater quality is alone influenced by the leachate from dumpsite while the surface water sources were least affected (Table 3 and Table 4).

The ground water level variation around the study area was almost similar to reduced level variation

Table 4. Water quality classification based on WQI value.

WQI value	Water quality	No of Samples	Percentage
<50	Excellent	0	0
50-100	Good water	0	0
100-200	Poor water	15	53.57
200-300	Very poor water	8	28.57
>300	Water unsuitable for drinking	5	17.86

of the ground surface. The top soil was found up to a depth of 1m below ground level, weathered/partly weathered rock layer was present next to the top soil. The groundwater table was identified within this weathered/partly weathered rock layer. In most of the sampling sites the water table was found to be present at a depth of about 5.5 m to 7.5 m. The reduced level of dumpsite was found as 54m, while the most polluted sampling site S1, S2 and S3 with the WQI value of 381.65, 354.06 and 463.67 respectively and were at an elevation of around 48m. This shows that the groundwater flows in Eastern direction from dumpsite towards Sivaji nagar around which the sampling sites S1, S2 and S3 were situated (Fig. 3). The groundwater flow happens through the cracks in the rock layer along the slope of the ground surface. The sampling stations S1, S2, S3, S4, S5, S12 and S13 were highly polluted because of their location along ground water flow direction. Moreover the sampling stations S1, S2, S3, S4 and S5 were located in the bell mouth region of watershed. The least polluted groundwater sampling site was S19 with the WQI value of 112.52 which has an elevation of 55m and was located in the upstream side of groundwater flow from dumpsite. The sampling sites S23, S24, S25, S26, S27 and S28 were surface water bodies which were situated far away from the dumpsite and hence they are less polluted.

Irrigation Suitability

The irrigation suitability in the water sampling sites was based on the presence of soluble salts and mineral constituents in the water samples. Higher concentration of salts and the insufficient or excess concentration of minerals can affect the growth of plants and soil [26]. In this study, irrigation suitability was evaluated based on the indices such as SAR, RSC, PI, SSP, MAR and KR. Table 5 shows the irrigation water quality indices for the classification of water samples.

SAR

Sodium Adsorption Ratio (SAR) is a useful index for predicting the tendency of a salt solution which can produce excessive exchangeable sodium in the soil [27]. Groundwater samples with SAR less than
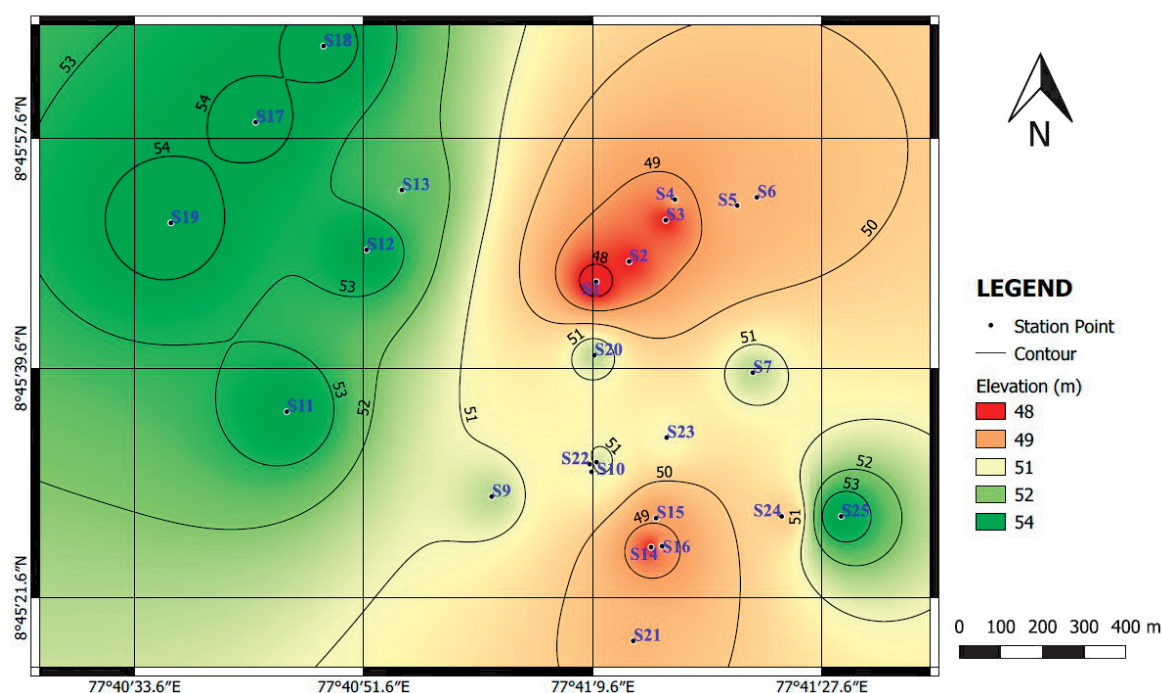
Fig. 3. Spatial variation of elevation around dumpsite.

Table 5. Irrigation Water Quality Indices for Classification.

Irrigation Parameter	Type of water	No. of samples	Percentage of Sample
S.A.R			
<10	Excellent	28	100
10 to 18	Good	0	0
18 to 26	Permissible	0	0
>26	Unsuitable	0	0
R.S.C	**Type of water**	**No. of samples**	**Percentage of Sample**
<1.25	Good	28	100
1.25 to 2.5	Marginal	0	0
>2.5	Unsuitable	0	0
P.I	Type of water	No. of samples	Percentage of Sample
>75%	Good	0	0
75-25%	Permissible	26	92.86
<25%	Unsuitable	2	7.14
S.S.P	**Type of water**	**No. of samples**	**Percentage of Sample**
<60	Suitable	28	100
>60	Unsuitable	0	0
M.A.R	Type of water	No. of samples	Percentage of Sample
<50	Suitable	17	60.71
>50	Unsuitable	11	39.29
K.R	**Type of water**	**No. of samples**	**Percentage of Sample**
<1	Suitable	27	96.43
>1	Unsuitable	1	3.57

10 are considered excellent and are highly suitable for irrigation [28]. Those samples with SAR greater than 26 are unsuitable for irrigation. In our study area, all the samples had SAR below 10 and are of excellent quality.

RSC

Residual Sodium Carbonate (RSC) is the amount of excess or surplus quantity of carbonate and bicarbonates compared to the alkaline Earth. It represents the terrible effects of carbonate and bicarbonate in water quality [29]. The higher the value of RSC, the higher is the potential for sodium hazard. This is because, at higher RSC values the calcium and magnesium ions get easily precipitated from the water, thus increasing the share of sodium in water and soil [30]. Continuous use of water with high RSC values affects the leaves of the plants and decreases the crop yield. Water with RSC values greater than 2.5 are unsuitable for irrigation, while that with RSC values less than 1.25 are good and suitable for irrigation. In our study area, all the 28 samples had RSC values less than 1.25 and are suitable for irrigation.

PI

The use of irrigation water for a long time has a great effect in the permeability of soil. This is influenced by the bicarbonate content, dissolved salts and sodium content. [31]. Based on PI, the water samples can be categorized as good, when it has value greater than 75% and the water is termed as permissible when it has its permeability index between 75% and 25%. Water is considered to be unsuitable for irrigation purpose, when PI value is less than 25%. In our study area, except the sampling sites S24 and S26, water from all other sampling sites were permissible for irrigation.

SSP

Soluble Sodium Percentage (SSP) is broadly used to determine the suitability of water for irrigation [32]. SSP helps in evaluating sodium hazard. High SSP results in the release of Ca^{2+} and Mg^{2+} ions to the soil due to the absorption of sodium by clay particles. Combination of sodium with carbonates results in alkaline soil whereas its combination with chloride results in saline soil which is unsuitable for agriculture [33]. Water samples with SSP less than 60 are suitable for irrigation purpose and that with SSP greater than 60 are unsuitable. In our study area, all the samples had SSP values less than 60 and are suitable for irrigation.

MAR

Magnesium Absorption Ratio (MAR) defined in equation (6) is an indicator of magnesium hazard, which occur when magnesium remains in equilibrium with water. In MAR index both calcium and magnesium

are taken into consideration as they both together exist in equilibrium with water [34]. Samples with MAR below 50% are suitable for irrigation purpose while that above 50% is unsuitable. Of the 28 samples, 17 samples were less than 50% of MAR and were suitable for the irrigation purpose, while 11 samples were found to be unsuitable.

KR

Kelly Ratio is the level of sodium measured against magnesium and calcium [35]. The water sample is considered unsuitable and the concentration of sodium is considered excess when KR>1. The water is suitable for irrigation purposes when KR<1 [36]. In the study area, Kelly Ratio showed that except sample S13, all other samples were suitable for irrigation.

Conclusions

From the present study it was found that in and around Ramayanpatti dumpsite most of the sampling sites have TDS, alkalinity, chloride, sulphate and TH values exceed permissible limits making water of those particular areas unsuitable for drinking purpose. While the presence of these pollutants is not very much harmful to human health, but this study does point out that there are strong possibilities that other lethal contaminant like metal ions may have reached these water sources along with the pollutants studied [37]. The WQI value for groundwater samples varied from 112.52 to 463.67 which represent groundwater around dumpsite were in the range of poor quality water to water unsuitable for drinking purposes. WQI value for samples from surface water sources ranges from 100.58 to 146.37 which shows the surface water sources were least affected by open dump than groundwater. The irrigation indices shows that almost all the samples were suitable for irrigation purpose. Hence, it can be used for irrigation without any prior treatment. It can also be identified that the flow of leachate depends on the natural topography of the land area. The presence of this open dumpsite possesses huge environment threats to the water sources, proper measures are required to avoid contamination of water sources due to open dump. To decrease the contamination of surface and groundwater sources the farmers are interested to use biopesticides and biofertilizers. A long- term and short-term management action plan should be framed for the efficient use of water resources.

Acknowledgements

Conflict of Interest

The authors declare no conflict of interest.

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