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GEO-SPATIAL ASSESSMENT OF MUNICIPAL SOLID WASTE EFFECT ON GROUND WATER QUALITY AROUND SOLAPUR DUMP YARD

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Abstract: Groundwater, a critical resource for domestic, agricultural, and industrial needs, is increasingly threatened by contamination due to waste mismanagement, particularly from landfill sites. Leachate generated in landfills is a significant source of groundwater pollution, as it permeates through soil, contaminating aquifers with dissolved substances. This study evaluates groundwater quality near the Solapur Municipal Corporation landfill in Maharashtra, India, focusing on key physico-chemical parameters, including pH, alkalinity, hardness, chloride levels, total dissolved solids (TDS) and total suspended solids (TSS). Samples of groundwater were collected during post-monsoon (November 2022) and pre-monsoon (April 2023) periods from 20 locations within a 1200-meter radius of the landfill site. These samples were analyzed using standard laboratory procedures to assess seasonal variations in water quality. Spatial distribution maps of the parameters were generated using QGIS software and inverse distance weighted (IDW) interpolation techniques. Final Pollution Distribution maps for post-monsoon season and post monsoon season were created using Weighted Linear Combination (WLC) method. Results revealed that groundwater quality is impacted by leachate contamination. Observed pH levels exceeded permissible limits, while most other parameters remained within allowable ranges. However, elevated hardness and high chloride levels, even within permissible limits, indicate potential contamination risks. TDS levels in some samples exceeded recommended limits, highlighting poor water quality. The Pollution Distribution maps indicated that the water was unfit for drinking overall around the 1200 m buffer zone of the dump yard.

Keywords: QGIS; Groundwater Quality; Municipal Solid Waste; Inverse Distance Weighted Interpolation; Weighted Linear Combination

Introduction

One of the crucial water sources for industrial, agricultural, and residential needs is groundwater (Prabhu & Shivakumar, 2018). With increased industrial and domestic waste generation, there has been a marked increase in the contamination of groundwater. The biggest problem that the cities in the world face today is with the generation of solid waste (Popoola *et al.* 2016). Landfill has been considered as one of the major causes of groundwater pollution and it is believed as one of the common methods to dispose municipal solid waste due to its favorable economics. Numerous substances found in the leachate generated by waste disposal sites have the potential to affect ground water (Mageswari *et al.* 2017). From the unsaturated zone, the leachate moves to the groundwater table. The local ground water becomes contaminated when leachate and ground water combine to generate a plume that travels in the direction of the ground water's flow (Morrison and Munster, 2014). The rate at which toxins are transported and the depository conditions at the location as they seep through the soil media determine how contaminated the aquifers are (Vasanthi *et al.* 2007). If the landfill does not serve as a dumping site for heavy metals, the physico-chemical properties to be monitored in groundwater include pH, alkalinity, hardness, chloride levels, total dissolved solids (TDS) and total suspended solids (TSS) (Singh *et al.* 2012). The major component of protecting the water environment around landfill sites is proper dump site operation, which keeps the leachate at the lowest level feasible. Given that groundwater is a significant source of water supply in both urban and rural regions, this is significant. *(S*ingh *et al.* 2016).

Groundwater samples in and around the landfill can be collected at different times in the year. A comprehensible analysis of the physico-chemical characteristics of groundwater quality can take place if the samples are collected in a post-monsoon period (around November) and a pre-monsoon period (around May) (Ram *et al.* 2021). GIS contouring techniques in QGIS can be used to do the spatial study of several physicochemical characteristics (Holloway, 2023). The spatial distribution maps for any physicochemical parameter can be prepared using the inverse distance weighted (IDW) Interpolation techniques (Gossel *et*

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al. 2012). The spatial distribution map of the pH, alkalinity, hardness, chloride levels, total dissolved solids (TDS) and total suspended solids (TSS) can be generated (Verma *et al.* 2019).

This study focusses on assessing the impact of Municipal solid waste in the groundwater surrounding the Solapur dump yard. Inverse Distance Weighted (IDW) Interpolation and Weighted Linear Combination (WLC) approach was used for the study.

Methodology

Study Area

According to a report by Maharashtra Pollution Control Board (2019), the Solapur Municipal Corporation processing plant and dumping yard is situated on Tuljapur Road, Solapur, Maharashtra, India (as shown in Figure 1). The plant spans an area of 55 acres, with coordinates Latitude: 17.70311409 and Longitude: 75.90792798. Approximately 300 to 350 tons of solid waste are generated daily in Solapur, of which 300 tons are collected, while the remaining 50 tons are processed at the source in compliance with the SWM Rules 2016. Solid waste is collected using *ghantagadis* (with a capacity of 350-550 kg) and unloaded at four transfer stations developed under the Smart City project. Additionally, 16 Road Compactor (RC) vehicles, each with a capacity of 8-10 tons, transport the waste in a segregated manner to the Solapur Bio-Energy System Pvt. Ltd. plant located on Tuljapur Road.

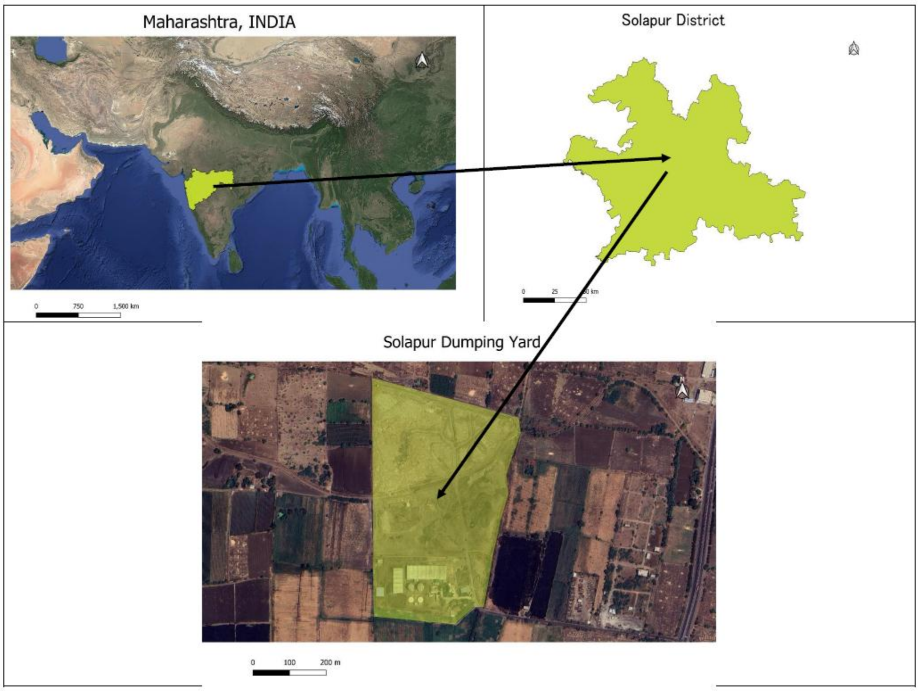

Figure 1. Study Area - Solapur Municipal Corporation processing plant and dumping yard

Groundwater Quality Parameters

Testing groundwater around a dumping yard for properties such as pH, alkalinity, hardness, chloride, total dissolved solids (TDS) and total suspended solids (TSS) is crucial to evaluate the potential impact of leachate contamination on the groundwater quality (Pramulyana *et al.* 2023). Dumping yards are known to produce leachate, a liquid by-product formed from the decomposition of waste, which can infiltrate the soil and reach groundwater (Mohan and Gandhimathi, 2009). Monitoring pH ensures the water's acidity or alkalinity remains within safe limits, as deviations can indicate contamination by acidic or basic compounds. Alkalinity reflects the water's capacity to neutralize acids, which is vital for maintaining its buffering ability against pollution (Barringer and Johnsson, 1996). Elevated chloride levels signal contamination from organic waste or sewage. Hardness indicates the presence of calcium and magnesium, which may increase due to mineral leaching from waste (Özdemir *et al.* 2009). TDS measures the total dissolved impurities in water, revealing the extent of contamination, while TSS serves as an indicator of the suspended impurities in the groundwater (Butler and Ford, 2017). Assessing these parameters helps identify pollution sources, understand their impacts on human health and the environment, and develop measures for groundwater protection and remediation (Abolli *et al.* 2022).

Workflow

The step-by-step process used to accomplish all goals is depicted in Figure 2. The process starts by collecting the location data of the dump yard. The location data is georeferenced in QGIS. Based on the total groundwater sources available around the dump yard site, a buffer zone is created (Gillurkar, 2017). Then, samples are collected from the groundwater sources and it's physico-chemical properties is analyzed in the lab. Finally, IDW interpolation and WL Combination analysis is performed in the QGIS to prepare pollution distribution maps (Mukherjee, 2014).

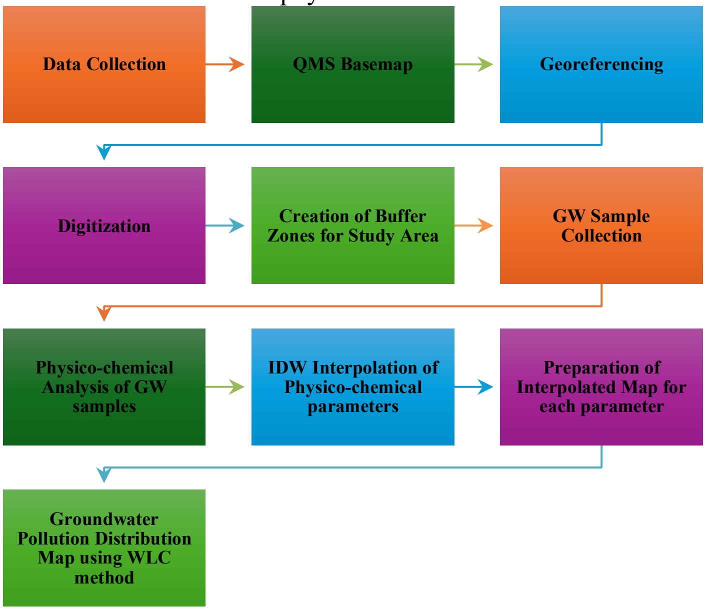

Figure 2. Flow Chart of Methodology

Data Collection

Twenty locations in and around Solapur dump yard were selected which were a source of groundwater collection (Unneesa and Bi, 2017). The extent of the area in which groundwater collection sources were present was selected as the buffer zone. The buffer zone encompassed 1200 m area around the dump yard site. The 1200 m buffer zone was divided into three sub-zones – 400 m, 800 m and 1200 m (Kozlowski and Peterson, 2018), as shown in Figure 3.

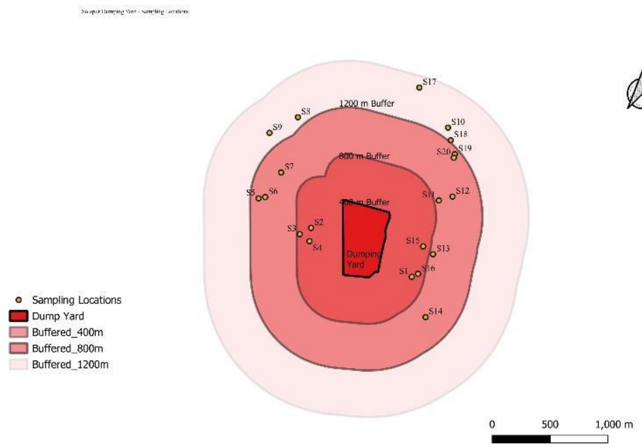

Figure 3. Study Area and Buffer Zone

All the 20 GW collection locations selected were around the dump yard site. No GW collection source was discovered in the dump yard. All the collection sources had groundwater depth between 100-150 m. Out of the 20 locations, only three sources were in the form of an open well, while the rest were borewells. Seven sources were being utilized for mainly agricultural process, twelve sources for washing and cleaning purpose and only five sources for drinking. Details are given in Table 1.

Table 1 Location and co-ordinates

Sample no.	Latitude	Longitude	Source	Depth (m)	Use of water
S1	17.70252	75.91165	Bore Water	100 m	Drinking, Washing & Cleaning
S2	17.7063066	75.9034621	Bore Water	100 m	Drinking
S3	17.70574	75.90249	Well	150 m	Agriculture
S4	17.70528	75.90333	Bore Water	150 m	Agriculture
S5	17.7086	75.89919	Well	150 m	Agriculture
S6	17.70858	75.89915	Well	150 m	Agriculture
S7	17.71061	75.90103	Bore Water	150 m	Drinking & Agriculture
S8	17.71489	75.90239	Bore Water	150 m	Agriculture
S9	17.71368	75.90008	Bore Water	150 m	Agriculture
S10	17.71408	75.9146	Bore Water	100 m	Washing & Cleaning
S11	17.70844	75.91385	Bore Water	100 m	Washing & Cleaning
S12	17.70844	75.91385	Bore Water	100 m	Drinking, Washing & Cleaning
S13	17.70874	75.91497	Bore Water	100 m	Drinking, Washing & Cleaning
S14	17.7041	75.91443	Bore Water	100 m	Washing & Cleaning
S15	17.69939	75.91277	Bore Water	100 m	Washing & Cleaning
S16	17.7097	75.91638	Bore Water	100 m	Washing & Cleaning
S17	17.70615	75.91105	Bore Water	100 m	Washing & Cleaning
S18	17.71719	75.91227	Bore Water	100 m	Washing & Cleaning
S19	17.71307	75.91473	Bore Water	100 m	Washing & Cleaning
S20	17.71176	75.91527	Bore Water	100 m	Washing & Cleaning

Georeferencing and Digitization

The entire study area was digitized and georeferenced in order to produce pollution maps from results obtained (Solomon *et al.* 2019). Google Satellite was added as a basemap using Quick Map Services in QGIS. At the beginning, 20 location point in QGIS were plotted as a delimited text layer. IX. After adding 20 locations then click on "OSM standard" installed previously with the help of quick map services, the study area in polygon shape was created (Kang *et al.* 2011).

Collection of Groundwater Samples

The Solapur Municipal Corporation processing plant dumping yard, located on Tuljapur Road, Solapur, was visited in November 2022 (post-monsoon season) to collect samples from 20 different locations within the study area. The sample collection process took one week to complete. Before collecting each sample, the latitude and longitude of the respective locations were verified using GPS. Groundwater samples were collected using 250 ml polyurethane bottles, which were carefully transported and stored in refrigerator at 4^0C to prevent any external contamination. To analyze and compare seasonal variations, the site was revisited in April 2023 (pre-monsoon season), and the entire procedure was repeated to compare the post-monsoon and pre-monsoon results (Abhishek, 2023; Shekhar and Jha, 2022).

Physico-chemical Analysis of GW Samples

The 20 samples brought from the site were tested in the lab for physic-chemical characteristics such as pH, Alkalinity, Hardness, Chloride level, TDS and TSS. The sample was analyzed using the standard procedures recommended by the American Public Health Association (APHA) (Khan *et al.* 2012).

Spatial Interpolation of Physico-chemical Properties

The interpolation of ground water quality parameters was performed by using IDW interpolation i.e. (Inverse distance weighting) interpolation. Interpolated area was obtained and after that, to highlight only the study area, the Raster was clipped by the masked layer (i.e. study area). After applying a suitable colour interval, the final interpolated map of individual physico-chemical properties was obtained (Nguyen *et al.* 2018).

Result and Discussion

Physico-chemical Properties (Post-monsoon)

Table 2 shows the physico-chemical properties of the 20 samples collected in post-monsoon season.

Table 2 Physico-chemical Properties (Post-monsoon)

Sample no.	pH	Alkalinity (mg/l)	Hardness (mg/l)	Chloride (mg/l)	TDS (mg/l)	TSS

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						(mg/l)
S1	7.6	184	680	499.84	2320	40
S2	7.35	352	480	500.55	800	80
S3	7.28	308	580	489.9	1760	80
S4	7.48	276	700	486.35	1760	40
S5	7.73	324	520	485.64	800	1080
S6	7.59	480	580	497.49	800	240
S7	7.52	344	620	498.73	400	80
S8	7.5	280	580	500.55	700	100
S9	7.62	296	500	498.82	630	10
S10	7.47	400	600	498.82	1000	40
S11	7.64	304	460	498.82	480	200
S12	7.68	256	400	461.21	1320	80
S13	7.86	304	740	500.32	1640	80
S14	7.3	408	660	500.55	4200	80
S15	7.39	468	600	506.48	2760	40
S16	7.76	508	400	499.8	3320	80
S17	7.93	356	500	498.06	640	40
S18	7.03	544	380	498.27	880	80
S19	7.29	584	360	499.05	920	40
S20	7.14	600	500	498	1200	80

From the data in Table 2, pH values lie between 7.0 – 8.0 which is within desirable limit (Bureau of Indian Standards, 2012). Alkalinity values of the samples ranged between 184-600 mg/l with only one sample lying within the desirable limit (<200 mg/l). Decomposing organic waste in the dump yard releases carbonate and bicarbonate ions, possibly increasing alkalinity. Other reasons can be construction debris like cement, lime, and ash. All the samples were found to have higher hardness, with values ranging between 360-740 mg/l (<200 mg/l). Reason for higher hardness level is because leachate dissolves minerals like calcium, magnesium, and iron from soil and waste. Chloride level in all the samples was around 500 mg/l, which is not desirable (<250 mg/l). Chlorides are released into the water by the plastics, food waste, salts, and sewage found in dump yards. Only two samples were found to be having desirable TDS values (<500 mg/l) and no sample was found to have desirable TSS (<5 mg/l). The higher values indicate decomposing biodegradable materials and leaching from plastics, metals, and industrial waste.

Physico-chemical Properties (Pre-monsoon)

Table 3 shows the physico-chemical properties of the 20 samples collected in pre-monsoon season.

Table 3 Physico-chemical Properties (Pre-monsoon)

Sample no.	pH	Alkalinity (mg/l)	Hardness (mg/l)	Chloride (mg/l)	TDS (mg/l)	TSS (mg/l)
S1	7.19	324	720	500	2210	40
S2	7.23	416	520	500.44	750	50
S3	8.29	384	560	499.84	1670	70
S4	7.85	232	720	500.33	1640	60
S5	7.34	608	480	497.28	810	30
S6	7.5	524	540	497.56	940	40
S7	8.01	344	660	499.48	520	60
S8	7.46	384	540	499.69	731	19
S9	8.83	432	450	500.35	620	20
S10	7.8	276	600	497	980	40
S11	7.96	260	480	497.284	620	40
S12	7.85	208	450	499.84	1320	40
S13	7.6	252	640	500.06	1580	80
S14	7.65	244	560	499.84	3240	40

S15	6.85	256	580	500.55	2360	40
S16	7.94	208	450	500.34	2540	60
S17	7.5	320	550	503.33	520	60
S18	6.83	350	450	504.84	840	20
S19	7.6	320	420	500.03	780	40
S20	6.4	300	550	500.56	1150	30

According to Table 3's data, pH values range from 6.4 to 8.8, with two samples falling outside of the desirable range. The samples' alkalinity values varied from 208 to 608 mg/l, and none of them fell inside the ideal range. Decomposing organic waste in the dump yard releases carbonate and bicarbonate ions, possibly increasing alkalinity. With values ranging from 420 to 720 mg/l, it was discovered that all of the samples had higher hardness. Reason for higher hardness level is because leachate dissolves minerals like calcium, magnesium, and iron from soil and waste. All of the samples had an undesirable chloride level of about 500 mg/l. Chlorides are released into the water by the plastics, food waste, salts, and sewage found in dump yards. Neither desirable TDS levels nor desirable TSS were detected in any of the samples. The higher values indicate decomposing biodegradable materials and leaching from plastics, metals, and industrial waste.

Interpolated Maps of pH level (Post-monsoon and Pre-monsoon)

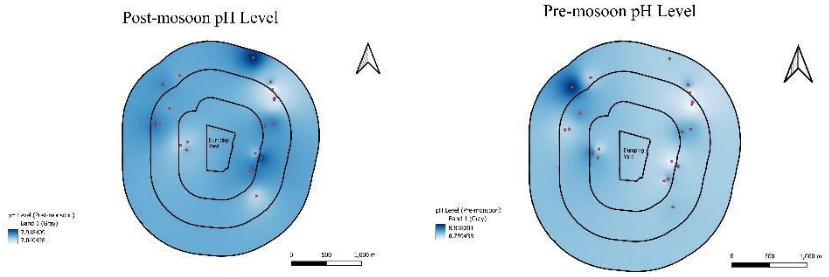

Figure 4. Spatial Distribution of pH level (Post-monsoon and Pre-monsoon)

According to Figure 4 for post-monsoon and pre-monsoon seasons, dark blue areas represent higher pH and lighter blue regions represent lower pH. The pH data shows seasonal variations between pre-monsoon and post-monsoon periods, reflecting the dilution effects of rainfall, which can neutralize acidity and create slightly alkaline conditions.

Interpolated Maps of Alkalinity level (Post-monsoon and Pre-monsoon)

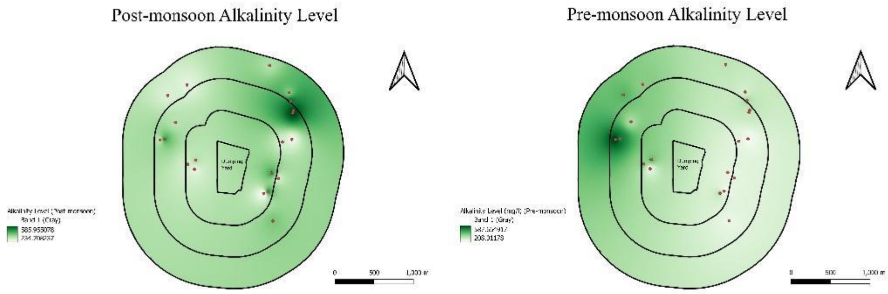

Figure 5. Spatial Distribution of Alkalinity level (Post-monsoon and Pre-monsoon)

According to Figure 5 for post-monsoon and pre-monsoon seasons, dark green areas represent higher alkalinity and lighter green regions represent lower alkalinity values. Post-monsoon alkalinity values range from 184 to 600 mg/L, which are generally lower. On the other hand, pre-monsoon alkalinity ranges from 208 to 608 mg/L, which indicates higher alkalinity concentrati ons.

Interpolated Maps of Hardness level (Post-monsoon and Pre-monsoon)

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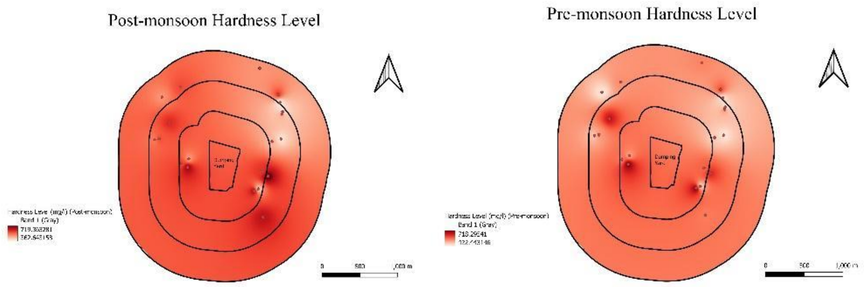

Figure 6. Spatial Distribution of Hardness level (Post-monsoon and Pre-monsoon)

According to Figure 6 for post-monsoon and pre-monsoon seasons, darker areas represent higher hardness and lighter regions represent lower hardness level. Post-monsoon hardness values range from 360 to 740 mg/L, often higher due to the influx of dissolved minerals. Pre-monsoon hardness values range from 420 to 720 mg/L, which is slightly lower.

Interpolated Maps of Chloride level (Post-monsoon and Pre-monsoon)

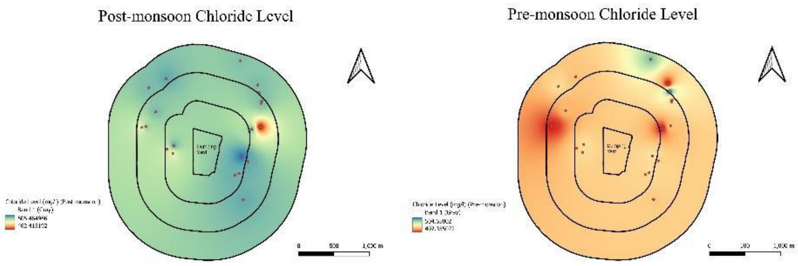

Figure 7. Spatial Distribution of Chloride level (Post-monsoon and Pre-monsoon)

According to Figure 7 for post-monsoon and pre-monsoon seasons, areas in red color represent higher Chloride and areas in green color represent lower Chloride level. The post-monsoon chloride level ranges from 461.21 to 506.48 mg/L, showing minimal variation. In contrast, the pre-monsoon chloride level ranges from 450 to 504.84 mg/L, reflecting a slightly higher variability.

Interpolated Maps of TDS level (Post-monsoon and Pre-monsoon)

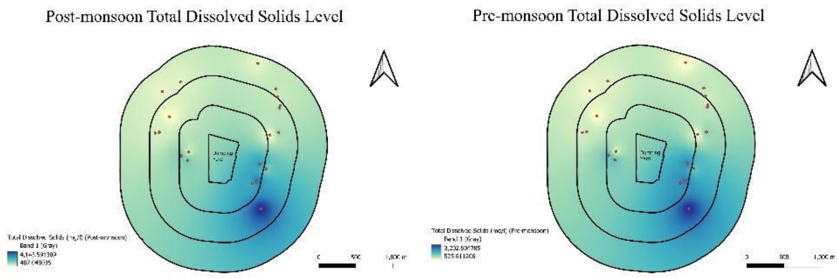

Figure 8. Spatial Distribution of TDS level (Post-monsoon and Pre-monsoon)

According to Figure 8 for post-monsoon and pre-monsoon seasons, areas in dark bluish represent higher TDS and areas in light greenish color represent lower TDS level. TDS values during post-monsoon range from 400 to 4200 mg/L, and are usually more than that as minerals and organic matter are introduced during the rainy sea-son. TDS values during pre-monsoon, ranging from 450 to 3240 mg/L, are generally lower due to reduced mineral input but with higher concentration.

Interpolated Maps of TSS level (Post-monsoon and Pre-monsoon)

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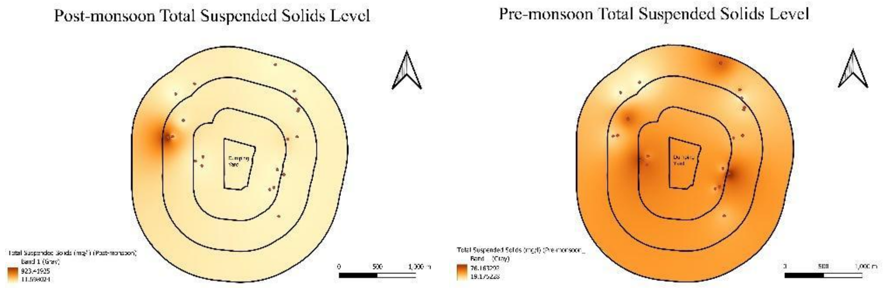

Figure 9. Spatial Distribution of TSS level (Post-monsoon and Pre-monsoon)

According to Figure 9 for post-monsoon and pre-monsoon seasons, areas in dark orange represent higher TSS and areas in light orange color represent lower TSS level. Post-monsoon TSS values ranged between 10 and 1080 mg/L, and typically, it is higher. For the pre-monsoon values, TSS was mostly ranging from 19 to 80 mg/L.

Pollution Distribution Maps using Weighted Linear Combination (WLC) method

Weighted Linear Combination method in QGIS was used to create a post-monsoon and pre-monsoon Pollution Distribution maps (Jyh-Rong, 2013). Using this method, individual raster layers of all the parameters (pH, alkalinity, hardness, chloride level, TDS and TSS) are normalized and then combined to create a single output layer. Each parameter was assigned a weight to represent its value relative to the other parameters (Akhtar *et al.* 2021).

Table 4 Physico-chemical Properties (Pre-monsoon)

Parameter	Weight
pH	0.2
Alkalinity	0.2
Hardness	0.15
Chloride	0.15
TDS	0.2
TSS	0.1

The weights displayed in Table 4 adjusted the values in raster layer of each parameter, and then all the weighted values were added together for each pixel to create the post-monsoon and pre-monsoon Pollution Distribution maps, as shown in Figure 10.

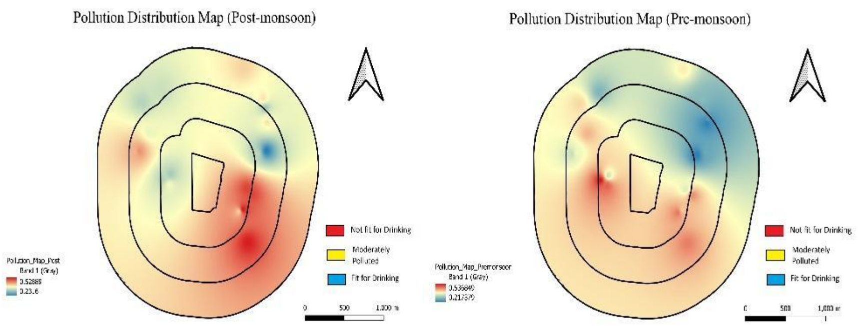

Figure 10. Pollution Distribution Maps (Post-monsoon and Pre-monsoon)

Conclusion

From the Pollution Distribution maps, it has been found that generally the water in and around the dump yard is not suitable for drinking, apart from the region north-east of the dump yard. Testing of the 20 sampling locations indicated that all the physico-chemical parameters (pH, alkalinity, hardness, chloride level, TDS and TSS) were within permissible limits, but not within the desirable limits.

QGIS can be very useful in showing the spatial variation of individual pollutants as well as overall pollution in any region. But, in order to properly train and apply the Inverse Distance Weighting (IDW) Interpolation and Weighted Linear Combination (WLC) methods, more sampling locations should be selected.

Using this method, distribution of heavy pollutants can also be mapped. Further research is needed to map the concentration of heavy metals in the dump yard.

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Data Availability Statement
The data used in this analysis is publicly available from the Google Drive at https://drive.google.com/drive/folders/1TEWRIW33TSTg6Q0_x0uHsKrn63559tIi?usp=sharing. Users can download the data.

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