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(RESEARCH ARTICLE)

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Physio-chemical and bacteriological quality of well water from Kottayam district, Kerala

Anju Ajikumar *, Neethu Nair MN and Punnen Kurian

Research Laboratory Department, Tropical Institute of Ecological Sciences Velloor, Kottayam, Kerala, India.

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Abstract

This study focused on determining of physio-chemical, Biological and Weighed water quality index of well water samples from twelve different stations in Kottayam district, Kerala. The water samples analyzed for physio-chemical parameters including pH, Electrical conductivity, TDS (Total Dissolved Solids), Total iron, Bacterial contamination and water quality index was calculated. All 120 samples were analyzed separately and were compared with the water quality standard prescribed by the APHA and IS 3025. It was found that the mean pH values showed slight variations ranging from 5.85±0.72- 7.19±2.09. The electrical conductivity showed variations ranging from 64.9±46.34- to 366.4±561.8. The well water samples were shown the TDS value under the permissible limit with a range of 42±39.8-248.2±393.03. A significant variation in total iron value was obtained from the Neendoor station and the range is 0.0033±0.0069-0.5525±1.703. Weighted water quality index was calculated based on physiochemical parameters and it is evident that the water from Neendoor station is unsuitable for drinking purposes. The bacterial concentrations of Pampady station showed 90% contamination and 65.8% of water samples were showed Indicator organism *Escherichia coli.*

Keywords: Physicochemical; Electrical conductivity; Total dissolved solids; Total Iron; Weighted Water Quality Index; Bacterial concentration; *Escherichia coli*

1. Introduction

Water is one of the most sensitive elements of the environment and is essential to human life as well as operations involving industry, agriculture, and other sectors. The increased rate of industrial development and population growth over the past few decades has resulted in a massive rise in the demand for fresh water[1]. Safe drinking water is a basic requirement for good health and it is also a basic human right. Nowadays, fresh water is becoming scarce in many regions of the world. It will become even more restrictive in the coming century as a result of increased urbanization, population growth, and climate change[2].As the world's population grows, so does the need for water supplies. In certain ways, human activities "squeeze" our oceans, rivers, and other inland waters not so much that they take up less space, but so that their quality suffers. It has been suggested that water pollution is the greatest global cause of fatalities and diseases, accounting for the deaths of more than 14,000 people per day[3].

Kerala's drinking water system is regulated and maintained by the state government, through the Kerala Water Authority (KWA), and local governments.All 44 rivers that originate in the Western Ghats of Kerala's Southern district are dying slowly and losing their natural flow patterns as a result of the combined impact of various interventions in the catchments and inside the river channel, such as deforestation of catchment areas, forest fragmentation, dams impeding flow, encroachment, and massive hill mining[4].

*Corresponding author: Anju Ajikumar

Kottayam is a district in the Indian state of Kerala. It is located in central Kerala. Kottayam district has a total area of 2208 sq. km [5]. The district is naturally divided into highland, midland and lowland, the bulk being constituted by the midland regions [6]. The district is bordered by the lofty and mighty Western Ghats on the east and the Vembanad Lake and paddy fields of Kuttanad on the west. The important rivers of the district are the Meenachil River, the Muvattupuzha River and the Manimala River. Kottayam's 2024 population is now estimated at 853,635.[UN World population review]. Ground water is the major source of drinking water in Kottayam district.Water quality is the link between all hydrological properties, including physical, chemical, biological, and microbiological markers, that describe the biotic and abiotic conditions of an ecosystem.[7].Groundwater is a vital supply of drinking water, but its quality is under threat due to over-abstraction, microbiological and chemical contamination.[8]In the present study a physical and bacteriological analysis was carried out for the well water samples from twelve different locations of Kottayam district, Kerala.

2. Material and methods

2.1. Study Area

In the present study, well water samples were randomly collected from twelve geographically different locations representing hilly terrain, semi- hilly terrain, and plain land of Kottayam district.The selection criteria of the sampling locations were based on characteristics of water conditions, land use, and anthropogenic activities, from the watersheds of Meenachil&Manimala River.

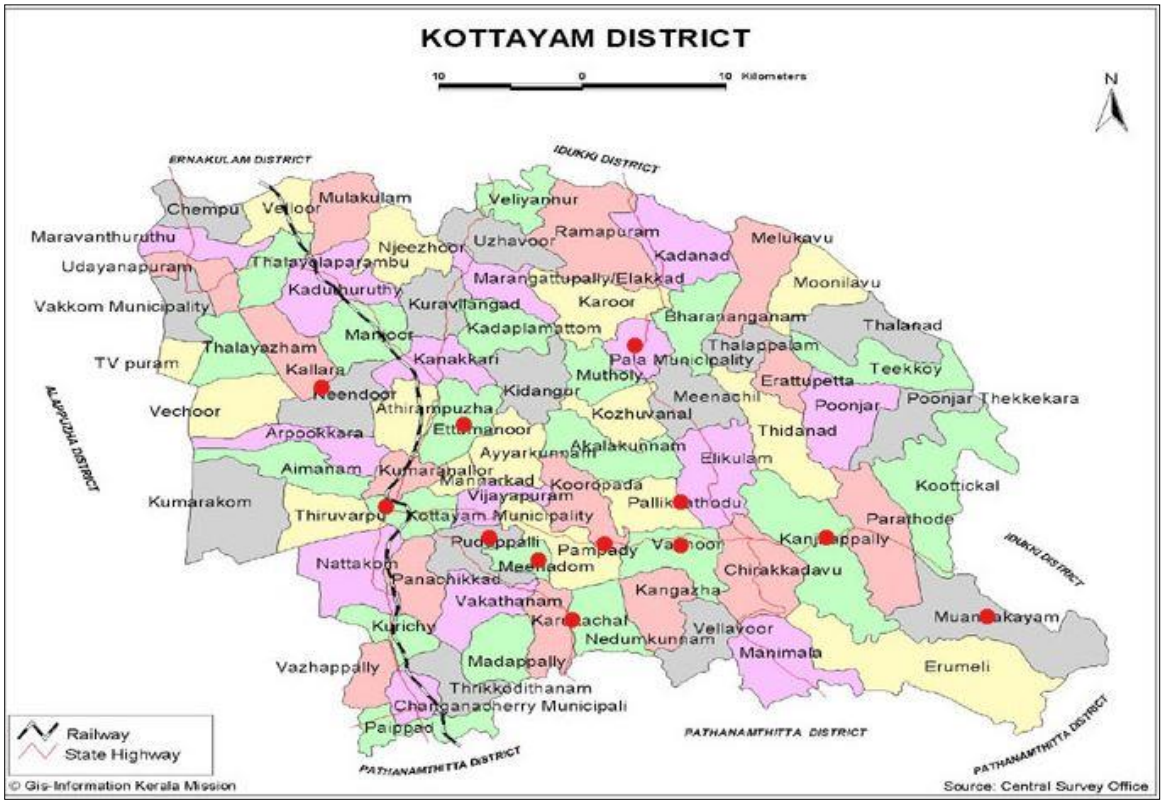

Figure 1 Location map of study area

Table 1 Sampling stations

Station No.	Station Name	Longitude [^{0}N]	Latitude [^{0}E]
1	Pala	9.7073	76.6732
2	Ettumanoor	9.6311	76.5660
3	Neendoor	9.6853	76.5055
4	Meenadom	9.5513	76.6161
5	Puthuppally	9.5653	76.5662
6	Kottayam	9.5984	76.5282
7	Karukachal	9.5016	76.6400
8	Pampady	9.5657	76.6442
9	Pallikkathod	9.6042	76.6813
10	Vazhoor	9.5599	76.7048
11	Kanjirappally	9.5595	76.7874
12	Mundakkayam	9.5371	76.8864

2.2. Sample Collection

The samples were collected from twelve stations and in each station ten well water samples were collected randomly from 1st March 2023 to 31st March 2024. The samples were collected in sterilized bottles with the necessary precautions as per IS3025.

2.3. Sample Analysis

2.3.1. Bacteriological analysis

The bacteriological analysis of water was done using the ISI622- 1981 (1996 reaffirmed) test method.MPN is performed here to ensure whether the water is safe for drinking or not. 10 ml of the sample was inoculated in double-strength tubes, 1 ml of the sample in three single-strength tubes, and 0.1 ml of the sample in another three single-strength tubes. The tubes were kept in an incubator at 37^{0}C for 24- 48 hrs for the detection of total coliform bacteria. Similarly, another set of tubes was kept in Incubator at 41^{0}C for 24 hrs for the detection of fecal coliform bacteria. For the confirmation test, the inoculums were transferred from a turbid-positive tube in the presumption test to an EMB agar plate using a sterile loop. The plate was incubated for 24 hrs and checked for bacterial growth.

2.3.2. Physio- Chemical analysis

Electrical conductivity& TDS

The physio–chemical parameters such as Electrical conductivity and Total dissolved solids were detected using an ESICO Microprocessor multi-parameter analysis meter. 0.1N potassium chloride was used as the standard and the probe was dipped in sample solution until a stable value was obtained.

pH

pH was detected using Systronix Digital meter, it was standardized with a buffer solution of pH range between 4 and 9.

Total iron

Total iron was analyzed using a Systronix UV-visible spectrophotometer. To 20.75 ml of the water sample, 2.5 ml sodium acetate buffer was added and mixed. 0.5 ml of Hydroxylamine hydrochloride was added to the flask and mixed. Finally, 1.25 ml of the 1,10 Phenanthroline solution was added and mixed thoroughly. Transfer portions of the solutions to the spectrophotometer test tubes. A standard was also prepared using Ferrous ammonium sulfate hexahydrate with concentrations 0, 0.5, 1,2, 2.5, and 3. Using the blank, zero the instrument at a wavelength of 508 nm. Readings of standards were taken and a calibration curve of Absorbance vs Concentration of iron obtained.

2.4. Statistical analysis

All data generated was analyzed statistically by calculating the mean and standard deviation and compared the values with the acceptable standards. Data collected was statistically analyzed using Microsoft Office Excel.

2.4.1. Water quality Index

WeightedArithmetic Water Quality Index is a popular method for classifying drinking water. WA-WQI is simple to use. It weighs water qualities based on their significance and allows users to select the water quality factors to include in the process.WA-WQI is calculated by using the following equation [9],

$$\mathbf{WQI} = \frac{\Sigma \mathbf{Q_I W_i}}{\Sigma \mathbf{W_i}}$$

3. Results and discussion

3.1. Bacteriological analysis

In this study, all sampling sites were detected for total, fecal coliforms and E.coli with the highest percentage of 90% in station 8 Pampady and the lowest percentage of 40% in Kanjirappally -station 11.The total coliform group has been considered as the primary bacteria for detecting the presence of disease-causing organisms in drinking water. It is the key indicator of water's appropriateness for human consumption. If there are a lot of coliforms in the water, there are likely other pathogenic bacteria or organisms[10]. The coliform bacteria include the genera *Escherichia*, *Citrobacter, Enterobacter, Klebsiella,* etc[11] Coliform bacteria are unlikely to cause any sickness. However, their existence in drinking water suggests that disease-causing organisms may be present in the water system [12].

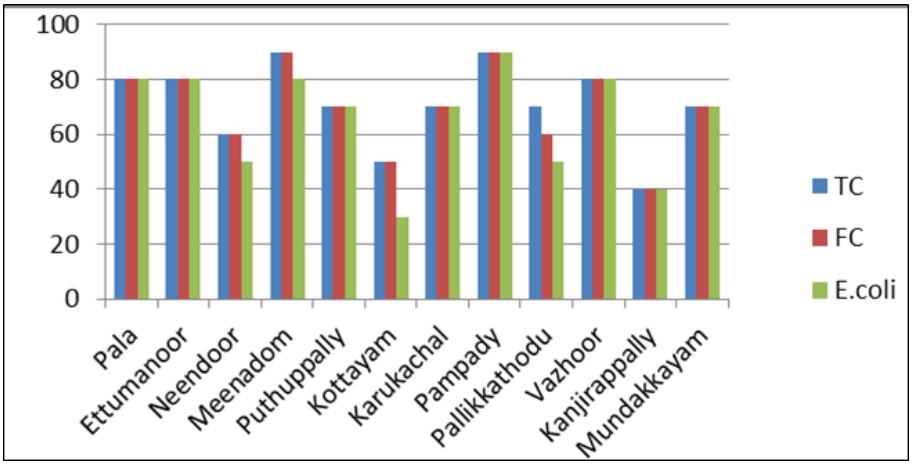

Figure 2 Percentile values of Total coliform from the study area

Table 2 Percentage of Coliform count in each station

Station name	TC %	FC%	*E.coli%*
Pala	80	80	80
Ettumanoor	80	80	80
Neendoor	60	60	50
Meenadom	90	90	80
Puthuppally	70	70	70
Kottayam	50	50	30
Karukachal	70	70	70
Pampady	90	90	90

Pallikkathodu	70	60	50
Vazhoor	80	80	80
Kanjirappally	40	40	40
Mundakkayam	70	70	70

3.2. pH

WHO recommends a maximum pH level of 6.5 to 8.5. The average PH of the tested samples ranges between 5.85±0.72-7.19±2.09.Hence, majority of the sample are slightly acidic and Neendoor station showed an average of 5.8. The acidic nature of the water may be due to the high level of organic pollution. Studies have shown that solutions with lower pH levels are more likely to dissolve heavy metals from the environment[13].This is a concern because exposure to heavy metals can be dangerous, leading to heavy metal poisoning and toxicity, with symptoms including**:** diarrhea, vomiting, weaknes, organ damage and suppression of immune system[14].

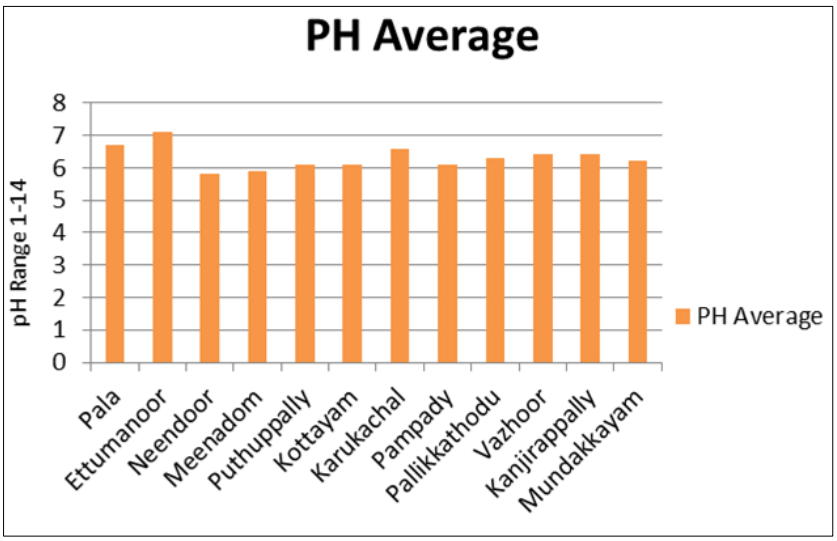

Figure 3 Mean values of pH from the study stations

Table 3 pH range and mean standard deviation of each station

Station no.	Station name	Range	Mean ± SD
1	Pala	5.85 - 7.38	6.78±0.48
2	Ettumanoor	5.65 - 11.24	7.19±2.09
3	Neendoor	4.11 - 6.86	5.85±0.72
4	Meenadom	4.75 -6.92	5.96±0.618
5	Puthuppally	4.41 - 7.63	6.18±1.53
6	Kottayam	4.8 - 6.9	6.1±0.68
7	Karukachal	5.2 - 8.79	6.64±1.310
8	Pampady	4.45 - 7.29	6.18±0.803
9	Pallickathodu	5.39 - 8.16	6.38±0.728
10	Vazhoor	5.57 - 7.5	6.4±55.5
11	Kanjirappally	5.48 - 7.19	6.41±0.75
12	Mundakkayam	5.13 - 9.33	6.2±1.236

3.3. Electrical Conductivity

According to APHA, the desirable limit of conductivity for drinking water is 110 µS/cm. The current investigation indicated that the mean range of EC value is from 64.9±46.34- 366.4±561.8 with the lowest range from Pallikkathodu and the highest range from Ettumanoor. Most of the electrical conductivity mean values were not under the desirable limit of 110 µS/cm, hence its evident that the water in the study area was considerably ionized and has higher level of ionic concentration activity due to small dissolved solids.If conductivity changes significantly due to current or other sources of disturbance, it may indicate damage to the body of water and its associated living organisms[15].

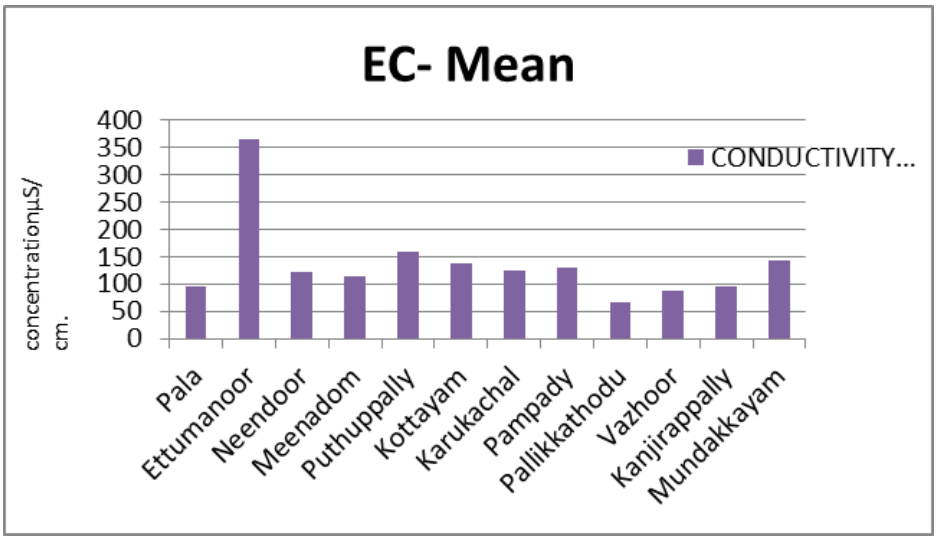

Figure 4 Mean values of Conductivity from the study stations

Table 4 Electrical conductivityrange and mean standard deviation ofeachstation

Station No.	Station name	Range	Mean±SD
1	Pala	51.5 - 167.7	95.8±34.19
2	Ettumanoor	45.5 - 1854	366.4±561.8
3	Neendoor	47.5 - 174.4	122.37±44.6
4	Meenadom	23.5 - 190.3	115±52.3
5	Puthuppally	56.2 - 202	158.4±121.1
6	Kottayam	33 - 257	139±87.12
7	Karukachal	55.8 - 182.2	124.7±42.21
8	Pampady	52.8 - 244	129±58.44
9	Pallickathodu	36.1 - 167.2	64.9±46.34
10	Vazhoor	30.8 - 168	87.53±53.53
11	Kanjirappally	12.58 - 153.3	94.34±45.04
12	Mundakkayam	35.9 - 573	143.79±157.1

3.4. TDS

The desirable limit for TDS is 500mg/ l and the maximum limit is 2000 mg/l which is prescribed for drinking water purposes. The concentration of TDS in the present study was observed in the mean range of 42±39.8 -248.2±393.03. The lower TDS value was obtained from Pallikkathodu with 42mg/l and the higher TDS value was obtained with a concentration of 248.2 mg/l from Ettumanoor.

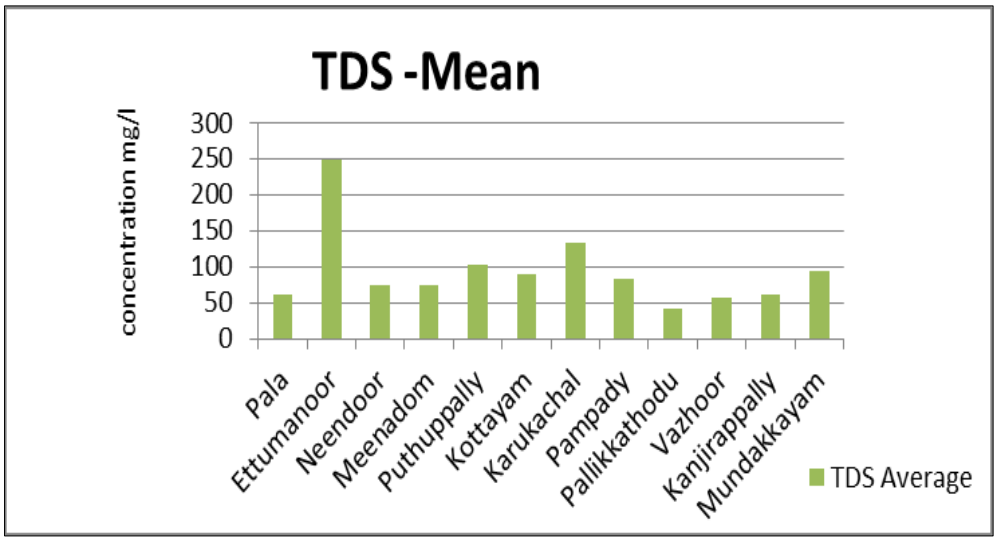

Figure 5 Mean values of TDS from the study stations

Table 5 Electrical conductivity range and mean standard deviation ofeach station

Station No.	Station name	Range	Mean± SD
1	Pala	33.4 - 109.3	62.34±22.28
2	Ettumanoor	24 - 1300	248.2±393.03
3	Neendoor	0.05 - 133.9	74.5±38.01
4	Meenadom	15.3 - 123.6	74.7±34
5	Puthuppally	37.05 - 310	102.8±78.5
6	Kottayam	22 - 168	90.27±56.47
7	Karukachal	36.1 - 573	133.03±156.7
8	Pampady	34.3 - 158.3	83.8±37.9
9	Pallickathodu	23.5 - 108.8	42±39.8
10	Vazhoor	19.9 - 107.6	57±34.8
11	Kanjirappally	8.18 - 99.6	61.3±29.3
12	Mundakkayam	23 - 107.4	93.44±101.9

3.5. Total iron

According to WHO, Concentration of iron in drinking water are normally less than 0.3 mg/l. From this study, the concentration of iron mean value ranges from 0.0033±0.0069 -0.5525±1.703 with the lowest value of 0.003 in Pala and the highest value of 0.55 in Neendoor. If Iron level in water at or exceeds 0.3 mg/l there will be a metallic taste and it is called a secondary maximum contaminant level, or SMCL, because the level is based on aesthetic (color and taste) reasons rather than health effects. The presence of iron corrosion products has been reported to promote bacterial activity in drinking water networks, leading to an increase in both suspended and biofilm associated bacteria, or an increased presence and /or culturability of coliforms, often used as a bacteriological water quality indicator[16].

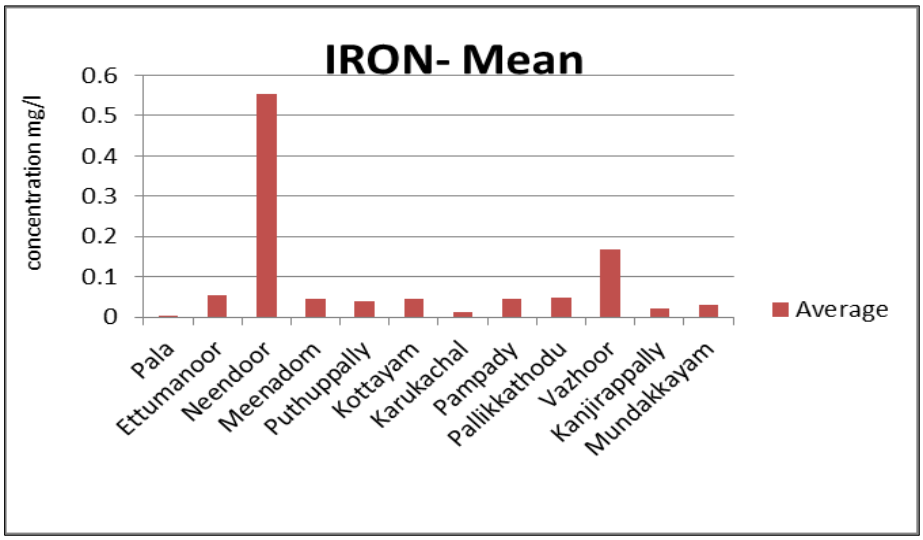

Figure 6 Mean values of Total Iron from the study stations

Table 6 Total Ironrange and mean standard deviation ofeach station

Station No.	Station name	Range	Mean± SD
1	Pala	0 - 0.021	0.0033±0.0069
2	Ettumanoor	0 - 0.25	0.053±0.073
3	Neendoor	0 - 0.021	0.5525±1.703
4	Meenadom	0 - 0.18	0.044±0.058
5	Puthuppally	0 - 0.21	0.039±0.062
6	Kottayam	0 - 0.14	0.045±0.049
7	Karukachal	0 - 0.06	0.014±0.023
8	Pampady	0 - 0.137	0.046±0.043
9	Pallickathodu	0 - 0.29	0.047±0.089
10	Vazhoor	0 - 1.21	0.169±0.36
11	Kanjirappally	0 - 0.06	0.022±0.028
12	Mundakkayam	0 - 0.069	0.03±0.063

3.6. Water Quality Index

Based on the Physio-Chemical parameters, the Weighted arithmetic water quality index was calculated and the obtained values are shown in Table7. Station No. 10 Vazhoor showed poor water quality with an index value 59.16 and Station No.3 Neendoor showed an index value of 186.1 which is unsuitable for drinking purpose. The water quality index ranges from 0-50 is considered the desirable range here, the other 10 stations showed excellent water quality.

Table 7 Weighted Arithmetic Water Quality Index (WA-WQI)

Rating of Water Quality	Water Quality Value
Excellent water quality	0 – 25
Good water quality	26 – 50
Poor water quality	51 – 75
Very poor water quality	76 - 100
Unsuitable for drinking purpose	Above 100

Table 8 Water quality index of different stations in Kottayam based on Physio- chemical Paramters

Station No.	Station Name	Water quality Index	Rating of water quality
1	Pala	3.82	Excellent water quality
2	Ettumanoor	16.8	Excellent water quality
3	Neendoor	186.17	Unsuitable for drinking purpose
4	Meenadom	23.9	Excellent water quality
5	Puthuppally	20.6	Excellent water quality
6	Kottayam	22.5	Excellent water quality
7	Karukachal	8.27	Excellent water quality
8	Pampady	22.8	Excellent water quality
9	Pallickathodu	21.24	Excellent water quality
10	Vazhoor	59.16	Poor water quality
11	Kanjirappally	12.49	Excellent water quality
12	Mundakkayam	16.9	Excellent water quality

4. Conclusion

The samples were analyzed for intended water quality parameters following internationally recognized and well-established analytical techniques[17]. Based on the findings, it was concluded that the well water of the study area in Kottayam district showed extreme bacterial contamination. The indicator organism *E.coli* was present in 65.8% of the samples. The sampling stations were located on the watersheds of Meenachil and Manimalariver. Meenachil river was highly influenced by various anthropogenic activities[18] Manimalayaralso showed extreme pollution[19]. The river water pollution may affect the quality of well water. It is evident that all the values of pH ,TDS, and Iron from different stations were under the desirable limit with an exception in Neendoor station with acidic pH and high iron concentration. According to R. Appenzeller et.al 2005, higher concentrations of Iron in water favour the growth of coliform group bacteria .From the weighed arithemetic water quality index calculation based on physio- chemical parameters, the water from Neendoor station showed an index value of 186.1 which is unsuitable for drinking purposes.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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