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Environmental impact assessment of solid waste disposal on groundwater quality

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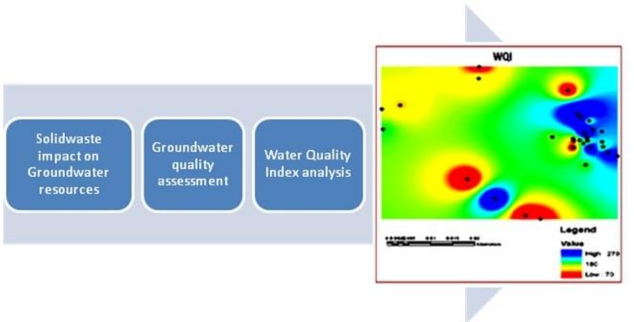
Graphical abstract



Abstract

This study focuses on the impact of solid waste on groundwater quality in the region of Ramayanpatti, Tirunelveli. Tirunelveli city generates 100 tonnes of solid waste in a day. Solid waste has organic matter, inorganic matter, and moisture content which leaches dissolved organic matter, and heavy metals to the groundwater. Rainfall runoff carries all the dissolved contaminants from the solid waste and infiltrates into the groundwater. Groundwater quality is characterized at 30 locations around the dumping yard. Water Quality Index(WQI) is calculated using important characteristics such as pH, TDS, Calcium, Magnesium, Alkalinity, Sodium, Potassium, Chloride, Nitrate, and Sulphate by its relative weightage. The Spatial distribution of WQI is drawn. Groundwater Quality is very poor in the surrounding region of solid waste dump yard and also in the areas of agriculture irrigated areas. Groundwater in other areasshall be used for domestic purposes except drinking with proper disinfection.

Keywords: Solid waste, Groundwater Quality, Characterization, Water Quality Index, Groundwater use

1. Introduction

Solid waste generation is posing a significant threat to the environment, which pollutes air, water, and land. The world is facing a very big challenge to dispose the solid waste safely in to the environment that is generated at very huge quantities from households, institutions, commercial establishments, and industries. Solidwaste dumping has negative impact on the water quality of Mthatha River(LiazolaBangani *et al.* 2023). Solidwaste dumping in an unscientific way has negative impacts on soil and groundwater quality (M. Choudhury *etal.* 2022). Leachates from solidwaste dumping yards polluted groundwater and this pollution control may take several decades to resume its original state (Sowmya Munagala*et al.* 2020). Continuous monitoring of groundwater quality is necessary to identify its suitability for drinking and agricultural purposes (Geethamani R. *et al.* 2023).

This study addresses the impact of solid waste leachates on groundwater quality. Solidwaste from the Tirunelveli Corporation of Tamilnadu in India is disposed-off at Ramayanpatti in the open yard. This practice leads to leaching contaminants into the soil and reaches the groundwater aquifer through infiltration. The continuous leaching of the contaminants gets transported day by day through vertical and horizontal movement beneath the ground surface with the rainfall and runoff. Groundwater samples were collected in and around the open dump yard in thirty places and were analyzed for sixteen water quality parameters as per the Standard Methods of Examination of Water and Wastewater, American Public Health Association (APHA) procedures. Groundwater characterization reveals that the quality of groundwater is affected by the leachate contaminants in the flow direction of groundwater movement from solidwaste dump yards. The Water Quality Index (WQI) arrived with due weightage to each water quality parameter, which is based on the impact on human health and it shows that the quality of the groundwater ranges from poor to unfit for drinking.Also, the leaching of nutrients from the agriculture field was also noticed which affects groundwater quality.

2. Background of the Study

Population growth and industrialization have led to the generation of waste in such huge quantities. Modern growth in packaging industries has initiated open market trading of all essential commodities that including food to household appliances, including electronic gadgets. Catchy printing on the packaging of a commodity has induced an attraction to consumers to buy products and results in Solid waste. Globalization opportunities of business including E-market modern trade of commodities increase the generation of solid wastes. These wastes pollute the air, water, and land. Solid waste contaminates air through the generation of gases, soil through leachates, and groundwater through the vertical and horizontal movement of leachates by rainfall. Groundwater pollution is very severe and hence immediate attention is necessary, if not groundwater resources cannot be utilized forever. Hence a study is undertaken to study the groundwater quality through characterization in the Ramayanpatti region where solid waste is dumped and where groundwater is used as a resource for all domestic purposes.

3. Objectives of the study

To evaluate the impact of solid waste dumping yards on groundwater quality and to assess the suitability of groundwater for domestic purposes through The Water QualityIndex(WQI).

4. Study area description

Tirunelveli district is located in the southern part of Tamil Nadu, India. Tirunelveli district has varied agro-climatic conditions ranging from extreme tropical to subtropical. Tirunelveli has a population of around 4.2 lakhs which disposes of around 100 metric tonnes of collected solid waste at the Ramayanpatti region in an open dump yard as obtained from Tirunelvei Municipal Corporation (**Figure 1**).

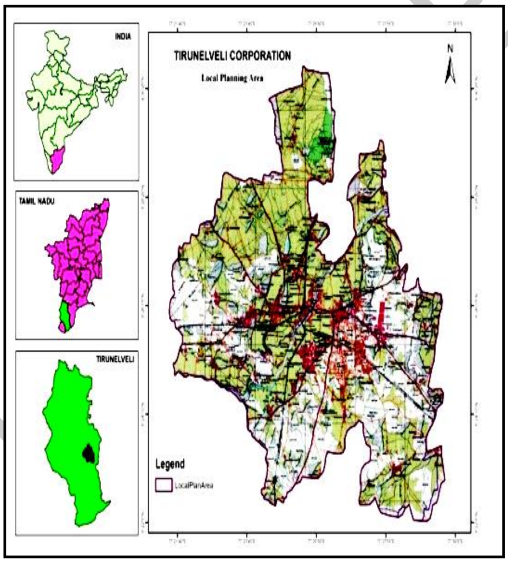


Figure 1. Tirunelveli Map.

These collected wastes are dumped in the available yard at Ramayanpatti, located on the outskirts of Tirunelveli local planning area. The relative humidity ranges between 70to 84%. The average minimum temperature is 23°C, and the average maximum daily temperature is 34°C, respectively. The normal annual rainfall of the district is 879 mm.

The topography of the Tirunelveli district is a flat, sloppy terrain in nature with an altitude of 45m above MSL and is endowed with small mountains and hillocks. The geology of the site is a hornblende-biotite gneiss structure. The geomorphology is buried pediment shallow and pediment with black cotton soil to the complex outcrop. The topsoil is 1 to 3m below ground level. The fractured rocks occur at 20 to 40m below ground level. The area is covered by red sandy soil on top and black cotton soil at the bottom.The general topography of the local planning area is generally flat in nature, with sloppy terrain in the high ground area, and the altitude is 36.4m above MSL and is endowed with small mountains and hillocks. It has a natural slope towards the river Tamirabarani.

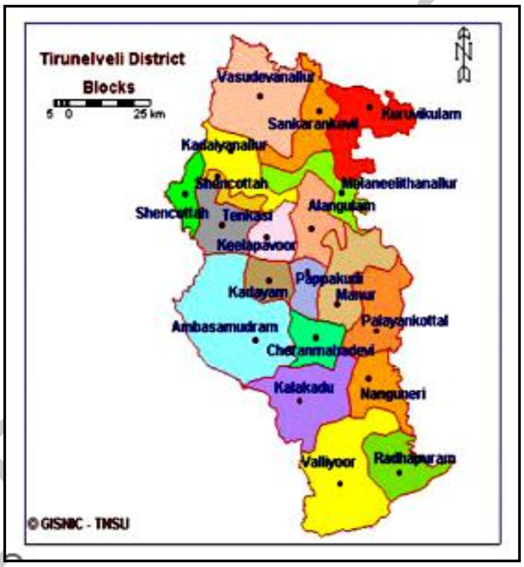


Figure 2. Tirunelveli District

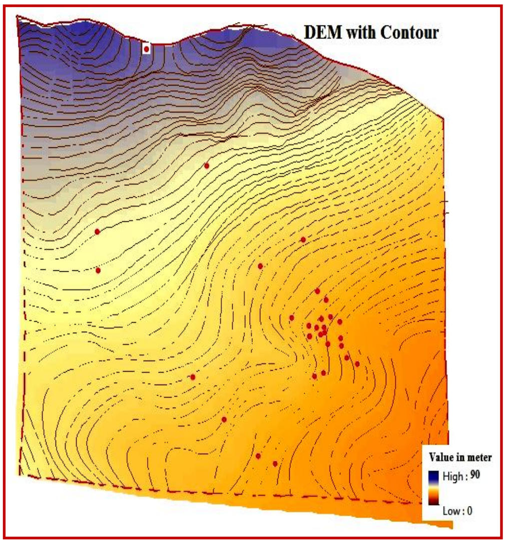


Figure 3. Sampling point locations

5. Materials and methods

A reconnaissance survey has been undertaken to identify the sampling points in and around the dumpsite. Thirty sampling points have been identified, and most of the points lie in the aquifer movement of groundwater from the dumpsite. Groundwater samples were collected from various sample points in the study area. Groundwater samples from tube wells/bore wells were collected in and around the study area at 30 locations, and the samples were subjected to a comprehensive physicochemical analysis. These locations have been identified based on the growth of residential area at Ramayanpatti village which is on the out skirts of the Tirunelveli city around the dump yard as well as from DEM topography image. The sampling point locations and digital elevation model are shown in **Figures 2 and 3** respectively. Google images of solidwaste dump yards and Waste stabilization ponds which arenearbyare shown in **Figures 4 and 5** respectively. The area selected for our study is 10×10 km.

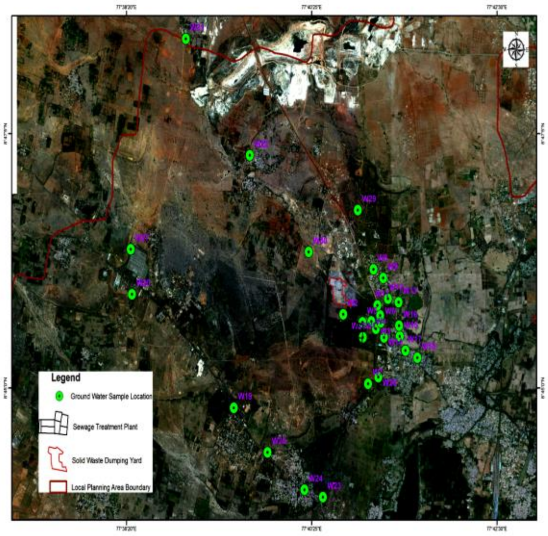


Figure4. Digital Elevation Model

Figure 5. Solid waste dump yard in red and WSP

The sampling points were marked as W1 to W30 as shown in **Figure 2**. Geo referencing of sampling points are given in the **Table 1**. Groundwater sampling is done for four consecutive months on the onset of monsoon. Samples have been stored and preserved as per the sampling methods of the Standard methods for Examination of Water and Wastewater, American Public Health Association (APHA manual). Groundwater sample is analyzed for ten chemical parameters. The procedure adopted for characterization is as per the standard methods of titration, flame photometric and spectro-photometric methods of the APHA manual. Groundwater quality is assessed for drinking water standards as per Indian Standards 10500-2012 except potassium. The standard for potassium is taken from the guide lines of World Health Organization.The Water Quality Index is classified as very good, good, poor, very poor, and unfit.The spatial distribution of WQI is made using surfer software.

6. Water Quality Index

The Chemical parameters such as pH, TDS, Alkalinity, Sodium, Calcium, Magnesium, Potassium, Chloride, Nitrate, and Sulphate wereanalysed and these parameters were rated based on a scale of 0 to 5based on their impacts on human health. Water quality indices were calculated with reference to the Bureau of Indian Standards for Drinking Water code IS 10500-2012 and World Health Organization guidelines for potassium in drinking water.

Figure 6. Solidwaste dump yard site

The relative weightage of each parameter was calculated as per the following mathematical equation as given below.

$$Wr = Wi/\sum Wi$$

Where,

Wr -Relative weightage, Wi - Weightage of each parameter.

Quality rating is calculated (**qi**) using the following mathematical equation

$$q_i = Ci/Si * 100$$

Where,

Ci -Chemical concentration of each parameter in mg/L,

Si –The maximum permissible limit of Indian standards drinking water standard for each chemical parameter in mg/L.

Finally, the Water Quality Index was calculated as per the following mathematical equation.

$$WQI = Wr \times q_i$$

The parameter weightage is assigned based on the severity of its impact on life.Weightage is higher if the severity is higher. Indian Standards& World Health Organization(WHO) standardsin drinking water are considered for finding the Water Quality Index. As Indian Standards do not have standards for potassium in drinking water, WHO standard is adopted. The rating for domestic purposes is classified into five Excellent, Good, Poor, Very poor, and Unfit. WQI up to 100 shall be used for human consumption and the rating above 100 shall be used for domestic purposes other than drinking.

7. Results and Discussions

In this present study, the groundwater quality in and around the solid waste dumpsite of the Ramayanpatti region was characterized for tenchemical parameters. The water quality index of the sampling points is shown in the table given below. The concentration of TDS, Calcium, Magnesium, and Nitrates exceeds the limit of the BIS standards. The Water quality indices of the sampling points are shown in the following **Table 4**.

Table 1. Geo referencing of sampling points

SAMPLING POINTS GEO-REFERENCING			
Sample ID	**Latitude**	**Longitude**	**Details**
W1	8.756967	77.6832	Bore
W2	8.7601	77.67952	Open
W3	8.75815	77.68563	Bore
W4	8.759167	77.68478	Bore
W5	8.759033	77.68313	Bore
W6	8.759033	77.68653	Open
W7	8.7506	77.68423	Bore
W8	8.766317	77.68512	Bore
W9	8.765133	77.68695	Bore
W10	8.759983	77.68643	Bore
W11	8.761367	77.68588	Bore
W12	8.7623	77.68787	Open
W13	8.761833	77.68987	Open
W14	8.756983	77.68717	Bore
W15	8.757133	77.6901	Bore
W16	8.7586	77.68997	Bore
W17	8.7552	77.69118	Bore
W18	8.75425	77.69342	Bore
W19	8.747133	77.6591	Bore
W20	8.76255	77.63992	Bore
W21	8.797683	77.64975	Bore
W22	8.781783	77.66187	Bore
W23	8.734983	77.67587	Bore
W24	8.735967	77.6724	Bore
W25	8.741067	77.66547	Bore
W26	8.751517	77.68613	Bore
W27	8.768733	77.63965	Bore
W28	8.756967	77.6832	Bore
W29	8.7744	77.68213	Bore
W30	8.7686	77.67298	Bore

Points W7, W8, W11, and W14 which are near a dump yard and pond have high WQI due tothe leachates of solidwaste and some extent to the liquid domestic waste from waste stabilization pond.Point W25 is affected due to the intensive practice of irrigation around the region. The water quality index shows that in most of the places, the water is poor to very poor, even unfit for drinking. The values of WQI show that the groundwater was contaminated with leachate in the direction of groundwater movement in the aquifer toward the Tamirabarani River as inferred from the digital elevation model of the study area. The area in and around point W25 is an agricultural practiced area and so it is contaminated with nutrients which is normally in use in agriculture practices.

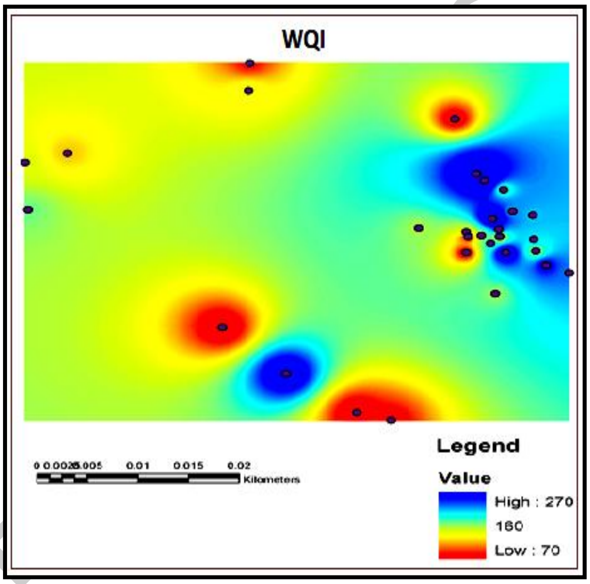


Figure 7. Spatial distribution of WQI

The spatial distribution of WQI shows that the solidwaste dumping yard produces leachate andaffects the groundwater quality.It is shown in the blue shade on the right-hand side of the image. The diminishing blue shade on the right of the image shows the movement of the leachate. The quality of groundwater is also very poor in the agriculture-practiced region as shown in the blue shade present at the bottom of **Figure 6** at sampling point 25 due to the use of chemical fertilizer. The region in the blue shade of the image, the water is unfit for drinking and shall be used for other domestic purposes (**Figure 7**).

Table 2. Assigned Weightage and calculated Relative Weightage factor

Parameter	Drinking Water Standards in mg/L except pH	Assigned Weightage (Wi)	Relative weightage factor, W_r
IS10500-2012 Standards - Acceptable Limit			
pH	6.5-8.5	3	0.104
Chlorides	250	3	0.104
Nitrate	45	5	0.172
TDS	500	5	0.172
Alkalinity	200	2	0.069
Sodium	200	3	0.104
Calcium	75	2	0.069
Magnesium	30	2	0.069
Sulphate	200	3	0.104
WHO Standards			
Potassium	5.2	1	0.033
		∑Wi=29	∑Wi=1

8. Conclusion

This study shows that groundwater in the region of Ramayanpatti area was contaminated with leachates from the solid waste dump yard. Chemical characterization of the sampling points shows that the concentrations of TDS exceed the limits of the BIS standards in the direction of movement of groundwater from municipal solid waste dump sites. The water quality index shows that the groundwater was polluted with leachates in the Ramayanpatti area. Groundwater in this region was not suitable for drinking purposes. Groundwater is polluted with leachates, and nutrients from the application of urea in agricultural areas in the direction of movement of groundwater. The direction of the movement of groundwater from the analysis is in the direction of east and south from the dump yard and agricultural areas. All other samples in general,shall be used for domestic purposes other than consumption. The groundwater in the study area shall be disinfected and used for other domestic purposes except drinking.Also, the groundwater in the agricultural practiced regions is highly contaminated with nutrients.Proper management of solid waste and proper application of manure in the agriculture fields shall bring down the contamination of groundwater.

Table 3. WQI rating table for domestic use

WQI Range	Type of water
<50	Excellent water
51-100	Good water
101-200	Poor water
201-300	Very poor water
>300	Unfit for use

Table 4. Water Quality Index and classification of samples

Sample ID	WQI	Rating	Sample ID	WQI	Rating
W1	130	POOR	W16	162	POOR
W2	133	POOR	W17	192	POOR
W3	152	POOR	W18	173	POOR
W4	132	POOR	W19	85	GOOD
W5	72	GOOD	W20	145	POOR
W6	108	POOR	W21	127	POOR
W7	217	VERY POOR	W22	97	GOOD
W8	233	VERY POOR	W23	93	GOOD
W9	144	POOR	W24	86	GOOD
W10	182	POOR	W25	206	VERY POOR
W11	257	VERY POOR	W26	144	POOR
W12	164	POOR	W27	125	POOR
W13	160	POOR	W28	80	GOOD
W14	233	VERY POOR	W29	84	GOOD
W15	133	POOR	W30	114	POOR

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