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Assessment of Water Quality Parameters and Determination of Water Quality Index of Tube Well Water in Vengalacheddikulam DS Division,Vavuniya District, Sri Lanka

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Abstract

An attempt was made to analyze the distribution pattern of selected water quality parameters in tube wells and to explore the water quality index of Vengalacheddikulam DS (Divisional Secretariat) division in Vavuniya district. Secondary data of water quality parameters in 60 tube wells were collected from Cheddikulam Pradeshiya Sabha (PS) and Water board of Vavuniya. Nine parameters such as pH, EC, TDS (Total Dissolved Solids), Alkalinity, Total Hardness, Sulphates, Chlorides, Fluorides, and Nitrates were analyzed for this study. WQI was calculated and analyzed based on the existing literatures. IDW technique was deployed to analyze the distribution pattern of this parameters including WQI in the study area. Water quality parameters except TDS and Sulphate were in greater than the acceptable level for human consumption in considerable parts of the study area. Nearly 44% of study area were falls in to above maximum permissible level of alkalinity. The WQI result reveals that nearly 21.5% of area is not suitable for human consumption. Remedial actions to be undertaken to overcome the prevailing water pollution issues in the region.

Keywords: Geographical Information System (GIS); Inverse Distance Weighted interpolation (IDW); Water Quality Index (WQI); Water quality parameters.

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1. Introduction

Ground water resources are the skeleton of earth and human life as they are readily available and have been accomplishing the need of human. Due to the anthropogenic activities such as rapid urbanization, industrialization, pollution, heavy agricultural activities the quality of ground water is diminishing. Therefore, assessment of quality of the ground water resource and the related hydro chemical study is inevitable to undertake suitable management strategies to ensure the water resource is fit for human needs.Geographic Information System (GIS) an effective tool for storing, managing, and displaying spatial data which encountered in water resources management [1]. Spatial interpolation is tool in GIS used to discover the values of unknown points. It is a technique of estimating the values of properties at un sampled locations based on the set of observed values at known locations [2]. Understanding the groundwater quality is important, as it is the main factor determining its suitability for drinking, agricultural and industrial purposes [3]. WQI is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water. Water quality and its suitability for drinking purpose can be examined by determining its quality index for human consumption [4]. It is an arithmetical tool used to convert large number of water quality parameters into a single cumulatively derived number [5]. Water quality indices are such approaches which minimize the data volume to a great extent and simplify the expression of water quality status [6].Objectives of this study are (1) to analyze and assess the distribution pattern of each water quality parameters (2) to explore the water quality index of Vengalacheddikulam DS (Divisional Secretariat) division.

2. Study Area

Vavuniya district is located in north central province of Sri Lanka. The district is situated in the agro ecological region of low country dry zone with a mean annual rainfall of 1400 mm and an average temperature of 28° C [7]. More than 75% of the populations in Vavuniya district depend on the ground water sources to perform their daily needs. The groundwater present in this region characterized as the shallow 'Regolith Aquifer' and the deeper fracture zone aquifer [8]. This ground water found in an irregular pattern in crevices and fractures within rocks with distinct water table. Vengalacheddikulam DS covers total area of 394.8 Sq.Km and 20 GN (Grama Niladhari) divisions [7].

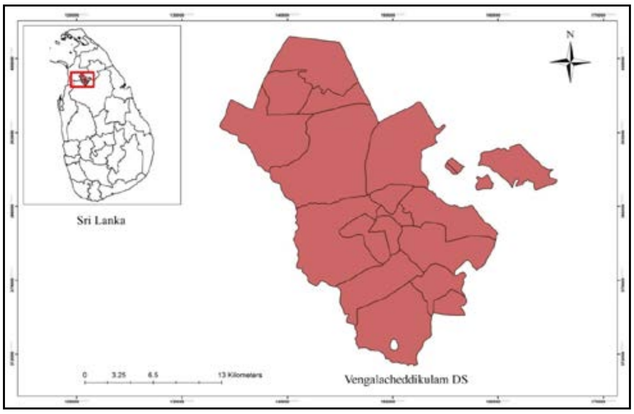

Figure 1: Study area

3. Methodology

Secondary data of water quality parameters in 60 tube wells were collected from Cheddikulam Pradeshiya Sabha (PS) and Water board of Vavuniya district. Nine parameters such as pH, EC, TDS (Total Dissolved Solids), Alkalinity, Total Hardness, Sulphates, Chlorides, Fluorides, and Nitrates were analyzed for this study. IDW (Inverse Distance Weighted) interpolation technique was deployed to analyze the distribution pattern of this parameters including WQI analysis in the study area using ArcGIS 10.2.2 [9, 10].

The resulted map for each water quality parameter was classified according to the desirable and permissible limit of drinking water standards used in Sri Lanka. Percentage of area under each category was calculated using ArcGIS platform. Finally, the Water quality index (WQI) was produced in the study area. The standards for drinking purpose have been considered for calculation of WQI.

The weight for the water quality parameters is considered to be inversely proportional to the recommended standards for the corresponding parameters [11].

Water Quality Index (WQI) is a very useful tool for communicating the information on the overall quality of water [12, 13]. The WQI was used to evaluate the suitability of water that extracted from tube wells from the study area for drinking purposes.

In this study, the calculation was performed based on SLS 2004 (Sri Lankan Standard) for drinking purposes. For the calculation of WQI, the mentioned nine water quality parameters were considered. The parameters in SLS with weight and relative weight was presented in Table 1.

Table 1: Weights and relative weights for studied parameters based on SLS 2004

Parameters	SLS	Weight (wi)	Relative weight (Wi)
EC (mg/L)	750-3500	4	0.118
Chloride (mg/L)	200-1200	3	0.088
Alkalinity (mg/L)	200-400	2	0.059
Fluoride (mg/L)	0.6-1.5	5	0.147
Total Hardness (mg/L)	250-600	3	0.088
Sulphate (mg/L)	200-400	4	0.118
pH	7-8.5	4	0.118
Nitrate (mg/L)	<10	5	0.147
TDS (mg/L)	500-2000	4	0.118
Total		34	1

For this study, parameters such as fluoride and Nitrate were assigned with maximum weight as 5.

The steps followed to calculate the final WQI is given in Figure 2.

Assigning weights for each water quality parameters (w_i) according to its relative importance over other parameters

↓

Calculation of Relative weight (W_i) using a weighted arithmetic index method

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

w_i: weight of each parameter,
n: number of parameter)

↓

Calculation of Quality scale/rating (Q_i) for each water quality parameter

$$Q_i = (C_i / S_i) * 100$$

Q_i - Quality rating (the rating based on concentration of i^{th} parameter.)
C_i – Concentration of the particular water quality parameter
Si - Sri Lanka drinking water standard

↓

Calculation of SIi for each parameter

$$SIi = Wi \times Qi$$

SIi – Sub index for i^{th} parameter
Q_i – Rating based on concentration of i^{th} parameter

↓

The overall water quality index (WQI) was calculated by adding together each sub index values of each groundwater samples as follows

$$WQI = \sum SIi$$

Figure 2: Flow chart of WQI calculation

[9, 14, 15, 16, 17]

Computed WQI values were classified as excellent, good, poor, very poor and unfit water for drinking purposes [5, 18] and it's shown in Table 2.

Table 2: Classification of WQI

WQI	Quality of Water
0-24	Excellent
25-49	Good
50-74	Poor
75-100	Very Poor
>100	Unfit for Drinking

4. Results and Discussion

Table 3 summarizes descriptive statistics of the various physical and chemical parameters such as minimum, maximum, mean and standard deviation of the groundwater samples from the study area.

Table 3: Descriptive statistics of tube well samples in study area

Variable	Minimum	Maximum	Mean	Standard Deviation
EC (mg/L)	166.0	2770.0	1102.7	451.1
TDS (mg/L)	348.0	1850.0	780.4	246.2
Turbidity (mg/L)	0.2	3.0	0.8	0.6
pH	6.5	8.0	7.3	0.3
Chloride (mg/L)	38.0	692.0	129.6	109.1
Hardness (mg/L)	204.0	1064.0	426.4	155.2
Alkalinity (mg/L)	248.0	628.0	398.4	87.5
Sulphate (mg/L)	5.0	73.0	30.9	16.4
Fluoride (mg/L)	0.4	2.1	1.1	0.5
Nitrate (mg/L)	0.004	19.4	5.5	4.8

4.1 Analysis on Distribution pattern of water quality parameters

4.1.1 EC (Electrical Conductivity)

The spatial distribution of EC is shown in Figure 4.

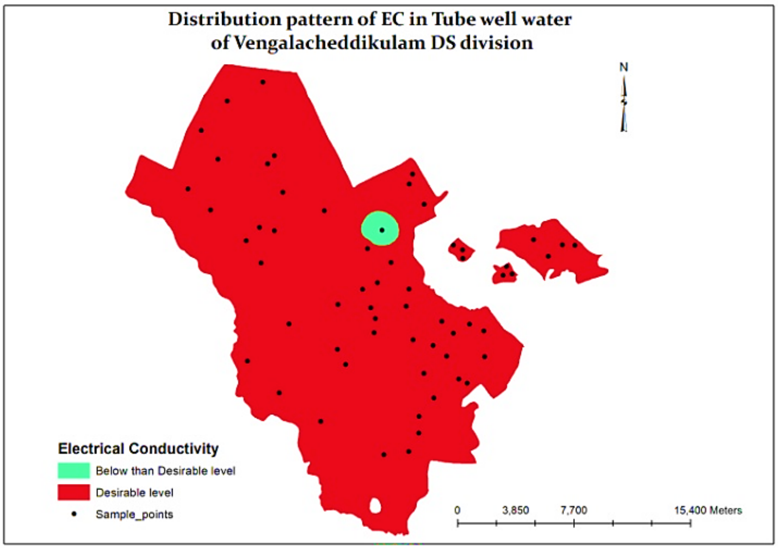

Figure 4: Spatial distribution pattern of EC

Electrical conductivity (EC) is measure of salt content of water in the form of ions. The EC value in study area ranges between 166-2770 mg/L. Only 1% of study area lies within poor range for drinking water purposes while nearly 99% of lies in desirable limit.

4.1.2 pH

The spatial distribution of pH is shown in Figure 5.

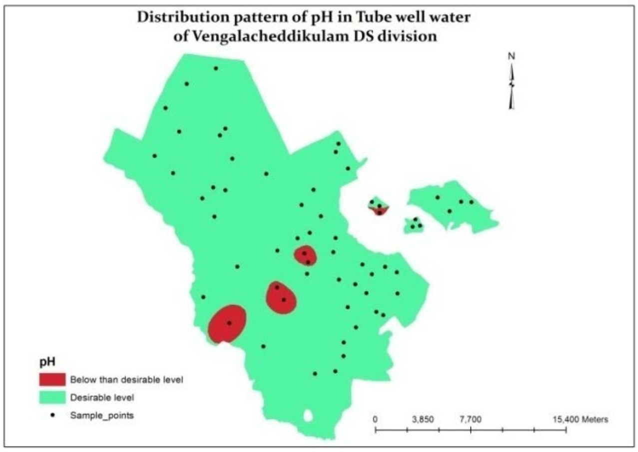

Figure 5: Spatial distribution pattern of pH

The pH value in study area ranges 6.5-8.0. pH is one of the most important parameters in drinking water and determines the acidic and alkaline nature of water [19]. Nearly 3.5% of study area shows below than desirable limit while nearly 96.5% of shows desirable limit regards pH.

4.1.3 TDS

The spatial distribution of TDS is shown in Figure 6.

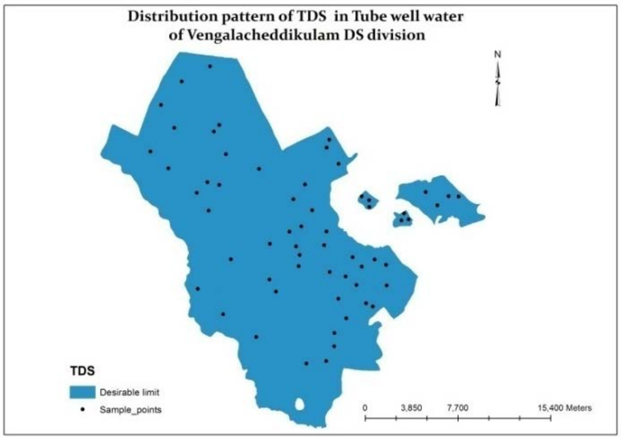

Figure 6: Spatial distribution pattern of TDS

TDS stands for total dissolved solids, and represents the total concentration of dissolved substances in water. TDS is made up of inorganic salts, as well as a small amount of organic matter. The TDS value in study area lies between 348-1850 mg/L, this reveals that almost the whole study area shows safer level of tube well water.

4.1.4 Total Hardness

The spatial distribution of Total hardness is shown in Figure 7.

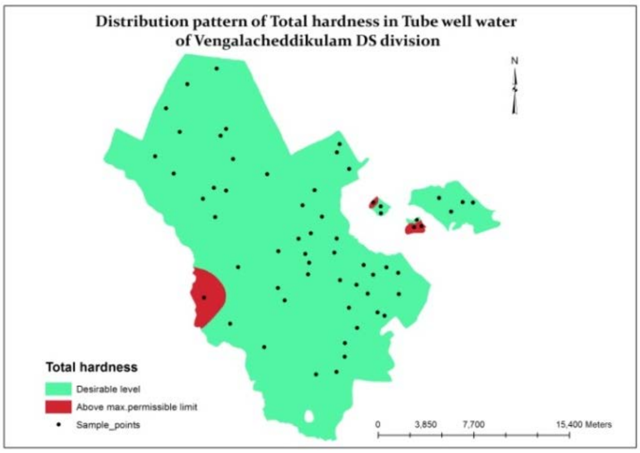

Figure 7: Spatial distribution pattern of Total hardness

The total hardness range in study area ranges from 204 to 1064 mg/L. 97.6% of the study area falls desirable and 2.4% falls above max. permissible limit. Generally, the hardness of the water is due to the presence of alkaline earths such as calcium and magnesium. Higher level of Hardness may cause heart diseases and kidney problems [20].

4.1.5 Chloride

The spatial distribution of Chloride is shown in Figure 8.

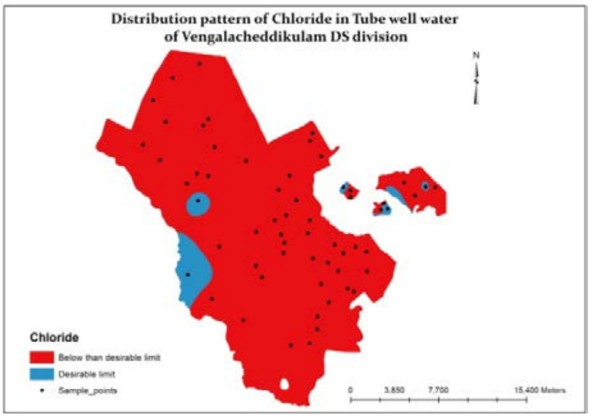

Figure 8: Spatial distribution pattern of Chloride

The origin of chloride in groundwater might be from diverse sources such as weathering, leaching of sedimentary rocks and soils, intrusion of saltwater, windblown salt in precipitation, domestic and industrial waste discharges, municipal effluents, etc. [21]. The Chloride range in study area lies between 38 to 692 mg/L. This reveals that 95.3% of the area falls below than desirable and 4.7% falls in desirable level.

4.1.6 Fluoride

The spatial distribution of Fluoride is shown in Figure 9.

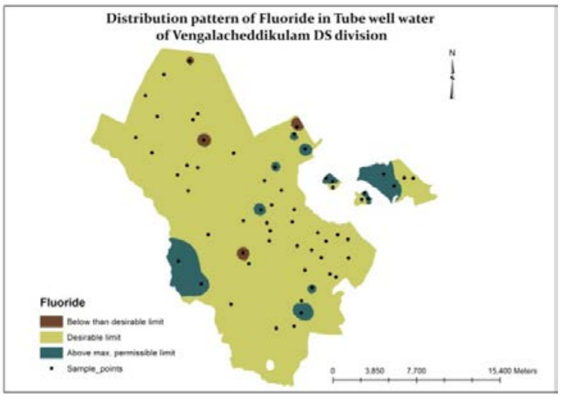

Figure 9: Spatial distribution pattern of Fluoride

Optimum contents of fluoride (0.5mg/l-WHO value) however are essential for the growth of bones and formation of dental enamel, while higher levels (>1.5 mg/L-WHO guideline value) in drinking water may pose a threat to human health such as dental fluorosis (even at 1mg/l), skeletal fluorosis, crippling skeletal fluorosis, renal diseases etc. Further, even at lower concentrations of fluoride, exposure over a long period of time can cause for kidney failures [22]. 7.4% of the study was falls above permissible limit and vulnerable to associated hazards while 0.8% falls within below desirable limit of fluoride

4.1.7 Sulphate

The spatial distribution of Sulphate is shown in Figure 10.

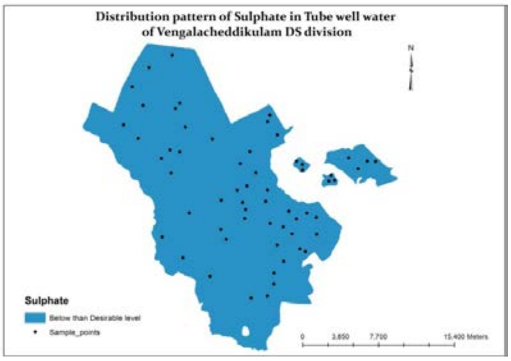

Figure 10: Spatial distribution pattern of Sulphate

Sulfate is one of the major anion occurring in natural waters. Sulphate range 5-73 mg/L and the study area ground water falls within desirable limit.

4.1.8 Alkalinity

The spatial distribution of Alkalinity is shown in Figure 11.

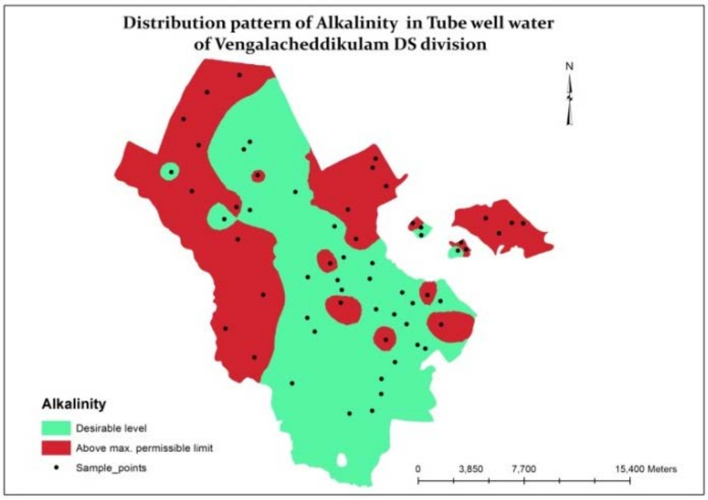

Figure 11: Spatial distribution pattern of Alkalinity

The alkalinity of water is the capacity to neutralize its acidic nature and characterize by the presence of hydroxyl ions. Alkalinity of tube water in the region were 248-628 mg/L. 56%, of the area falls under desirable limit, however 44% study area lies above max. permissible limit.

4.1.9 Nitrate

The spatial distribution of Nitrate is shown in Figure 12.

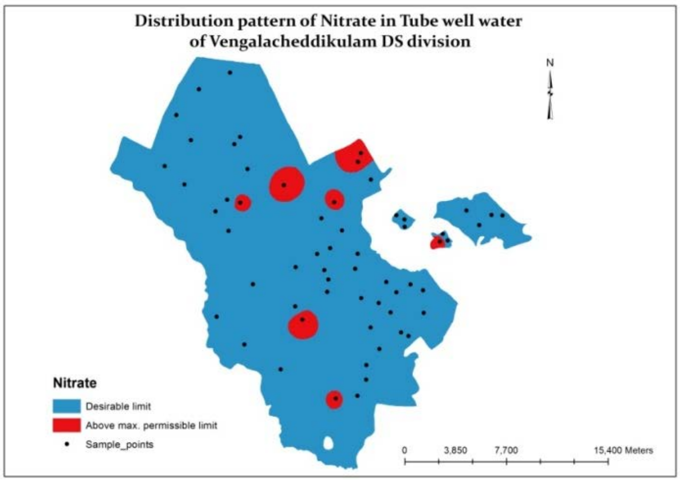

Figure 12: Spatial distribution pattern of Nitrate

Nitrate level in the study area ground water ranges from 0.004 to 19.4 mg/L. Only 4.6% of the study area falls above maximum permissible limit. Nitrate has been implicated a number of currently inconclusive health outcomes such as cancer hypertension, increased infant mortality, central nervous system birth defects, diabetes, spontaneous abortions, respiratory tract infections, and changes to the immune system [23, 24].

4.2 WQI Analysis

The spatial distribution of WQI of the study area is shown in Figure 13.

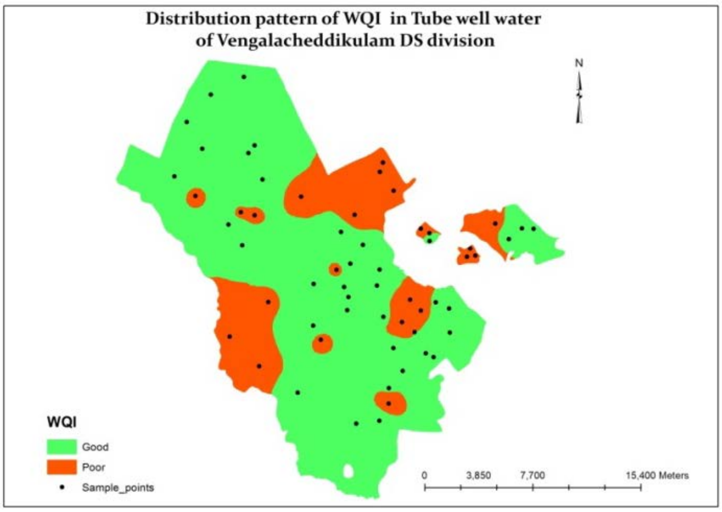

Figure 13: Spatial distribution of WQI

From the Comprehensive assessment by considering all water quality parameters, 78.5% of the study area is in safe zone to access the drinking water. Nearly 21.5% was considered as potential risk area where the water is not fit for the human consumption.

It clearly shows that the remedial measures should be taken to in Vengalacheddikulam DS division are in order to avoid the water related diseases.

5. Conclusion

Water quality parameters except TDS and Sulphate level were greater than the acceptable level for human consumption in considerable parts of the study area. GIS techniques can be used for its effective decision making ability on water pollution assessment Nearly 44% of study area falls in to above maximum permissible level of alkalinity.

WQI result indicated that nearly 21.5% of area is not suitable for human consumption. Therefore, the inhabitants of this area may be more vulnerable to the associated health hazards.

It is recommended to take necessary action in order to overcome the existing ground water related problems in the study region.

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