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Assessing and mapping the groundwater potability in Vallipuram coastal area, Jaffna peninsula, Sri Lanka by weighted arithmetic water quality indexing method

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Abstract

Ground water is an extremely valuable resource and pollution of ground water resources is a matter of serious concern. Though more than 80% of people in the Jaffna region, rely on ground water self-supply wells, the extent to which self-supply wells delivers safe water and the associated risk factors for contamination remain unclear. In response to community requests and the National Water Supply & Drainage Board's (NWS&DB) provision of water from four ground water wells through 150m lateral pipes, a study was initiated to assess quality of well water within a 1.5km radius from the NWS&DB wells. This study involved the evaluation and mapping of groundwater quality parameters and the application of the Water Quality Index (WQI) to determine water potability. The study revealed that numerous parameters, such as turbidity, color, TDS, total hardness, total alkalinity, chloride, fluoride, total iron, calcium,

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and sulfate concentrations, exceeded SriLankan drinking water standards, while pH, nitrate, nitrite, and total phosphates remained within acceptable limits in all 120 wells. Heavy metals like arsenic and cadmium were absent in all samples. Microbiological results showed contamination with total coliformand *E.coli* bacteria throughout the study area. Considering physical and chemical parameters, the WQI values ranged from 4.5 to 287.2, with 72 wells suitable for drinking. However, when microbiological parameters were factored in, only three wells were deemed safe for drinking, underscoring the critical necessity for aquifer protection, thorough cleaning, and the immediate implementation of regular well chlorination or disinfection measures tosafeguard the health and well-being of the community.

KeyWords:Groundwater, Microbiology, WaterQualityIndex

Introduction

The quality of ground water plays pivotal roles in sustaining communities, particularly in regions like the Jaffna Peninsula, where groundwater serves as the primary source for diverse water needs. With the absence of perennial rivers or major water supply schemes and the prevalence of brief seasonal rainfall, the people of the Jaffna Peninsula heavily rely on the limited groundwater resource (Harshan et al., 2016). However, the escalating concern regarding groundwater pollution emphasizes the need for a comprehensive assessment of its quality. In response to this, the Water Quality Index (WQI) emerges as a crucial tool, a simple yet comprehensive compound indicator that aggregates information from various water quality parameters (Ravi et al., 2016). This index serves to convey water quality information in a singular value, aiding planners, policymakers, and the public in making informed decisions. Given that more than 80% of the population in the Jaffna region depends on groundwater from self-supply wells, there is a pressing need to understand the extent to which these wells deliver safe water and to identify associated risk factors. The lack of comprehensive studies on groundwater quality in the Vallipuram area poses a significant threat to the safety and sustainability of drinking water supplies in the region (Suntharalingam et al., 2021). This research gap hinders the ability to accurately assess the extent and severity of groundwater contamination, identify specific contaminants of concern, and develop effective mitigation strategies. Without adequate research, policymakers and water resource managers are left to make decisions based on assumptions or incomplete information, which could lead to ineffective or even counterproductive outcomes (Piyathilake et al., 2022). Addressing this research gap is crucial for protecting public health and ensuring the long-term sustainability of groundwater resources in Vallipuram. The main objective is to assess and map the distribution of groundwater quality parameters and determine its potability. Specific objectives include assessing the physical, chemical, and microbiological quality of groundwater in the Vallipuram coastal area, evaluating the distribution of drinking water quality parameters through mapping the case study area, and determining the potability of groundwater through water quality indexing. This study is to provide a comprehensive understanding of the current state of groundwater quality in Vallipuram, laying the foundation for informed decision-making and sustainable management of this vital resource.

Materials and Methods

The study area was the Vallipuram coastal area which covers Puloly south, Puloly east, Katkovalam and Vallipuram, and in Vadamarachchi, Northern Province, Sri Lanka. A total of 120 domestic wells within a 1.5 Km radius of the four NWS&DB dug wells in the Vadamarachchi sand dune aquifer were randomly sampled during the second inter-monsoon season (between mid-October to mid-November 2022), which is the driest period in the northern region of Jaffna

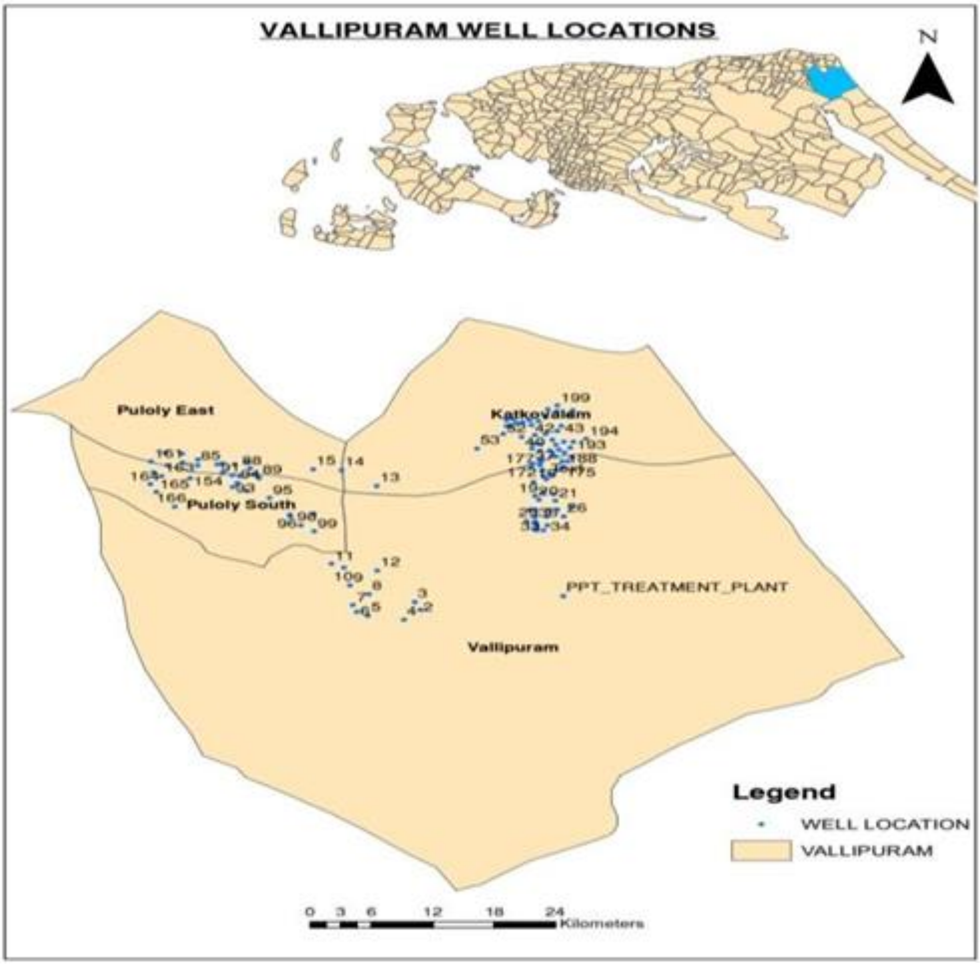

Figure 1: Ground water sampling locations in the study area

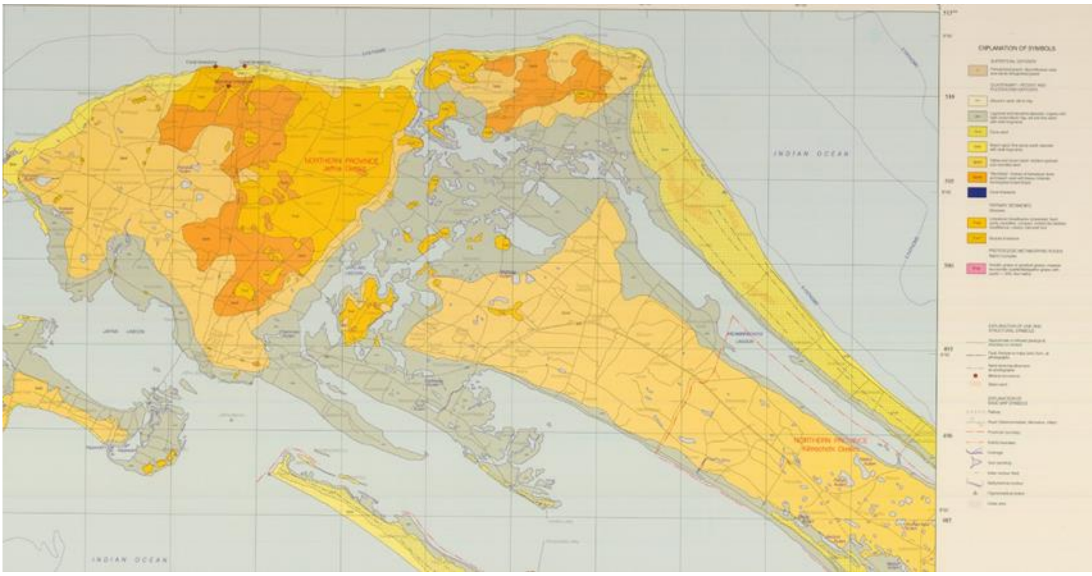

Figure 2: Geological Characteristics of the study area

Table 1. Geology of the study area

Division	**Wellidentity**	**GeologicalSuperficialdeposits**
Pulolysouth	Wells1-18	Organic rich dark-brown clay, slit and fines and with shell fragment and Yellow and brown sand, medium grained subrounded sand
Pulolyeast	Well19-35	Yellow and brown sand, medium grained subrounded sand
Katkovalam	Well36-75	Dunesand
Vallipuram	Well76-120	Dunesand

Sampling, Transportation, Storage

Table 2. Method of analysis

S.N	WaterQualityParameters	MethodofAnalysis	Unitofmeasurement
1	Colour	APHA2120C	Pt/Counit
2	Turbidity	APHA2130B	NTU
3	pH at25°C ±2°C	APHA4500–H^+B	-
4	ElectricalConductivity	APHA2510B	$\mu Scm^{-1}/mScm^{-1}$
5	Chloride(asCl)	APHA 4500– Cl^-B	mg/L
6	TotalAlkalinity(as$CaCO_3$)	APHA2320	mg/L
7	Nitrate(asNO_3-)	APHA4500-NO_3^-E	mg/L
8	Nitrite(asNO_2^-)	APHA4500-NO_2^-B	mg/L
9	Fluoride(asF^-)	APHA4500-F^-D	mg/L
10	TotalPhosphate (asPO_4^{3-})	APHA4500-PD	mg/L
11	TotalDissolvedSolid	APHA2540C	mg/L
12	TotalHardness (as $CaCO_3$)	APHA2340C	mg/L
13	TotalIron	APHA 3500- FeB	mg/L
14	Sulphate(as SO_4^{2-})	APHA4500-SO_4^{2-}E	mg/L
15	Calcium(asCa)	APHA3500-CaB	mg/L
16	Manganese(asMn)	APHA3111MnB	mg/L
17	Cadmium(as Cd)	APHA3113Cd B	mg/L
18	Arsenic(as As)	APHA3114AsC	mg/L
19	TotalColiform	SLS 1461PartI:2015	Nos /100mL
20	E.Coli		Nos /100mL

A stainless-steel round vertical standard water sampler was used to collect samples from the middle of each well. All water samples were collected, preserved, and transported to the laboratory according to the American Public Health Association (APHA) guidelines

Data Collection and Data Analysis

For the purpose of evaluating the distribution of drinking water quality parameters by mapping of the case study area, the coordinates so each sampling location were established using Global Navigation Satellite System (GNSS) RTK Receivers at the site. Data were analyzed using ArcGIS 10.8 package and Microsoft Excel. An interpolation technique (Inverse DistanceWeighted-IDW) was used toanalyzethespatialpatternsofdrinkingwaterqualityparametersincasestudy area.

Determination of Water Quality Index (WQI)

The results of the study show that the electrical conductivity (EC) and total dissolved solids (TDS) of groundwater in Vadamaradchi, Jaffna Peninsula, are high. The EC ranged from 394 to 8120 μS/cm, with 70% of the samples exceeding the permissible limit. The TDS ranged from 252 to 5197 mg/L, with 68.3% of the samples above 500 mg/L. The highest EC and TDS values were recorded in the Puloly East and south division than Katkovalam and Vallipuram division.

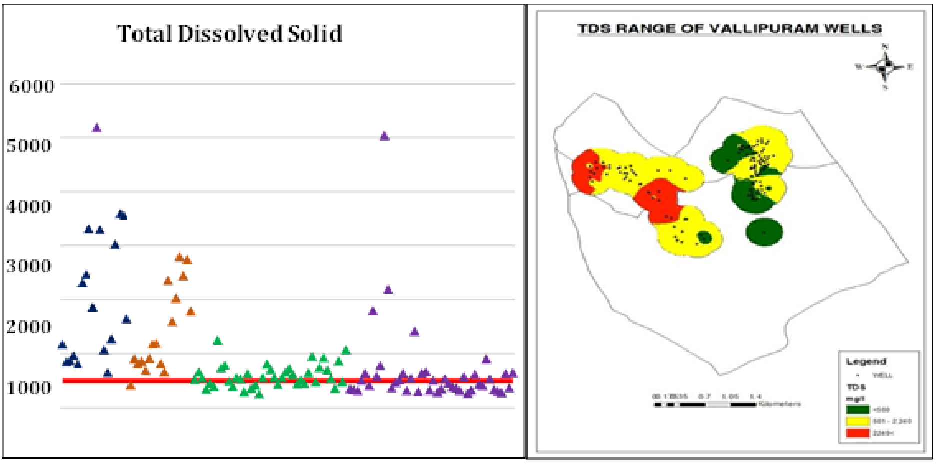

Figure 3: Variation of TDS of Groundwater and Spatial distribution in the study area

Figure 3 shows the total dissolved solids (TDS) in well water samples collected from the Puloly, Katkovalam, and Vallipuram regions. The TDS is a measure of the total amount of dissolved minerals in water, and it is an important indicator of water quality. The graph shows that the TDS of well water in Puloly east and Puloly south are generally higher than Katkovalam and Vallipuram. Average TDS of Puloly south, Puloly east, Katkovalam and vallipuram are 2107, 1423, 591, 666 mg/L respectively.

This is likely due to the geological differences between the regions. Puloly east and south have yellow-brown sand, while Katkovalam and Vallipuram have sand dunes. Sand dunes are more porous and permeable than yellow-brown sand, which allows them to filter out minerals more effectively. The graph also shows that there is a wide range of TDS values within each region. This is likely due to a variety of factors, such as the geological condition, depth of the well, the proximity to sea, and the presence of septic tanks.

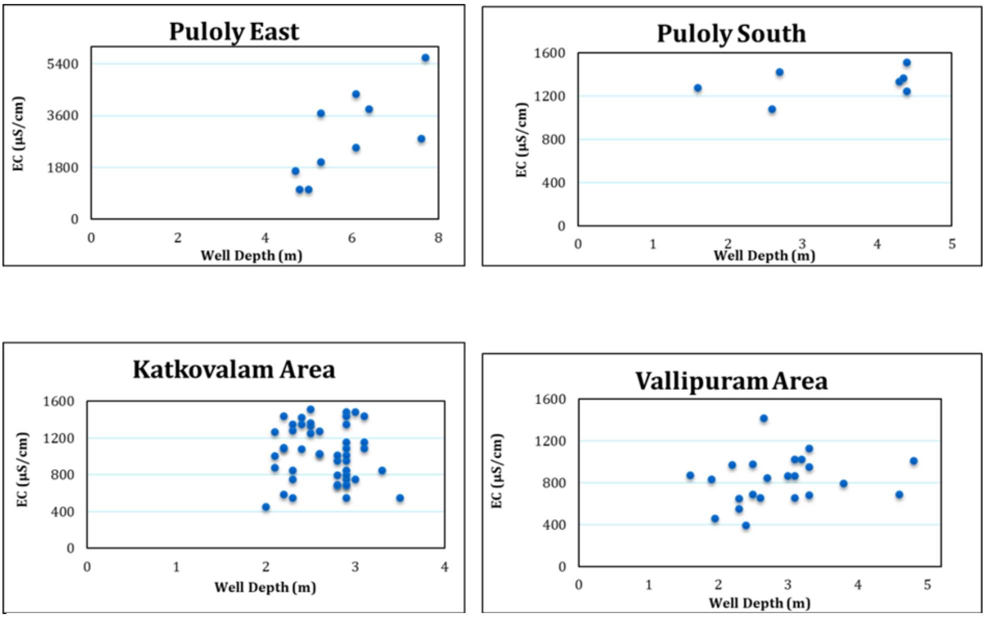

Figure 4: EC values variation in to wells depth in the study area

Figure 4 shows the relationship between well depth and electrical conductivity (EC) in the Puloly East, Puloly South, Katkovalam, and Vallipuram areas of Jaffna. The EC in Puloly East increasith well depth, indicating that the groundwater becomes more saline with depth. This is likely due to the presence of saltwater intrusion from the nearby ocean. The yellow and brown sand in this area is also more permeable than the organic-rich dark brown clay in Puloly South, which allows saltwater to infiltrate more easily. The EC in Puloly South is generally lower than in Puloly East, and it does not increase significantly with well depth. This is likely due to the presence of the clay layer, which acts as a barrier to saltwater intrusion. The EC in Katkovalam and Vallipuram is similar to that in Puloly South, and it does not increase significantly with well depth. This is likely due to the presence of sand dunes in these areas, which help to prevent saltwater intrusion. Dunes can act as a natural barrier against seawater intrusion by filtering out salt from the water as it percolates through the sand.

Fluoride

During the study period, Fluoride of the groundwater was in the range of 0.00 to 2.70 mg/L with the average of 0.48mg/L and 85.8% of the samples are below 1mg/L. Fluoride intake plays a beneficial role in dental health and the optimal drinking water concentration of fluoride for dental health is generally between 0.5 to 1.0 mg/L. Excess fluoride exposure can lead to dental fluorosis, which creates white streaks or brown stains on teeth, creates pits in teeth or even break the enamel of the teeth. Mikunthan et al. (2013) have reported that the average concentration of fluoride ranged from an undetermined value to 0.61 mg/L in Jaffna region.

Nitrate and nitrite

All nitrate and nitrite samples were below the Sri Lankan Drinking Water Quality Standard (SLSI 614:2013).Nitrate, Nitrite levels in the groundwater of Vadamarachchi ranged from 0.00 to 12.4 mg/L, 0.000 to 0.032 mg/L respectively during the study period. The low nitrate and nitrite contamination levels are likely due to the geological conditions of the aquifer, which are not conducive to agriculture.

Mahagamage et al. (2019) reported a higher nitrate concentration of 38.51 mg/L in an agricultural well near Maruthanarmadam and Ehanathan et al. (2020) reported nitrate concentrations ranging from 20 to 30 mg/L in the Jaffna peninsula. Mikunthan et al. (2013) have reported that the concentrations of nitrite values ranged from an undetermined value to 0.053 mg/L in Jaffna region.

Total iron

Iron levels in the groundwater of Vadamarachchi ranged from 0.00 to 1.32 mg/L during the study period. 92.5% of the iron samples were below 0.3 mg/L, which is the Sri Lankan Drinking Water Quality Standard (SLSI 614:2013) for iron is not hazardous to health, but it can give water an unpleasant taste, odor, and color. Mikunthan et al. (2013) reported that the concentration of iron values ranged from an undetermined value to 0.31 mg/L in Jaffna region.

Total phosphates

Phosphates enter waterways from human and animal waste, laundry and cleaning detergents, industrial effluents, and fertilizer runoff. Phosphate excess has been well a critical factor in the pathogenesis of mineral and bone disorders associated with chronic kidney disease. Total phosphates of the groundwater during study period were in the range of 0.00 to 1.46 mg/L and clearly indicate that all the samples were within the SLS limit. Ehanathan et al. (2020) have reported phosphate content ranging from 3.8 to 1.3 ppm in Jaffna peninsula.

Chloride

Chloride levels in the groundwater of Vallipuram ranged from 20 to 2877 mg/L during the study period. 72.5% of the chloride samples were below 250 mg/L, which is the Sri Lankan Drinking Water Quality Standard (SLSI 614:2013) for chloride. Chloride is generally not considered a health risk, but it can affect the taste of drinking water at relatively low concentrations. The average chloride content of groundwater in the study area was 535 mg/L. The chloride content was the highest in Puloly South (1056 mg/L) and the lowest in Katkovalam (86 mg/L).

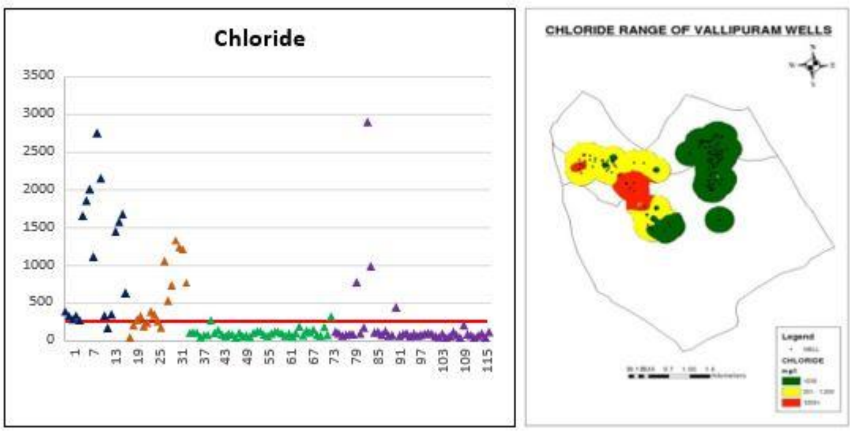

Figure 5: Variation of chloride of Groundwater and Spatial distribution in the study area

The high chloride content in Puloly South is likely due to the presence of organic-rich dar brown clay in the area. This clay can trap chloride ions from the surrounding salt water. The low chloride content in Katkovalam is likely due to the presence of sand dunes in the area. Sand dunes can act as a natural barrier against saltwater intrusion, which can help to prevent chloride contamination of groundwater. Velauthamurty et al. (2021) reported that chloride concentration in Valikamam area in Jaffna peninsula range from 25.927 to 225.24 mg/L.

Total alkalinity

Alkalinity is the water's capacity to resist changes in pH that would make the water more acidic. The alkalinity of the drinking water is too high and can have a salty taste. The results show that Total Alkalinity of the groundwater was in a range of 136-562 mg/L and 75% of the samples are above the SLS level of 200 mg/L.

Total hardness and calcium

The total hardness of the groundwater in the study area ranged from 150 to 2362 mg/L; 63.3% of the samples had total hardness levels above 250 mg/L, which is the Sri Lankan Drinking Water Quality Standard (SLSI 614:2013) for total hardness. This suggests that the groundwater in the study area is generally hard. The high hardness of the groundwater in the study area is likely due to the presence of calcium and magnesium ions in the water. These ions can be leached from rocks and minerals into the groundwater.

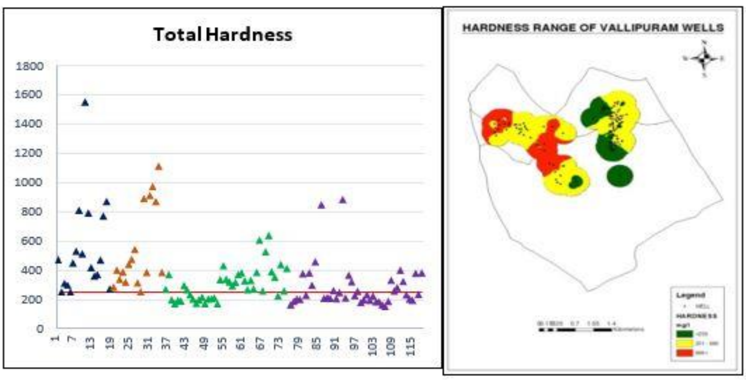

Figure 6: Variation of total hardness of Groundwater and Spatial distribution in the study area

The calcium content of the groundwater in the study area ranged from 26 to 360 mg/L; 43.8% of the samples had calcium levels below 100 mg/L. Mikunthan et al. (2013) reported that the calcium concentration varied from 49 mg/L to 286 mg/L in Jaffna region.

Microbiological quality of the water

Total coliforms were detected in 97% of the wells in the study area in the range of 12 to 2000 colony forming units (CFU) per 100 milliliters (mL) of water with the average of 1772 CFU/mL. These findings indicate that the groundwater in the study area is heavily contaminated with total coliforms. Total coliforms are a group of bacteria that are commonly found in the environment. While not all total coliforms are harmful to human health, their presence in drinking water is an indicator that other, more harmful bacteria may also be present.

E.coli was detected in 85% of the wells in the study area. The average E.coli count was 403 CFU/mL. The presence of E.coli in the groundwater is a serious concern, as it indicates that the water has been contaminated with fecal matter. E.coli is a type of bacteria that is found in the intestines of humans and animals. Fecal contamination of water can occur when sewage leaks from septic tanks or sewers, or when animal waste is not properly disposed. During the study it was found that 79% of the wells in the study area were located within 20 meters of a septic tank while 21% of the wells were located between 20 and 30 meters of a septic tank. 88% of the wells were unprotected, meaning they did not have a well cover or well walls. These findings suggest that the location and construction of the wells in the study area may be contributing to the contamination of the groundwater.

Heavy metal quality of water

Cadmium and arsenic

All the water samples collected from domestic drinking in study area have not contained arsenic and cadmium at detectable levels.

Water Quality Index (WQI)

Table 2. Water Quality Index

Water quality status	WQI range	WQI with Physical and chemical parameters	WQI with physical, chemical and microbiological
Excellent	0–25	60%	4%
Good	26–50	23.3%	3%
Poor	51–75	5%	1%
VeryPoor	76–100	3.3%	0%
Unsuitable	Above100	8.3%	92%

According to the Water Quality Index by considering physical and chemical quality, there were seventy-two (60%) domestic wells showing excellent water quality and ten (4%) wells were unsuitable for drinking purposes. When microbiological parameters were incorporated, a mere 3 (4%) wells were deemed suitable for consumption. The excess Total coliform and E. coli found in the well water is the main factor reducing its quality

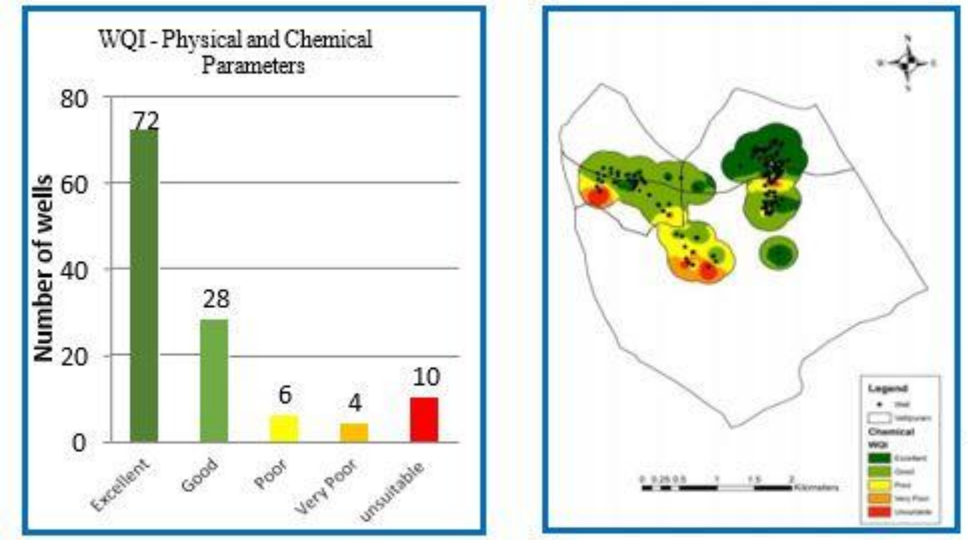

Figure 7: WQI Range of Physical and chemical parameters

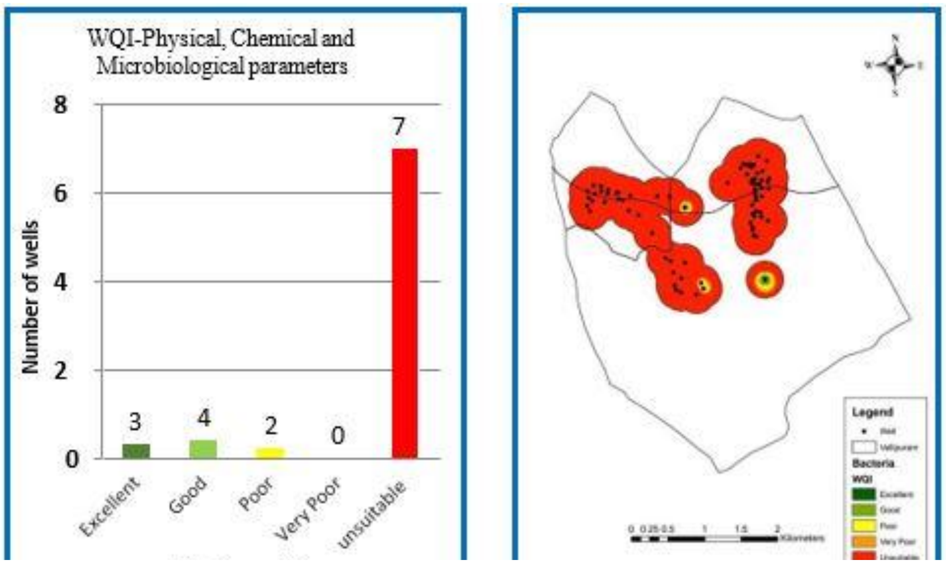

Figure 8: WQI Range of physical, chemical and microbiological parameters