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Assessment on Water Quality Index for The Ground Water in Southern Part of Tamilnadu

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ABSTRACT
Anthropogenic activities over the years had adversely affected the environment especially the aquatic ecosystem. This paper aims to compare the ground water quality status of Tirunelveli District of Tamil Nadu. The ground water samples were collected and analyzed for 24 physical-chemical parameters as per the standard procedures. Subsequently, the ground water quality is determined using 4 different Water Quality Index (WQI) methods such as Arithmetic mean index, geometric mean index, NSFWQI and BCWQI. The results indicated that the qualities of the ground water samples were therefore not suitable for human consumption without adequate treatment. Regular monitoring of groundwater quality, abolishment of unhealthy waste disposal practices and introduction of modern techniques are recommended. Further actions should be taken into consideration to further improve the quality of ground water, hence, promoting a healthier environment to the surrounding communities.
Keywords : Ground water, Water quality index, Physico-chemical parameters, Tirunelveli District.

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INTRODUCTION

Protecting of water bodies for all purposes such as, drinking, recreational activities, and fish and wildlife, requires regular assessing and monitoring of their quality status. Hydrochemical facies are varies in groundwater aquifers due to differing lithologiesn. Aris [2] reported that mineral weathering, saline water intrusion, chemical fertilizers, organic manure, domestic sewage and the oxidation of organic carbon by nitrate are the source of variation in hydrochemistry of groundwater. United Nations Enviroment Programme [12] has reported that 75% of the population in developing countries lack adequate sanitary facilities and dump most of their waste into the nearest water bodies such as streams, rivers, lakes, and estuaries, lagoons and the seas, thereby polluting such water body. Consequently, water related diseases such as cholera, typhoid fever, hepatitis and dysentery are rampant.

Water quality index is one of the most effective tools to monitor the surface as well as ground water pollution and can be used efficiently in the implementation of water quality upgrading programmes. The objective of an index is to turn multifaceted water quality data into simple information that is comprehensible and useable by the public. Water quality index was first formulated by Horton [7] and later on used by several workers for the quality assessment of different water resources. It is one of the aggregate indices that have been accepted as a rating that reflects the composite influence on the overall quality of numbers of precise water quality characteristics [10]. Water quality index provide information on a rating scale from zero to hundred. Higher value of WQI indicates better quality of water and lower value shows poor water quality.

Advantages of Water Quality Index

- Conveniently summarizes complex water quality data
- Facilitates clear communication of results to a large general audience
- Provides mechanism to gauge/trend several parameters over several years
- A wide range of parameters can be used simultaneously within the index, including the use of biological indicators (bacteria levels), physical parameters (dissolved oxygen, turbidity, dissolved solids) and chemical parameters (concentration of heavy metals, petroleum products)

- Compliance values or standards (as established by a written Code or other regulatory document) for each parameter can readily be incorporated into the index

Hence, the present study was carried out to evaluate and compare the status of ground water of Batlagundu town in Dindigul District and Tirunelveli District as a part of continuous monitoring.

MATERIAL AND METHODS

In order to determine water quality index, ground water samples collected from six sampling stations in triplicates. Samples were collected in polythene bottles and analyzed for various water quality parameters as per standard procedures APHA, AWWA, WPCF [1], Trivedi and Goel [11] and NEERI [8] given in Table 1.

Table 1: Water quality parameters units and analytical methods used

S.N	Parameters	Abbreviation	Units	Analytical Methods	Instruments
	Physical Parameters				
1.	Temperature	Temp	^{0}C	Instrumental	Mercury Thermometer
2.	Colour	Colour	Pt-Co Scale	Visual comparison method	---
3.	Turbidity	Turbidity	NTU	Nephelometric method	Nephelometer
4.	Odour				
5.	Total Dissolved Solids	TDS	mg/L	Filtration and Gravimetric method	Temperature controlled oven
6.	Electrical conductivity	EC	µS/cm	Instrumental	Electrometric
	Inorganic Parameters				
7.	pH	pH	pH unit	Instrumental	pH meter
8.	Total Hardness	Hardness	mg/L	Digital Titrimetric	EDTA Titration
9.	Total Alkalinity	Alkalinity	mg/L	Digital Titrimetric-	Neutralising With standard HCl
10.	Calcium	Ca	mg/L	Digital Titrimetric	EDTA Titration
11.	Magnesium	Mg	mg/L	Digital Titrimetric	EDTA Titration
12.	Chloride	Cl	mg/L	Digital Titrimetric	Argentometric Titrimetric method
13.	Sulphate	SO_4	mg/L	Colorimetric Turbidimetric method	UV – VIS Spectrophotometer
14.	Nitrate	NO_3	mg/L	Colorimetric PDA method	UV – VIS Spectrophotometer
15.	Nitrite	NO_2	mg/L	Diazotisation Method	UV – VIS Spectrophotometer
16.	Fluoride	F	mg/L	Colorimetric SPANDS method	UV – VIS Spectrophotometer
17.	Sodium	Na	mg/L	Flame photometric method	Flame Photometer
18.	Potassium	K	mg/L	Flame photometric method	Flame Photometer
19.	Iron	Fe	mg/L	Colorimetric method	UV – VIS Spectrophotometer
20.	Ammonia	NH_3	mg/L	Nesslerization method	UV – VIS Spectrophotometer
	Nutrient/Organic Parameters				
21.	Phosphate	PO_4	mg/L	Colorimetric Stannous chloride method	UV – VIS Spectrophotometer
22.	Dissolved Oxygen	DO	mg/L	Titrimetric method	Winklers Iodometric method
23.	Biochemical Oxygen Demand	BOD	mg/L	5 days incubation,20^0C	Winkler Azide Method
24	Chemical Oxygen Demand	COD	mg/L	Potassium dichromate oxidation(open reflux,titrimetric)	Dichromate method

Study area and sampling sites

Tirunelveli District

The Tirunelveli District is located in southern part of Tamilnadu and surrounded by Virudhunagar District on the North. Thoothukudi District on the East, Kanyakumari District on the South and Western Ghats on the West. Tirunelveli has its own individuality from rice to culture. The name Tirunelveli has been composed from the three Tamil words is "Thiru-Nel-Veli" meaning “Sacred Paddy Hedge". Tirunelveli Palayamkottai is popularly known as "Oxford of South India". The Tirunelveli District is located in the world map, between 08.8’ 09.23’ latitude and 77.09’ and 77.54’longitude. This District is having 3 Revenue Divisions comprising of 11 Taluks, 19 Development Blocks, 556 Revenue Villages and 425 Village Panchayats. The maximum precipitation is contributed by the North East Monsoon (555.08mm) followed by the South west monsoon(189.6mm)and the Summer (127.7mm) and the Winter (74.5 mm) The total geographical area of the District is 6,823 sq.km. Map of the study area is given in Figure (1). The description of sampling sites is given in Table 2.

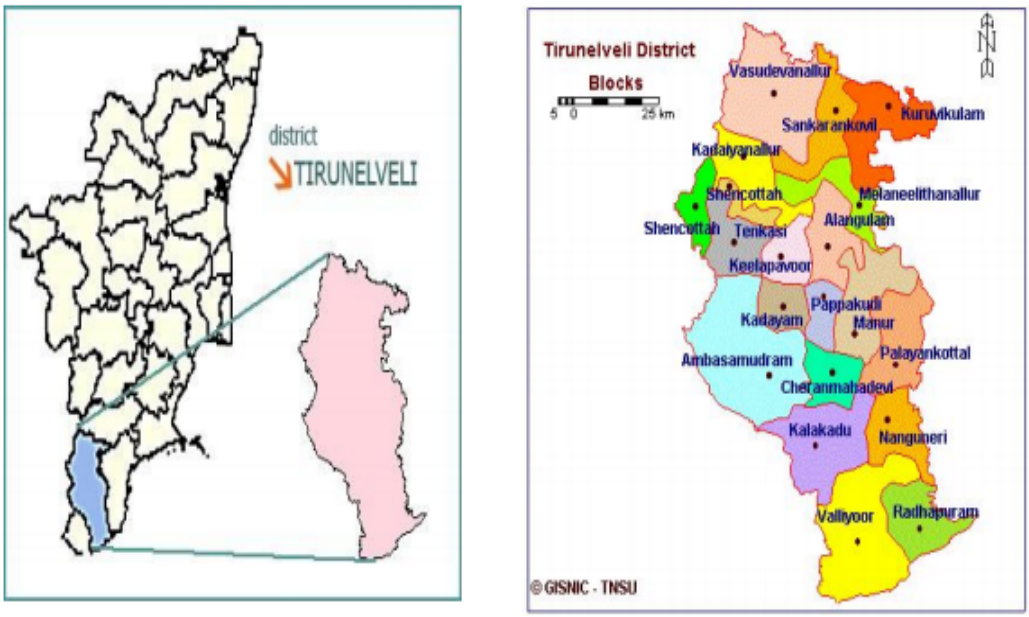

Fig.1 Map of 19 blocks in Tirunelveli District

Table 2 : Description of 19 sampling sites in Tirunelveli District

Site No	Sampling Sites
S_1	Ambasamudram
S_2	Alangulam
S_3	Cheranmadevi
S_4	Kalakad
S_5	Kuruvikulam
S_6	Keelapavoor
S_7	Kadayam
S_8	Kadayanallur
S_9	Meelaneelitha Nallur
S_{10}	Manur
S_{11}	Nanguneri
S_{12}	Pappakudi
S_{13}	Palayamkottai
S_{14}	Radhapuram
S_{15}	Shencottai
S_{16}	Sankarankovil
S_{17}	Tenkasi
S_{18}	Vasudevanallur
S_{19}	Valliyoor

Water Quality Index (WQI)

The water quality index (WQI) is a mean to summarize large number of water quality data into simple terms for reporting to management and the public in a consistent manner. It is recognized as one of the most effective way of communicating information on water quality to both citizens and policy makers. It may be defined as a 'rating that reveals the composite influence of a number of water quality parameters on the overall water quality'. It is a single value indicator to the water quality. It integrates the data pool generated after collecting due weights to the different parameters. Numerous water quality indices have been formulated all over the world which can easily judge out the overall water quality within a particular area promptly and efficiently. In this study, four different methods have been used to calculate WQI on the basis of measured physico chemical parameters. It is calculated from the point of view of the suitability of ground water for human consumption at selected sampling sites of S_1 to S_{11} in Tirunelveli district.

RESULTS AND DISCUSSION

Physico chemical parameters

In order to determine the water quality, ground water samples collected from sampling stations in triplicates. Samples were collected in polythene bottles and analyzed for 24 physico-chemical parameters as per standard procedures APHA [1] and Trivedi and Goel [11]. The experimental values were compared with standard values recommended by World Health Organization [13] and Indian standards for drinking purposes [4].

The sampling site Tenkasi (S_{17}) of Tirunelveli district show minimum values for eight water quality parameters namely turbidity, total dissolved solids, electrical conductance, total hardness, calcium, magnesium, sulphate and sodium. The sampling site Ambasamudram (S_1) show maximum values for four parameters such as total dissolved solids, electrical conductance, chloride and sulphate. High concentration of these parameters influences the taste, hardness and corrosive property of water. The remaining sampling sites were within the range of WHO [13] and BIS [4] limits.

Water Quality Index (WQI)

WQI calculation by US National Sanitation Foundation Water Quality Index, NSF-WQI [5]

In this study the water quality index (WQI) was determined according to National Sanitation Foundation (Brown *et al*., 1970) which created and designed a standard index. The mathematical expression for NSFWQI is given by

$$NSF\ WQI = \sum_{i=1}^{p} W_i I_i \text{----------(1)}$$

Where

I_i = sub index for i^{th} water quality parameter.

W_i = weight associated with i^{th} water quality parameter.

p = number of water quality parameters.

The physico chemical parameters such as dissolved oxygen (DO), pH, biochemical oxygen demand (BOD), temperature, total phosphate, nitrate and turbidity are used to calculate WQI. The results are recorded and transferred to a weighting curve chart where a numerical value is obtained. For each test, the numerical value or Q value is multiplied by a "weighting factor". The resulting values are then added to arrive at an overall water quality index.

This index is simple and requires minimum water quality data for calculations. All sampling sites S_1 to S_{19} in Tirunelveli district showed medium water quality and are varied from 52.13 to 67.58. It is often noticed that sudden changes in water temperature and oxygen saturation levels are attributed to change the WQI.

WQI calculation by weighted arithmetic index method [5]

This method has been used for the calculation of WQI with eleven physico chemical parameters. The parameters are pH, total alkalinity, total hardness, total dissolved solids, calcium, magnesium, chloride, nitrate, sulphate, Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD). WQI has been calculated by using the standards of drinking water quality recommended by the Bureau of Indian standards [4] and Indian Council for Medical Research (1975). The quality rating or sub index (q_n) was calculated using the following expression.

$$WQI = \frac{\sum q_n w_n}{W_n} \text{----------(2)}$$

$$q_n = 100 \frac{[V_n - V_{10}]}{[S_n - V_{10}]} \text{----------(2a)}$$

where

q_n = Quality rating for the n^{th} quality water parameter

V_n = Estimated value of the n^{th} parameter at a given sampling station
S_n = Standard permissible value of the n^{th} parameter
V_{10} = Ideal value of n^{th} parameter in a pure water

Ideal value in most cases V_{10} = 0 except in certain parameters like pH and DO. Calculation of quality rating for pH and DO ($V_{10} \neq 0$) is 7.0 and 14.6 mg/L respectively. Unit weight was calculated by a value inversely proportional to the recommended standard values S_n of the corresponding parameters.

$$W_n = \frac{K}{S_n} \text{----------(2b)}$$

where
W_n = Unit weight for the n^{th} parameter
S_n = Standard permissible value of the n^{th} parameter
K = Constant for proportionality
The overall water quality index was calculated by aggregating the quality rating with the unit weight linearly. The suitability of WQI values for human consumption is rated as 0-25 = Excellent, 26-50 = Good, 51-75 = Poor, 76-100 = Very poor, >100 = Unfit for drinking.(Table 4).
WQI indicates the quality of water in terms of index number which represents overall quality of water for any intended use. In Tirunelveli district S_1 to S_{19}, the sampling site Kalakad (S_4) (86.13) found under very poor category (76-100) and rest of the sampling sites found under poor category over the study period. This water quality rating study clearly shows that, the status of the water body is eutrophic and it is unsuitable for the human uses.

WQI calculation by geometric mean index method [10]

Water quality index is calculated using geometric mean index method proposed by Tiwari and Mishra [10]. For calculating WQI, the following steps were used.

$WQI = \sum_{n=1}^{14}(SI_n) = \sum_{n=1}^{14}(Q_n)^{W_n}$ OR WQI= $antilog_{10\ (\sum_{n=1}^{14} W_n log_{10} Q_n)}$----(3)

$$Q_n = 100\frac{[V_n - V_i]}{[V_s - V_i]} \text{----------(4a)}$$

Where
Q_n = Quality rating
V_n = Actual amount of n^{th} parameter
V_s = Recommended WHO standard of corresponding parameter
V_i = the ideal value of this parameter
V_i = 0 except for pH and DO
V_i = 7.0 for pH
V_i = 14.6 mg/L for DO

Unit weight (W_n) was calculated by a value inversely proportional to the recommended standard values S_n of the corresponding parameters.

$$W_n = \frac{K}{S_n} \text{----------(3b)}$$

S_n = Standard permissible value of the corresponding parameter prescribed by WHO
K = Constant for proportionality

$$\sum_{n=1}^{14} W_n = 1 \text{----------(3c)}$$
$$SI = (Q_n)^{W_n} - - - - - - - (3d)$$

In this study, for the calculation of WQI fourteen parameters were chosen. The parameters are pH, turbidity, conductivity, total alkalinity, total dissolved solids, total hardness, calcium, magnesium, chloride, fluoride, iron, dissolved oxygen, biochemical oxygen demand and chemical oxygen demand. The WQI has been calculated by using the standards of drinking water quality recommended by the World Health Organisation [13]. The sampling sites of S_1 to S_{19} in Tirunelveli district are fluctuated between good to poor water quality and are varied from 69.20 to 177.84. Higher WQI can therefore be considered as unfit for human consumption without prior treatment.

WQI calculation by British Columbia Water Quality Index [3]

British Columbia Water Quality index was developed by the Canadian Ministry of Environment as increasing index to evaluate water quality. It provides possibility to make a classification on the basis of all existing parameters. This method is calculated using 12 parameters such as pH, total alkalinity, total hardness, calcium, nitrate, nitrite, phosphate, chloride, total dissolved solids, magnesium, dissolved oxygen and biochemical oxygen demand. The following expression is used for the calculation

$$BCWQI = \left[\frac{\sqrt{F_1^2 + F_2^2 + \left(\frac{F_3}{3}\right)^2}}{1.453}\right] \quad \text{…….. (4)}$$

The number 1.453 was selected to give assurance to the scale index number from zero to 100. It is important to note that respected samplings and increasing stations increase the accuracy of British Columbia index. The BCWQI model consists of three measures of variance from selected water quality objectives (Scope; Frequency; Amplitude).

Scope (F1): The number of variables whose objectives are not met.

Frequency (F2): The frequency by which the objectives are not met.

Amplitude (F3): The amount by which the objectives are not met.

The measure for scope (F1) is calculated as follows:

F1 = [Number of failed variables/Total number of variables] X100 …….. (4a)

The measure for Frequency (F2) is calculated as follows:

F2 = [Number of failed tests/Total number of tests] X100 …….. (4b)

The measure for Amplitude (F3) is calculated as follows:

The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as follows.

When the test value must not exceed the objective

$Excursion_1 = (Failed\ test\ value|Objective) - 1$……(4c) For the cases in which the test value must not fall below the objective

$Excursion_2 = (Objective|Failed\ test\ value) - 1$…….. (4d)

$$\text{nse} = \frac{\sum_{i=1}^{n} excursion}{no.of\ tests} \text{……} (4e)$$

$$F_3 = [\frac{nse}{0.01\ nse + 0.01}] \text{……} (4f)$$

In this method BCWQI is used for the determination of overall water quality of study area. Low values of BCWQI have been attributed to high level of impurities. The point of interest from the results refers to BCWQI for the raw water as the drinking water resource, which appears to be less satisfactory (45.0-64.9) in the studied area such as S_1 to S_{19} in Tirunelveli district (47.23) [9]. This may reflect the discharge of pollutants to a water resource system from domestic sewers, storm water discharges, industrial effluents and agricultural runoff. This clearly indicates that the water must be treated to remove physical and chemical impurities.

The WQI values for 4 methods for all the sampling sites in Tirunelveli district are given in Table 4 .

CONCLUSION

Due to lack of experts in water analysis and poor inspection of water quality of study area, the water quality indices for particular consumption are considered as a simple method for the primary recognition of ground water quality. Therefore, the study of WQI concluded that the water quality at all the sampling sites in Tirunelveli district, most of the methods report more or less same range. The total quality of the water in those sampling sites is being studied and can also be applied to all other sampling sites under investigation. The spatial distribution of WQI generated in this study will also be of much use for the planners in the management and monitoring of water resources.

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