Original Article

Water Quality Index of Arkavathi River and Surrounding Groundwater

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Abstract

Aim: Finding out the water quality of Arkavathi river, a tributary of the Kaveri system and surrounding groundwater is the aim of the present work using the water quality index (WQI) method. **Materials and Methods:** WQIs contribute a single number which indicates altogether quality of water at a particular sampling point based on varied water quality parameters. An effort has been ready to invent a WQI using 11 water quality parameters such as pH, temperature, dissolve oxygen, alkalinity, chloride, iron, nitrate, fluoride, total hardness, total dissolved solids, and biochemical oxygen demand measured at five various locations along the Arkavathi river just downstream of wastewater disposal points of Ramanagar town and six groundwater samples surrounding the river basin. Weighted arithmetic WQI technique was used to discover overall WQI. **Results:** The values of WQI for downstream of wastewater disposal points of Ramanagar town rivers vary from 33.78 to 76.82 and for groundwater vary from 38.6241.77 to 65.95. Based on this, the river quality and groundwater at some of the sampling stations were not suitable for drinking. **Conclusions:** The quality of water is substandard because mainly in the river samples because of the disposal of untreated sewage and industrial effluent generated from the Ramanagar town is directly without any treatment, improper sanitation condition in the nearby city banks of the river, and also, wastewater discharge from surrounding villages, human activities, urban runoff, and agriculture activities.

Keywords: Groundwater, river, water quality, water quality index

Introduction

One of the major difficulties overlook at the current time is the risk of the potable water resource. Water is one of the foremost vital natural resources of all forms of life, this concept of animals, humans, plants, and other living organisms. Freshwater is an important concern for mankind; meanwhile, it is openly linked to human welfare. Water is used for different purposes such as domestic, agricultural, power generation, industry, and recreation. Hence, everyone should have a bit of knowledge about the quality and quantity of water sources for its betterment practice, application, and management.[1]

Industrialization, modernization, and an increase in population lead to increasing water demand for different activities, and also, surface and subsurface water qualities were affected by natural and human ventures. Therefore, universal national planning and resource management system concerning water with prominence on the assignment of significance among the inconsistent usages is essential.[2] Because of the thickening population, urban development, industrialization, and upgrading technology, significant concern about the quality of water goes on increasing. Furthermore, the water gets easily contaminated in different ways due to improper management of the disposal of wastewater generated from different activities.[3]

The availability of fresh water is very essential for human fortunes. Although more than 75% of the world is covered by water, only a small scale will be used for suitable for mankind. Every biotic organism required water for its survival and good health. Most communicable diseases are escalating through the water. Therefore, it is the duty of the government or local authorities to supply wholesome water to

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the community to maintain the health and welfare of society. Due to anthropogenic and human activities, 90% of the surface and subsurface water sources are polluted and safe water is not accessible to most consumers.[4]

Nowadays, most people residing in urban and rural areas are depending on the surface or subsurface water sources to fulfill their water demands. Therefore, the monitoring of surface and subsurface water quality is very important to form the point the welfare of society. The drinking water qualities stipulate water suitability for human consumption. The quality of water is analyzed based on the various water quality parameters such as physical, chemical, and biological and if the values exceed, the acceptable limits of ware quality standards than human health are at risk.[5] It is very essential to study the quality of surface and subsurface water sources to create awareness and highlight the status of the environment even for the layperson and also helpful for overall national planning and resource management. In an aquatic ecosystem, the water quality is finding out by several physical, chemical, and biological factors. The main drawback in water quality monitoring is the difficulty related to examining the huge number of measured variables and the variation in the values of the measured parameters because of natural and anthropogenic effects.

One of the constructive techniques to convey evidence on the quality of water tendency is the practice of the appropriate indices. Indices are created or based on the values of various physicochemical and biological parameters in a water sample. This will give a guideline for evaluating successes and failures of the management approach and a yardstick for improving water quality.[7]

The index comes up with a solo number that constitutes comprehensive water quality at a certain position and time interval based on some water quality parameters. This will simplify complicated results into very well understandable and usable information. This index is finding out using different parameters and giving water quality information that is more easily interpretable.[5]

The expression of water quality index (WQI) is done by the following steps: (i) parameters selection which extremely affects the quality of water, (ii) every physicochemical and biological parameter is transformed into an equal scale of unit, (iii) assignment of weightage to each of the parameters, and (iv) combination of subindices for each parameter into a final index value. The various methods are utilized by various researchers to evaluate WQI.[6] A WQI provides a distinctive rating that indicates the overall water quality at a particular stretch and time based on certain water quality constraints.[8,9]

The main intent of this research work was to monitor the water quality and status of WQI of Arkavathi river, nearby Ramanagar town, Karnataka state, and groundwater surrounding the river. The partially treated municipal wastewater from the city, as well as the untreated effluent coming out from the silk reeling industries, was discharged into this running water body and the same is used for irrigation by the people residing at the downstream side of the Ramanagar town. The WQI is finding out by analyzing some of the physicochemical and biological parameters of the river and also groundwater in the surrounding area.

Materials and Methods

Study area: Arkavathi river is a nonperennial river, it is originating in the Nandi Hills of Chikkaballapura district, and it is a tributary of the Kaveri river which connects at 34 km south of Kanakapura, Ramanagar district at the place named Sangama after flow across Ramanagar and Kanakapura cities.

Downstream of Arkavathi river, 5 sampling stations were identified at an interval of 1 km up to 4 km in length, 4 sampling stations on the right of the river bank, and 2 sampling stations on the left river bank as shown in Figure 1.

In order to better understand the water quality in a specific area, it is important to analyze both surface and subsurface water samples. In this study, we will be examining samples taken from 11 different locations in the study area, including rivers and bore wells. Grab samples were collected in 2 L Polyvinyl chloride (PVC) containers during premonsoon seasons and were analyzed for various physicochemical and biological parameters as per standard methods for the examination of water and wastewater american public health association (APHA). After this analysis, an index was calculated to simplify the data. WQI by the weighted arithmetic method is evaluated using the recommendations in agreement with "The Indian Standard Drinking Water Specification IS 10500: 2012 of Drinking water standards 2012". The list of river and groundwater sampling station and location details is as shown in Table 1.

Ethical clearance

Ethical approval for this study (Ethical Committee KKGECKRP/Civil/EC/2022-23/06) was provided by the Ethical Committee Department of Civil Engineering, K.R. Pet Krishna Government Engineering College, Krishnarajpet, Karnataka, India on 28 June 2023.

Figure 1: Map shows the water sampling point in river and groundwater

Table 1: List of sampling points along with location

Sampling point	Details of sampling points
RS1	River water sample at starting point from Ramanagar town near railway bridge
RS2	River water samples at 1 km downstream from RS1 near Achalu village
RS3	River water samples at 2 km downstream from RS1 near Achalu factory
RS4	River water sample at 3 km downstream from RS1 near Achalu doddi village
RS5	River water samples at 4 km downstream from RS1 near K. P. doddi Village
BR1	A borehole water sample was collected from the right bank of the Arkavathi river, which is the source of water for Achalu village drinking water supply
BR2	A borehole water sample was collected from the right bank of Arkavathi river, which is the source of water for Achalu doddi village drinking water supply
BR3	A borehole water sample was collected from the right bank of Arkavathi river, which is the source of water for Krishnapura doddi village drinking water supply
BR4	A borehole water sample was collected from the right bank of Arkavathi river, which is used for Agricultural purposes near Chennammana Halli village
BC1	A borehole water sample was collected from the left bank of Arkavathi river, which is used for Agricultural purpose near Krishnapura doddi village
BC2	A borehole water sample was collected from the left bank of Arkavathi river, which is the source of water for Sidlakallu village drinking water supply

Results

The results of physicochemical and biological parameters of the water samples, e.g. biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH value, nitrate, chloride, dissolved oxygen (DO), total dissolved solids, fluoride, iron, total hardness, alkalinity, and *Escherichia coli* tests as per the standard procedures and results were graphically represented in Figures 2-13.

In the present research study, the pH reached from 7.14 to 7.395 for river water samples and 6.78–7.77 for bore well samples and it is observed the values of pH of narrow variation in all stations.

In the present research study, the values of DO ranged from 0 to 1.05 mg/L in river water samples and 4.35–5.5 mg/L in bore well samples. The concentration of DO in the water samples mainly depends on atmospheric dissolution, the amount of organic matter present, and the amount of oxygen consumed by microbes for the degradation of organic matter. Therefore, DO measurement is very essential for the treatment of organic matters present in bore well water samples and rivers. The DO concentration at the RS1, RS2, and RS3 samples is nil since sewage water and some small-scale industrial wastewater generated in the city are discharged into the stream and the DO of the RS4 and RS5 sample downstream of Ramanagar city increases because of the self-purification of streams.

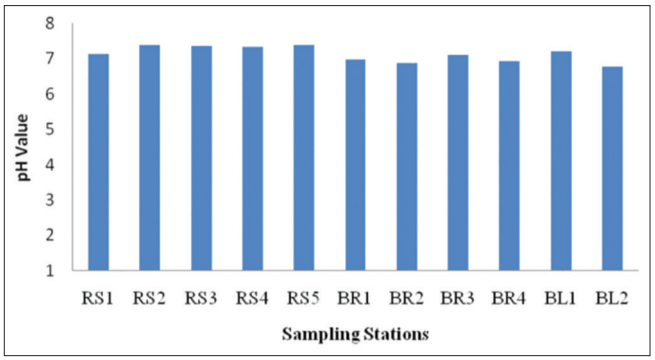

Figure 2: Variation in pH values

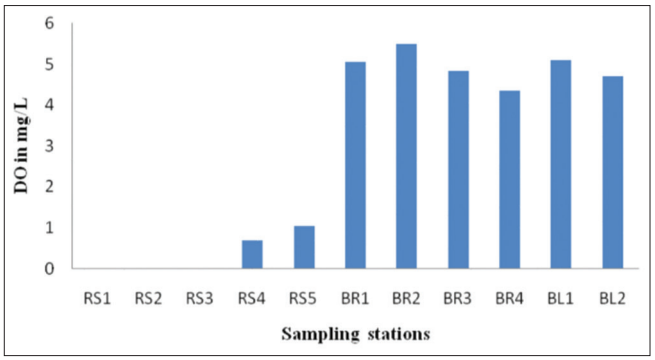

Figure 3: Variation in DO values. DO: Dissolved oxygen

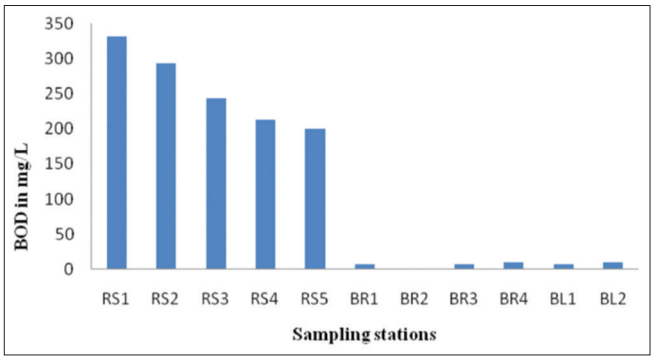

Figure 4: Variation in BOD values. BOD: Biochemical oxygen demand

In the present study, the values of BOD varied from 200 to 332 mg/L and 0 to 9.92 mg/L for river and bore well water samples, respectively. In the river water samples, the amount of BOD present is beyond the acceptable limit of drinking water because of all the domestic wastewater and industrial effluent generated in the Ramanagar town is directly discharge into river without any treatment. Therefore, due to the presence of organic and inorganic matters that present in the disposed water, the concentration of BOD in the stream is high. The issue of effluent disposal into the Arkavathi river in Ramanagar city is a growing concern for both the environment and public health. Domestic and industrial waste, if not properly treated, can have a detrimental impact on the river's ecosystem and also pose a threat to those who rely on it for drinking water and other daily needs.

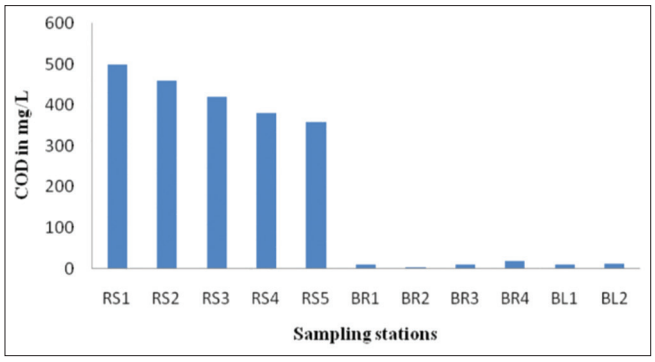

Figure 5: Variation in COD values. COD: Chemical oxygen demand

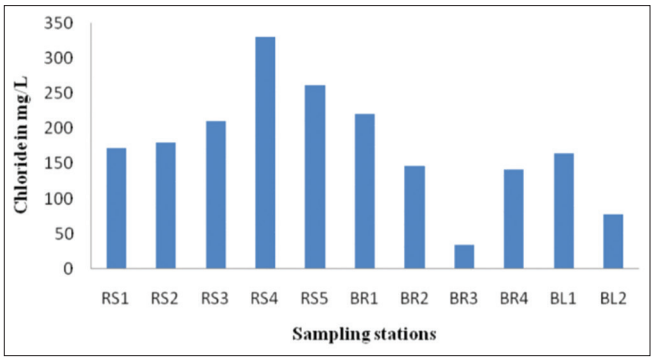

Figure 6: Variation in chloride values

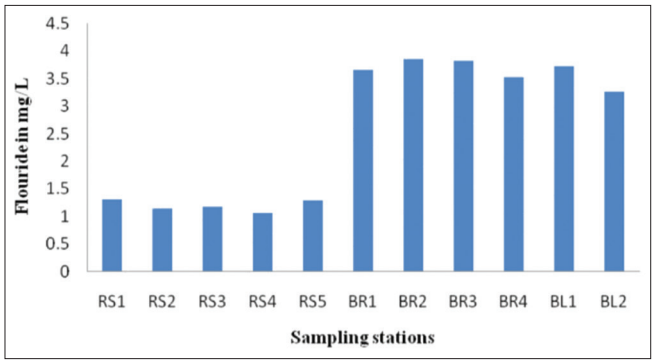

Figure 7: Variation in fluoride values

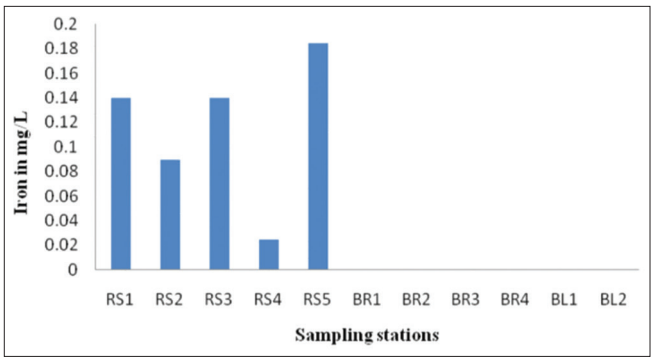

Figure 8: Variation in iron values

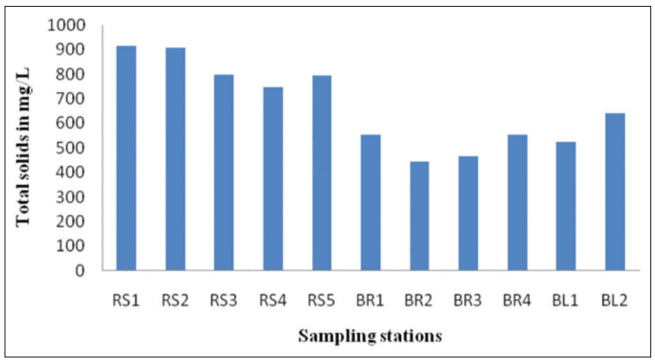

Figure 9: Variation in total solids values

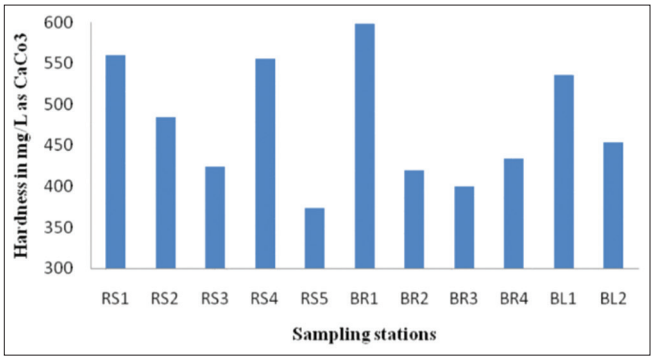

Figure 10: Variation in total hardness values

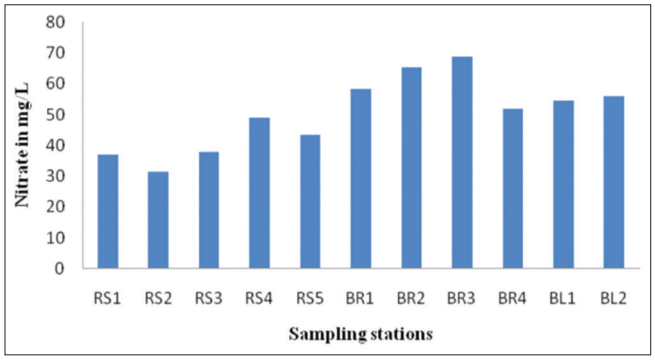

Figure 11: Variation in nitrate values

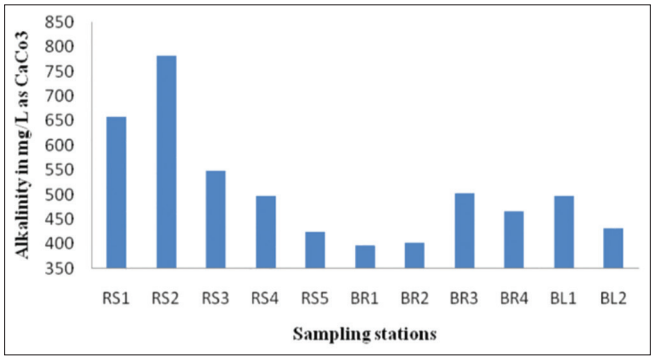

Figure 12: Variation in alkalinity values

The values of COD differ from 360 to 500 mg/L for river and 4 to 20 mg/L for bore well water samples. In the river water samples, the presence of COD is high since as the effluents discharge into the river from different sources which were

contained both biodegradable and nonbiodegradable matter, and hence, the concentration of COD in the river is more than the drinking water quality standards.

In the present study, the values of BOD varied from 200 to 332 mg/L and 0 to 9.92 mg/L for river and bore well water samples, respectively. In the river water samples, the amount of BOD present is beyond the acceptable limit of drinking water because of effluent disposal by domestic and industries generated in the Ramanagar city into running Arkavathi river. The values of COD differ from 360 to 500 mg/L for river and 4–20 mg/L for bore well water samples. In the river water samples, the presence of COD is high as the effluents discharge into the river from different sources which were contained both biodegradable and nonbiodegradable matter, the values of chlorides ranged from 172 to 331 mg/L for river and 34 to 221 mg/L for bore well water samples. In the river as well as in the bore well water samples, the concentration of chloride is within the permissible limit; the values of fluorides ranged varied from 1.065 to 1.32 mg/L and 3.267 to 3.86 4 mg/L for river and bore well water samples, respectively. In the river water samples, the concentration of fluorides is within the permissible limit, but in the bore well samples, the concentration is more than the permissible limit because of natural fluoride content which presents in the earth crest will dissolve when the water percolates through the soil bed, the values of iron differ from 0.09 to 0.185 mg/L for river water samples and nil for bore well water samples. In the river as well as in the bore well water samples, the concentration of iron is within the permissible limit.

In the present research study, the values of total dissolved solids differ from 750 to 917 mg/L for river and 446–642 mg/L for bore well water samples. In the river as well as in the bore well water samples, the concentration of total dissolved solids is within the permissible limit; the values of total hardness ranged from 374 to 560 mg/L as $CaCO_3$ in river water samples and 400–598 mg/L as $CaCO_3$ for bore water samples, respectively. In the river as well as in the bore well water samples, the concentration of total hardness is within the acceptable limit; the values of nitrates differ from 30 to 49 mg/L for the river and 52 to 69 mg/L for bore well water samples, respectively. In the 4th river water sample and all the bore well water samples, the concentration of nitrate is more than the permissible limit as per drinking water quality standards, because of direct disposal of domestic wastewater generated from the Ramanagar town which contains high concentration of nitrates and also due to excess usage of manure for agricultural purpose, which may reach the river during the storm runoff. Unlike agricultural activities, yield improves the nitrate concentration in surface water and ground.

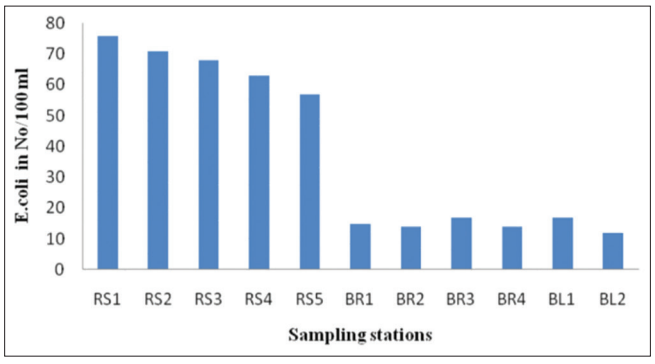

Figure 13: Variation in *Escherichia coli* values

In the present study, the values of alkalinity differ from 424 to 658 mg/L as $CaCO_3$ and 396 to 502 mg/L as $CaCO_3$ for river and bore well water samples, respectively. In the first river water sample, the concentration of alkalinity is more than the permissible limit as per the drinking water quality and in the remaining river and bore well water samples, the concentration is within the limit. The higher value of alkalinity is due to the presence of two common minerals such as magnesium and calcium, which will affect the hardness of the water, and the values of *E. coli* differ from 57 to 76 cfu/100 mL for river and 12 to 17 cfu/100 mL for bore well water samples. These variations in *E. coli* values in all the water samples were because of untreated or partially treated domestic sewage discharge to Ramanagar town into the Arkavathi river. The main source of fecal contaminants is due to human and animal activities.

Water quality index

The WQI is one of the most productive, elementary, and simply plain tools to evaluate water quality for its acceptability for various purposes. WQI for all 11 samples was analyzed using the weighted arithmetic index method. Parameters such as pH, temperature, DO, alkalinity, chloride, Iron, nitrate, fluoride, BOD, total dissolved solids, and total hardness. The values of water quality parameters and assigned unit weights are presented in Table 2.

Classification of water quality into 5 categories created on its WQI value and is tabulated as shown in Table 3.[10]

Based on the classification samples, RS1, RS2, RS3, RS4, RS5 (river water samples) and 6 (bore well samples) BR1, BR2, BR3, BR4, BC1, BC2 are unsuitable for drinking and the

Table 2: Water quality parameters and their given unit weights[3]

Parameters	Unit weight (Wi)
pH	0.1176
Dissolved oxygen	0.07
BOD	0.05
Temperature	0.037
Nitrate	0.0222
Total dissolved solids	0.0005
Alkalinity	0.0016
Chloride	0.001
Iron	3.3333
Fluoride	0.666
Total hardness	0.0016

BOD: Biochemical oxygen demand

Table 3: Scale of water quality based on water quality index

WQI	WQ rating
0–25	Excellent WQ
26–50	Good WQ
51–75	Poor WQ
76–100	Very poor WQ
>100	Unsuitable for drinking

WQ: Water quality, WQI: Water quality index

Table 4: The water quality index of different water samples

Samples details	WQI	WQ
RS1	76.82	Very poor
RS2	55.80	Poor
RS3	76.58	Very poor
RS4	33.78	Good
RS5	76.66	Very poor
BR1	65.95	Poor
BR2	44.42	Good
BR3	44.25	Good
BR4	41.27	Good
BL1	43.40	Good
BL2	38.62	Good

WQ: Water quality, WQI: Water quality index

remaining water samples showed good water quality, which is mentioned in Table 4.

Discussions

Based on findings come out from water quality analysis of 11 sampling stations (5 river samples for 54 km length downstream of Ramanagar town and 6 bore well samples in the surrounding area of the river) and 11 different physochemical and biological parameters and calculations of WQI by the weighted arithmetic method, it is observed that, the DO concentration of the river is less because of high concentration of organic matters that present in the river so the amount of oxygen required for complete degradation organic matters for microbes that present in the river is more therefore the DO concentration of the river in upstream sampling stations is less and on the downstream goes on increase due to self-purification of streams. Similarly, the concentrations of BOD, COD, and nitrates in the river samples are more than the drinking water quality standard because of the biodegradable and nonbiodegradable matters present in the mixed stream due to direct disposal of sewage and industrial effluent come out from the Ramanagar town. The concentration variations in *E. coli* values in all the water samples of river and bore well samples, because of untreated domestic sewage discharge generated from Ramanagar town are directly discharge into the Arkavathi river. The main source of fecal contaminants is due to human and animal activities.

It is observed that in all samples of the river, the fluoride concentration of is within the permissible limit, but in all the bore well samples, the concentration of fluoride is more than the permissible limit, and it may be due the presence of natural fluoride content that presents in the earth crest which will dissolve when the water percolates through the soil bed. It is possible to conclude that quality of water is not suitable for drinking purpose and it requires some treatment to reduce the contamination level of some of the parameters. From the study, it is observed that the WQI of river water samples at different sampling stations from 1 km to 54 km goes on varies with the distance such as very poor, poor, very poor, good, and very poor, respectively, at 5 sampling points with the direction of flow of water. This is because of the high concentration of some of the parameters such as DO, BOD, and COD and nitrates present in the mixed river water. In all the bore well water samples, the WQI is good, since with the river water quality is improved due self-purification process and also before recharging underground water table of bore well due to flow of river, infiltration process will take place by that the quality of water in the bore wells may improve.

Technically, in the streams, quality of water goes on improving with distance due to the self-purification of streams, but the WQI of water goes on varying with distance and it is may be due to the entry of sewage water received from nearby villages or due to surface runoff or due to agricultural runoff, the WQI of the stream may go on varies. Therefore, it is better to identify the point and nonpoint sources which may vary the quality of river water.

Conclusions

In this research work, overall, the physicochemical water quality parameters indicated variation at all the Arkavathi rivers and surrounding underground water sampling points. From the results, it is observed that pH, temperature, chloride, iron, fluoride, total dissolved solids, and total hardness values of river samples were within the permissible limit of drinking water quality, but other parameters such as DO, BOD, COD, nitrate, and *E. coli* concentrations in almost all the river water samples were exceeding the drinking water quality standards because of the presence of organic and inorganic matters that present in the mixed river water due to direct disposal of domestic and industrial wastewater come out from the Ramanagar town and which may be directly effecting on the WQI values. Based on WQI values, in the river water samples except for S4, the remaining samples of water are unfit for drinking and in the case of bore well samples except for the BR1 water samples, other samples' water quality is good. Hence, poor quality water requires extensive treatment before consumption for drinking purposes. However, DO is less than the saturation value at all sampling points, and alkalinity value at S1 and S2, nitrate value at S4, *E. coli*, BOD, and COD values at all sampling points exceeds the acceptable limit. In bore well samples except for nitrate, fluoride, and *E. coli,* remaining parameters were within the limit at all the sampling locations. Based on WQI values, in the river water samples except for S4, the remaining samples

of water are unfit for drinking and in the case of bore well samples except for the BR1 water sample, other samples' water quality is good. Water is a precious resource that sustains life on our planet. However, the quality of water at some river and groundwater sampling points has been declining due to various factors such as illegal discharge of sewage, industrial effluent, high anthropogenic activities, agricultural runoff and urban runoff. Hence, poor quality water requires extensive treatment before consumption for drinking purposes. In the present study, research work is carried out only for premonsoon season, only for the 4 km length downstream of Ramanagar town, and it is further suggested that research work should be carried out throughout the year for the total length of the river (for 34 km) and then concludes the overall quality of Arkavathi river since it is the main source for drinking water as well as irrigation for Ramanagar and Kanakapura town and surrounding rural areas.

Acknowledgments

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Nil.

Conflicts of interest

The quality of river is mainly depending upon the point and nonpoint sources which may effect on the quality of river water. Hence, it is better to find different point and nonpoint source along the length of river and then concludes the WQI of the river water and also the quality of water varies with season of year. Hence, research work is to be carried out throughout the year and then only concludes the overall quality of river water.

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