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Evaluation of the Quality of Water Treated Through Existing Riverbank Filtration Wells on the Bank of River Tungabhadra at Somlapur, Karnataka

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Abstract

Tungabhadra River is the minor river which flows through drought-prone regions of Karnataka. Industrial contamination has harmed the Tungabhadra River. The primary aim of the present study is to assess the physical and chemical parameters at selected sampling stations of the Tungabhadra River. The samples of the treated industrial wastewater, river water and treated RBF well water samples were collected periodically from April 2021 to March 2024 and the water quality analysis for necessary water quality parameters were conducted. As per the analysis the river water quality started deteriorating at the sampling station Nadiharlalli and Airani due to discharge of effluent from industries and domestic wastewater from towns into the River. The result also indicates that along the river stretch, the self-purification occurs naturally. It is further observed that, there is a substantial improvement in the quality of river water when it undergoes the purification process through installed RBF wells at Somlapur village. Geographical Information System software MapInfo Professional used in the present study is helpful for decision makers in managing and mitigating pollution in the Tungabhadra River.

Keywords: Riverbank filtration · River Water quality · Tungabhadra River · Water treatment

1. Introduction

Rivers are the important sources of water and these will fetch water and nutrients to zones around the world. The civilizations begin to form on the banks of rivers. In this world, many of the rivers are confronting the risk of pollution influenced by human activities like urban, industrial and agricultural activities along their banks. The rivers of India provides livelihood for the people across our country. The significant urban communities of India are situated on the banks of river. Based upon the origination, all the rivers of India can be classified as Himalayan rivers and peninsular rivers. Himalayan rivers are perennial rivers, as they will get the water from the rainfall in monsoon as well as the melting of ice in summer. Peninsular rivers flow fully during monsoon season only as the rivers are more dependent on rainfall.

Karnataka is the land of many important rivers. In Karnataka state, there are seven major river systems with their tributaries. The Krishna River is about 1300 km in length which originates at Mahabaleswar in Maharashtra, and meets the sea in the Bay of Bengal at Hamasaladeevi in Andhra Pradesh. Tungabhadra River is one among the most important tributaries of Krishna River. Tungabhadra River is formed by the Tunga and Bhadra rivers that originate in the Western Ghats and joins the Krishna River. Tungabhadra River is the minor river which flows through drought-prone regions of Karnataka. The problem of pollution is further coalesced during the summer because of the incline flow in the river. The major cause of pollution along the Tungabharda River is the discharge of sewage from towns situated on the banks of the Tungabhadra River.

Industrial contamination has harmed the Tungabhadra River. The downstream river water after the effluent disposal point has a bad odor and turned into dark brown. The polluted Tungabhadra River has affected nearly ten lakh people in the sub-basin. Thus, pollution of Tungabhadra River needs an immediate attention through evaluation of water quality periodically. The main aim of present study is to evaluate the physical and chemical parameters of River water samples from selected locations of the 40km stretch of Tungabhadra River water from Harihar to Somlapur. Further to determine water quality index to gain the information regarding the quality of river water across the stretch. Analysis of performance of installed RBF well as a low cost water treatment technology is carried out. Geographical Information System tools may assist the decision makers in managing and controlling pollution in the Tungabhadra River.

2. Background

Water is thought to be the source of 21% of India's infectious diseases [9]. The discharge of effluents from the industry

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into the river causes pollution in river water. The study performed on the Tungabadra river based on the physico-chemical and bacteriological parameters including levels of algal community showed substantially high pollution load through algal indicators [2] [3].Poisonous compounds in industrial wastewater are difficult to remove from their homogenous solution condition [4]. The concentration of Fe and Mn were exceeding the permissible limit in the water samples collected during pre and post monsoon seasons [6]. Riverbank filtration (RBF) is a water treatment technique that involves pumping water from nearby alluvial aquifers into wells on the riverbank, during this process number of physical, chemical, and biological reactions occur during the underground journey, increasing the quality of the surface water [8]. Biodegradable compounds were removed spontaneously, resulting in fewer chemicals being required for future flocculation and oxidation stages [11].

Purification of the polluted river water can be treated with various techniques and RBF is one of the low cost treatment technique for purifying river water and it can reduce membrane treatment costs by 10-20 percent [5] [7] [10]. The self-purification technique is a common natural purification along the river stretch and the technique of RBF showed drastic improvement in water quality with economically low cost [13] [14]. The site selection in a RBF project plays very crucial role and the use of geospatial technology is economical compared to conventional methods [9]. Four RBF wells were installed along the bank of Kali river and it was found that the RBF well water showed the lower concentrations of dissolved metals compared to preexisting drinking water sources [15].

RBF were introduced four rural villages along a 64 km stretch of the upper Krishna River in southern India and it has been observed that there is E. coli removal percentages of >99.9% [16]. GIS software is a technique by which critical decisions are made at managerial level showed mostly used. From the above review, it is noted that there are no studies related specific to GIS applications of RBF for Tungabhadra river. In this present study the authors are presenting their study of GIS mapping of RBF site for Tungabhadra river.

Historical Context of Pollution

The Tungabhadra River in Karnataka has long been an economic lifeline for the residents of over a hundred villages along its banks. However, in recent decades, industrial pollution, primarily from two factories—Harihar Polyfibres (HPF) and Gwalior Rayon and Silk Manufacturers (GRASIM)—have severely impacted the river's health. The locals, once dependent on the river for drinking water, irrigation, and fishing, now face the devastating consequences of this pollution. The industrial units located along the Tungabhadra have been discharging untreated effluents for decades. Since the 1970s, HPF and GRASIM have released toxic substances like sodium hydroxide, mercury, zinc, and other harmful chemicals into the river. These pollutants, which include effluents from textile production and chemical processes, have caused significant water contamination, making the river dangerous for both humans and aquatic life. The pollutants, which are discharged at a rate of around 33,000 cubic meters per day, have turned the water murky and discolored, especially during the summer months when the river's flow is low and the toxic substances become concentrated.

In the mid-1980s, studies by the Central Inland Capture Fisheries Research Institute (CICFRI) revealed alarming levels of mercury and other contaminants in the river, decimating fish populations. In 1994, a large fish kill event prompted local villagers to take action. In villages like Guttur, Airani, and Herebidari, fish were found dead along the riverbanks, and those who consumed the fish became ill. Residents were forced to deal with a range of health problems, from stomachaches to skin rashes. This marked a critical point in the battle for the river's survival.

Despite several petitions and protests against the polluting industries, legal actions were often delayed or dismissed. In 1985, the Karnataka State Pollution Control Board (KSPCB) and the courts were petitioned by environmentalists, fisherman associations, and affected villagers. However, repeated cases of industrial negligence, like untreated discharges and outdated technology, made little impact on the polluting companies, which continued their operations with little regard for the environments.

The Fight for Accountability

In the 1990s, local organizations like the Samaj Parivartana Samudaya (SPS), led by activists and villagers, began organizing protests, filing lawsuits, and demanding better pollution control measures. They held exhibitions during local festivals like the Mylar Jatra to raise awareness about the severe pollution and its effects on the river and local livelihoods. The villagers also collected signatures from thousands of people, urging the state government to take action against HPF and GRASIM, which were both owned by the Birla group. The resulting pressure led to a more concerted effort from local communities, who formed environmental committees called Tungabhadra Parishar Samitis to coordinate their protests and legal battles. participated.

The efforts of these groups were not in vain. In 1983,

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HPF installed an Effluent Treatment Plant (ETP) to treat the wastewater before releasing it into the river. However, as with many industrial pollution control measures, it was difficult to ensure continuous monitoring and effective functioning. The plant's daily operating costs were high, and in the absence of consistent public pressure, there were concerns that it could be underused or poorly maintained, as had been the case in other industries around India. Nevertheless, in recent years, there has been a concerted effort from HPF to modernize its effluent treatment infrastructure, including the recovery of 93% of its waste.

Present-Day Scenario and Improvements

The situation has evolved significantly in recent years. As a result of continuous activism and legal pressure, significant improvements have been made in the treatment of effluents from both HPF and GRASIM. The most notable change is the drastic reduction in biochemical oxygen demand (BOD), which is a key indicator of pollution in water bodies. The chemical oxygen demand (COD) levels have also decreased, indicating a reduction in the chemical load being released into the river. According to the Karnataka State Pollution Control Board (KSPCB), the river's water quality is now largely compliant with pollution standards, with the exception of its discoloration, which remains a persistent problem.

Effluent treatment processes have been updated, with HPF investing in two separate ETPs for their pulp and fiber plants. These systems now treat the wastewater through primary clarification and neutralization, followed by secondary treatment via extended aeration activated sludge processes. The treated water is discharged only when it meets the prescribed environmental standards, and continuous monitoring of the effluent quality has been implemented.

The villagers have noticed some improvements as a result of these changes. For example, fish populations are beginning to recover, and crop yields have seen a modest increase. The incidence of skin diseases has also dropped, which is a sign of improved water quality. While these improvements are welcome, villagers remain vigilant and continue to push for further progress. They are determined that the river should return to its original state of purity, not just for their own benefit but for future generations as well. To ensure sustainable access to clean and safe water for the communities living along the Tungabhadra, there is an urgent need to implement low-cost treatment strategies that can directly address the water quality issues. One such solution is Riverbank Filtration (RBF), a method that utilizes natural filtration processes as water percolates through the riverbed and surrounding soil layers before being extracted for use. RBF systems can significantly improve water quality by reducing contaminants such as heavy metals, pathogens, and industrial pollutants, while being cost-effective and less energy-intensive compared to traditional treatment methods.

Implementing RBF along the banks of the Tungabhadra would not only help provide cleaner water to the villagers but also promote environmental sustainability by harnessing the natural filtration capabilities of the river ecosystem. Given the historical struggles and the ongoing need for safe drinking water, RBF could serve as a vital part of a broader integrated water management plan for the region. By utilizing this low-cost, eco-friendly technique, the villagers can reduce their dependency on large-scale, expensive treatment plants and help restore the health of the river. This approach would empower local communities to take ownership of their water resources, ensuring that future generations can benefit from a clean, safe water supply and continue to thrive alongside the river that sustains them.

3. Materials and Methods

Study area

The study was carried out in the Ranebennur Taluka, Haveri district, in central Karnataka, India (Figure1). According to the 2011 census, the total population of the Taluka is 3,35,281. The total area of Ranebennur taluka is 901 sq.km with population density of 372 per sq.km. The bulk of the population is engaged in agriculture and related activities. During several field visits, five villages of Ranebennur taluka on the bank of river Tungabhadra were identified as sampling locations including Somlapur village in which RBF were already installed. The Tunga River and the Bhada River are the major rivers situated in Karnataka. These two rivers have their source in the Western Ghats of Chikkamagaluru district. These two rivers flow through Chikkamagaluru district and enter the Shivamogga District apart. Furthermore, the two rivers join in near the village of Kudli in the Shivamogga district and then flow as the Tungabhadra River. The Tungabhadra River is about 531 km long and it flows eastwards and finally joins the Krishna River at Gondimalla, Mahbubnagar district in Telangana.

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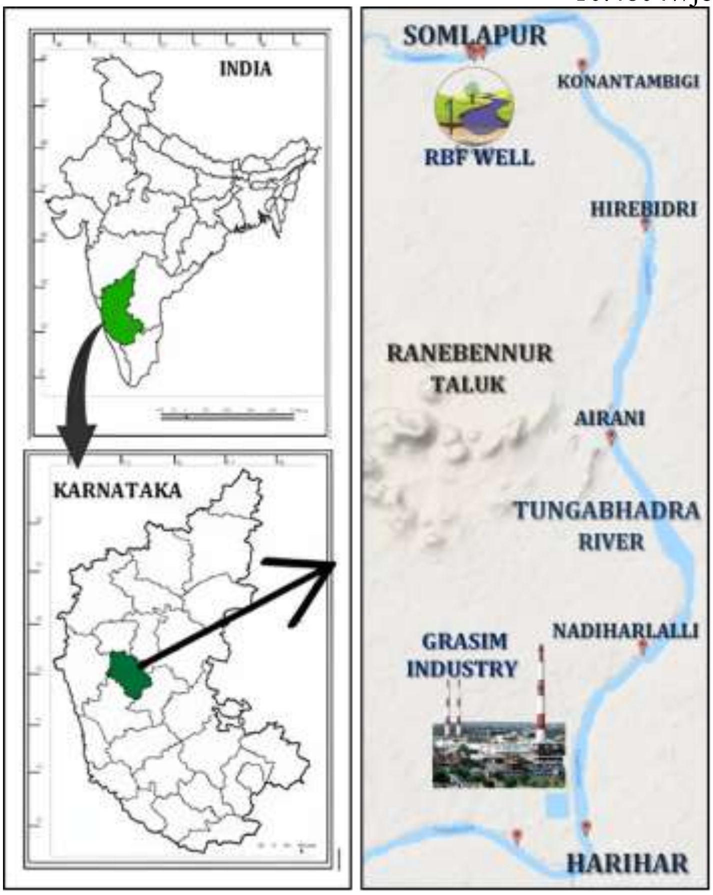

Figure 1. Location Map of the Study Area of the River Tungabhadra from Harihar to Somplapur

Site Selection

The Tungabhadra River flows about 80 km before reaching the town of Harihar in the Davanagere district. The total of contaminated river sections extends over 60 km from Harihar to the Haralahalli Village Bridge, Haveri District. The selected study area is about 40 km stretch of River Tungabhadra origin from Harihar in the Davanagere district till Somlapur, in Haveri district of Karnataka. The Study site of installed RBF wells is located at the bank of the River Tungabhadra at Somlapur, which is about 120 km downstream from its source. The agricultural activities are quite common on either side of Tungabhadra River bank. The major crops on both sides of banks are Paddy, Sugarcane, Coconut, etc. The Agricultural runoff may also join river throughout the 40km stretch of the river. The primary source of water pollutants alongside the stated Tungabhadra River stretch is the entry of sewage from CMC-Harihar. Harihar Polyfibres and Grasilene industries located on the bank of Tungabhadra River at Kumarpattanam. These industries draw the water for processing from Tungabhadra River and discharge the treated trade effluent from the industries runs in a canal for about 0.5 km to Tungabhadra River near a village called Nalavagal.

Somlapur

Somlapur is a small Village in Ranebennur Taluk in Haveri District of Karnataka State, India. It comes under Somlapur Panchayath. Total population of the village is about 1600 as per 2011 census (Source-somlapura Panchayath). The average annual rainfall is found to be 792MM (CGWB). It lies at an altitude of 583 meters above mean Sea level. It is located at a distance 48 KM towards East from District headquarter Haveri and 20 KM from Taluk headquarter Ranebennur. Majority of the area is covered with red sandy followed by the medium soil and black soil. The red loamy and lateritic soils are seen in very minor portions of the southern border of the Haveri district.

Table 1. Surface water sample codes of sampling stations along Tungabhadra River

Code	Description)	Latitude	Longitude
S1	Tungabhadra New bridge in Harihara	14°30'56.68" N	75˚ 81´64.28"E
S2	Harihara bridge (old) in Harihara	14°31'2.87" N	75°47'5.43" E

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S3	Nadiharalalli	14°33'14.03" N	75°48'37.06" E
S4	Airani Mata	14°35'46.22" N	75°48'15.03" E
S5	Hirebidri	14°38'19.21" N	75°48'39.52" E
S6	Konantambige	14°40'18.59" N	75°47'52.18" E
S7	Somlapur	14°40'29.87" N	75°46'29.38" E
RBF1	1st Riverbank filtration well at Somlapur	14°40'29.00" N	75°46'38.82" E
RBF2	2nd Riverbank filtration well at Somlapur	14°40'28.03" N	75°46'32.21" E

Description of the RBF well design and operation

The Riverbank Filtration (RBF) wells situated at Somlapur along the Tungabhadra River were drilled using an air hammer rotary method (approx.,4 m to 8 m) at a selected site Figure 2. L is a distance between a RBF well and the river, which ranges from 25.5 m to 58.8 m. The water table depth varies from 8.25 m to 10 m below ground level. The water must be removed from the wells using pump, in this process water from river passes through soil strata and enters the well. The collected water samples were chemically analyzed to observe the water quality.

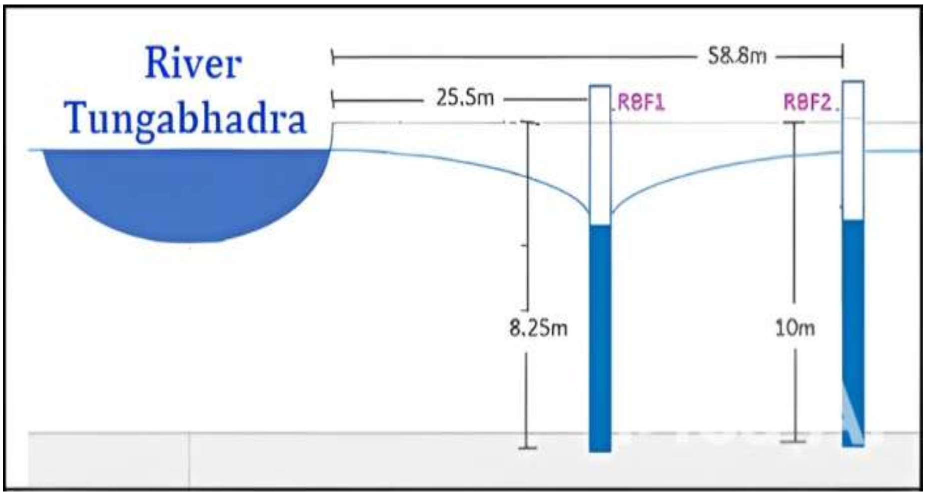

Figure 2. Schematic RBF cross-section with RBF1 and RBF2 at Somlapur

After drilling, the well development process mainly involved flushing out the drill mud using pressurized water. The design of the RBF well field was based on the local hydrogeological conditions, particularly the characteristics of the Red lateritic and Red sandy soil, along with the Schist-type lithology, riverbed sediments, and the depth to the bedrock. Each well was fitted with a solid steel casing of 6 inches in diameter, extending from 0.6 meters above the surface to 6 meters below the ground. The steel well screen, also 6 inches in diameter with welded holes, penetrated 6.9 meters of the unconfined aquifer and an additional 0.5 meters of solid bedrock. No casing or screen was installed in the bedrock itself. The geological conditions encountered during drilling included unconsolidated deposits up to a depth of 24 meters from the surface, with bedrock encountered between 24 and 36 meters deep. A submersible electric pump, purchased locally, was used for the RBF wells. The pump, rated at 2 horsepower and designed to operate on a 230-volt single-phase supply, had a capacity of approximately 8 cubic meters per hour at a 100-meter head. The steel casing of each well extended about 0.6 meters above the ground surface, and the well heads were encased in a 1-meter by 1-meter concrete slab for protection. A steel cap was placed on each well for further security.

Water Sampling and Analysis

To achieve the objectives of the study, the month wise data of treated industrial wastewater from Effluent Treatment Plants before discharging into the river is collected periodically for three years from April 2021 to March 2024. The data is collected from the Continuous online effluent analyzing device which is installed at mixed effluent outlet point at the established monitoring station. Further the field study was carried out in the study area to understand the impact of the industrial wastewater discharged into the river. The present study area is about 40 km stretch of River Tungabhadra. In entire stretch seven sampling points were selected on the basis of point source of pollution which mainly includes

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domestic and industrial wastewater. The details of the sampling stations along Tungabhadra River are as in Table 1 and Figure 1.

Samples of surface water samples were collected from the study area by Grab sampling method just below the surface as the parameters more pronounced at the surface. The timing of surface water sample collection was scheduled shortly after the industrial or sewage discharges crucial to capture their effects. Two water samples were collected from RBF wells located at Somlapur Village. The quantity of samples is collected with the extent of laboratory analysis, to be performed. One liter of samples was collected for both surface and RBF wells sample from each location and chemicals were added for preservation. While sampling quality control measures were ensured by calibrating the instruments and following SOPs for sample collection, handling, preservation, and analysis, so that the data collected is accurate, reliable, and representative. The selection of water quality parameters were based on the rationale that will help identify or quantify specific pollutants such studying the effects of industrial and domestic discharge and the physical and chemical properties of the water, which can influence other factors and indicate changes in water quality. Some of the parameters like pH, Temperature, Electrical Conductivity, Dissolved oxygen and Total dissolved solids were measured in the field at the time of sample collection and other chemical parameters were analyzed in the laboratory as per the APHA Standard Methods for the Examination of Water. Based on the laboratory results of water quality parameters, the water quality index was determined in order to describe the overall quality of water collected from selected sampling stations at the study area.

RBF well Yield and River Discharge

Pumping Test

To assess the well's performance and its ability to meet the water demand of the local population, a well capacity test was conducted. The test was performed during all three seasons to evaluate the sustainable yield of the well. During the pumping test, water was continuously pumped from each RBF well for approximately 3 hours to determine the safe yield in cubic meters per hour. Every 15 minutes, the yield was measured using a water meter installed at the outlet of the RBF well, and the average yield was calculated based on these observations. This process helped ensure that the wells could reliably supply water to meet the needs of the community without depleting the aquifer. Riverbank filtration can be induced by pumping of wells placed adjacent to the river. Pumping produces a hydraulic potential gradient from the river towards the wells. RBF systems consist of well fields that draw water from an aquifer that is hydraulically linked to surface waters. As this system draws river water, yield of well will depends on river flow. Therefore, it becomes essential to understand the river flow/discharge. River discharge is the total volume of water flowing through a river channel at any given time & point. It is expressed as m^3/sec (cumecs). The discharge of the river Tungabhadra is recorded on daily basis by the water commission board, Davangere at various gauge stations placed along the river stretch. The discharge data of river was collected from the Haralahalli gauge station.

Geospatial Analysis

Geospatial analysis was carried out using geographic information system (GIS) software MapInfo Professional to visualize the data on a map with symbols, themes and labels to see patterns. The first stage of the digitizing process is registering the map. The study area Map including sampling stations were registered by entering the coordinates (e.g., longitude, latitude) of each control point. This allows MapInfo Professional to overlay multiple map layers in a single map. The water quality data base has been imported to MapInfo Professional software to create thematic maps and also can visualize the data information of each sampling locations on the map itself.

4. Result

Analysis of treated industrial wastewater before discharging into the river

In the present investigation, a total of 36 treated industrial wastewater samples were analyzed monthly over a three-year period (April 2021 to March 2024). The objective of the analysis was to evaluate the consistency, variability, and compliance of key water quality parameters prior to discharge into the river. Table 2 summarizes the minimum, maximum, mean, median, standard deviation (SD), and coefficient of variation (CV) for 15 parameters, providing insights into the behavior and stability of the treated effluent.

Table 2. Descriptive Statistics of the parameters of treated industrial wastewater for the period from April 2021 to March 2024

Sl.	Parameters	Min	Max	Mean	Med	SD	CV
1	Total Suspended Solids, mg/l	46	55.75	51.704	52	2.780	0.054
2	Total dissolved Solids, mg/l	1611	1856	1782.9	1792.5	61.851	0.035

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3	Temperature Deg. C	31	33.4	32.45	32.7	0.660	0.020
4	pH	7.1	7.54	7.24	7.2	0.146	0.020
5	Oils & Grease mg/l	0.9	2.55	1.94	1.955	0.396	0.204
6	BOD_3 at 27 ° C mg/l	16.5	18.1	16.988	16.8	0.480	0.028
7	COD mg/l	158.6	168	163.78	162.8	3.072	0.019
8	Mercury (as Hg) mg/l	ND	ND	ND	ND	ND	ND
9	Hexavalent Chromium (as Cr+6) mg/l	ND	ND	ND	ND	ND	ND
10	Total Chromium (as Cr) mg/l	ND	ND	ND	ND	ND	ND
11	Zinc as (Zn) mg/l	0.16	0.2	0.181	0.18	0.016	0.087
12	Sulphate (as SO4) mg/l	754.8	908.3	841.22	848.95	41.460	0.049
13	Phenolic compounds (as C6H5OH) mg/l	ND	ND	ND	ND	ND	ND
14	Bioassay as per IS 6582 – 1971 % Survival	100	100	100	100	0	0
15	Sulphide (as S) mg/l	1.24	1.81	1.638	1.69	0.154	0.094

The analysis of the treated industrial wastewater over a three-year period reveals that the treatment system has maintained a generally consistent and effective performance across most parameters. Total Suspended Solids (TSS), Total Dissolved Solids (TDS), temperature, pH, BOD, and COD all showed low coefficients of variation (CV < 6%), indicating stable treatment operations and good process control. The pH remained within a narrow neutral range, and temperature fluctuations were minimal, both favorable for aquatic ecosystems. While BOD and COD values were relatively stable, they hovered at moderately high levels, suggesting that while biological and chemical treatment is effective, further polishing may enhance compliance with stricter environmental standards. TDS levels, though consistent, were relatively high and could impact the salinity of the receiving river water if not properly diluted downstream.

Notably, toxic pollutants such as mercury, chromium (both hexavalent and total), and phenolic compounds were consistently below detection limits, demonstrating effective source control or treatment. The bioassay test results showing 100% survival confirm the treated effluent's non-toxic nature. However, oil and grease and sulphide levels exhibited greater variability, pointing to fluctuations in industrial load or treatment performance in those specific units. Zinc and sulphate levels remained within acceptable ranges but should be monitored for potential cumulative effects. Overall, the statistical analysis confirms that the treated wastewater is generally compliant, non-toxic, and stable, though certain parameters like oil & grease and BOD warrant attention for potential process optimization or regulatory tightening.

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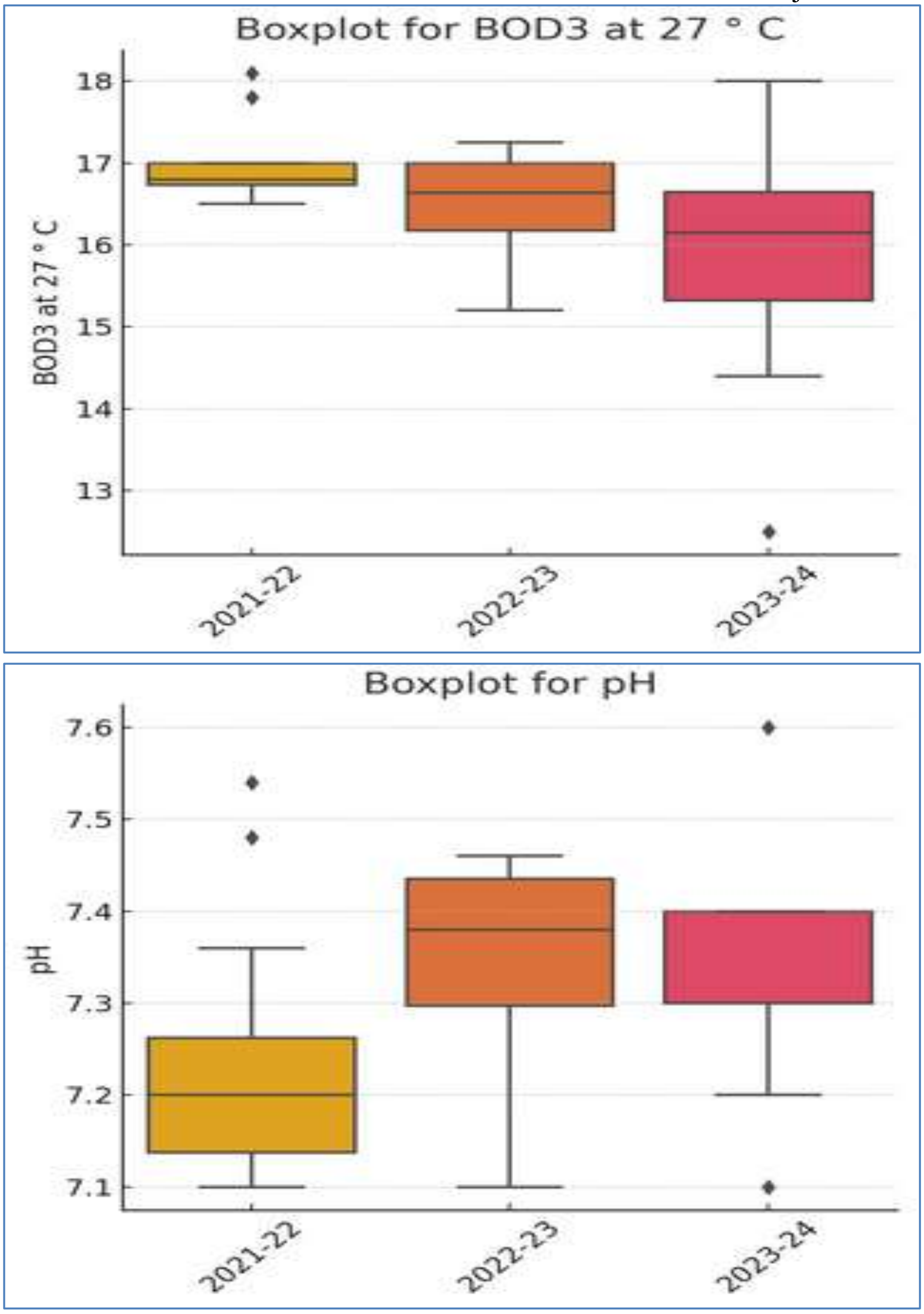

Figure 3: Seasonal Boxplots Showing Monthly Variations of Key Wastewater Quality Parameters (BOD_3, & pH,) from April 2021 to March 2024.

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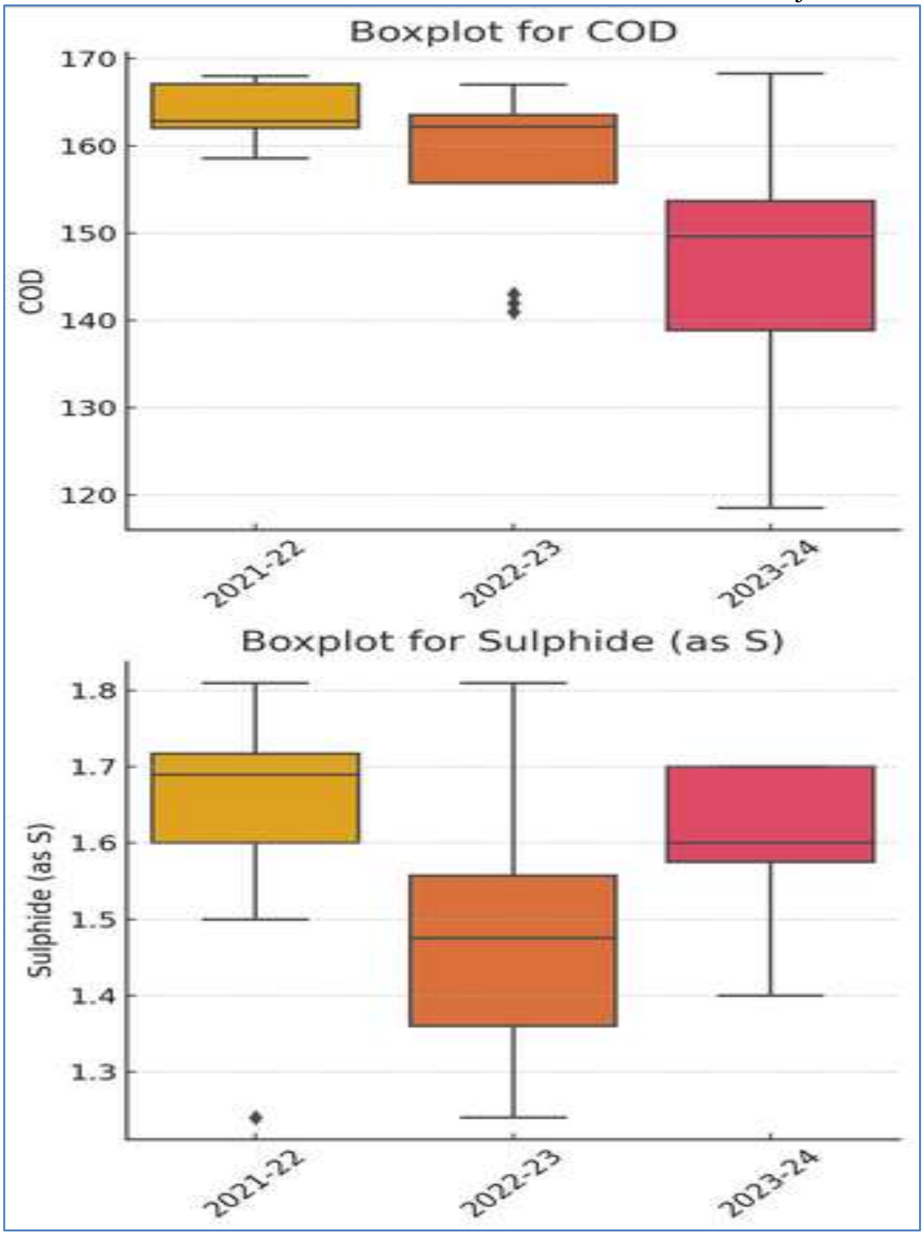

Figure 4: Seasonal Boxplots Showing Monthly Variations of Key Wastewater Quality Parameters (COD, & Sulphide) from April 2021 to March 2024

The seasonal trends observed through boxplots, as shown in Figure 3 and 4, indicate that BOD_3 and COD levels remained relatively stable across all three years, with only minor outliers, particularly during the monsoon months (July to September), suggesting potential runoff or process fluctuations during this period. The pH levels were stable throughout, remaining well within the permissible range, indicating effective neutralization processes. Sulphide concentrations were consistently maintained near 1.6–1.7 mg/L, with notably reduced variability in the final year (2023–24), reflecting improved operational consistency and treatment efficiency.

Water quality

The physico chemical parameters of the Tungabhadra River during the month of January 2024 are displayed in Table 3. The BIS Specifications for drinking water has been compared accordingly. The river water quality decreased from Nadiharlalli to Airani due to discharge of effluent from industries and domestic wastewater from towns into the River. The results also indicate that along the river stretch, the self-purification occurs naturally. Also there is a substantial improvement in the quality of water when it undergoes the purification process through installed RBF wells at Somlapur village.

pH ranges from 6.5-8.5 is normally acceptable as per guidelines. The pH values of the Tungabhadra River samples ranged from 7.47-8.56 in the surface water samples. The water is alkaline in nature due to large quantity of non-point sources mixing with the river water. It has been observed that there is a decrease in the pH value of the samples

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collected from RBF wells.

Temperature is an important parameter because it has an impact on aquatic organisms' biochemical processes. The temperature range at the industrial wastewater discharge point was determined to be between 30.1 °C and 30.3 °C in this study. Upstream water temperatures ranged from 29.6°C to 30.1°C, whereas downstream water temperatures at spots S5, S6 and S7 ranged from 27.3 °C to 29.8 °C. In RBF wells temperatures ranged between 29.6 °C and 31.6°C.

Total Dissolved Solids is a measure of solid material dissolved in water. The TDS concentrations of upstream water samples were found to be in the range from 119.6 mg / L to 161.9 mg / L. The values of water samples near the discharge of industrial effluent point varied between 252 mg / L and 254 mg / L. the results indicate, effluents contain maximum concentration of dissolved solids. The downstream water samples were also determined to be within the regular legal ranges, i.e., 319 mg / L to 370 mg / L. The TDS level at all sites including RBF wells are below the desired limit of 500 mg / L.

In the present study, EC at the discharge site of industrial effluent varied between 597-583 mS/cm. It has been observed that at the downstream and upstream sides of the river the EC values were in the range of 290-790 mS/cm. It has been observed that there is a substantial increase in the EC value of the samples collected from RBF wells.

In the river stretch, due to the discharge of large amount of organic waste there is substantial depletion of dissolved oxygen level. The DO values near the discharge point of industrial effluent found to be low (4.9 to 5.7 mg / L) because of absorption of high inorganic and organic loads leads to oxygen deficiency. The DO values upstream water ranging from 7.5 to 8.1 mg / L, the downstream water had DO value varied from 7.4 to 8.2 mg / L, indicates the river water is naturally purified. In RBF wells there is a substantial decrease in DO values ranged between 6.5 to 6.9 mg / L.

The amount of oxygen required by microorganisms in the oxidation of organic materials is measured by biochemical oxygen demand. In the present work BOD levels in the upstream water were modest, ranging from 4.22 to 6.61 mg / L. At the industrial effluent disposal point the BOD varied from 6.02 to 7.11 mg / L, indicating that partially treated effluent is discharged into the river. During the study, the downstream from the discharge point had a range of 3.34 mg / L to 4.1 mg / L. It has been observed that there is a substantial decrease in the BOD value of the samples collected from RBF wells ranging from 0.55 to 0.74 showing the signs of purification.

Hard and soft water are the two types of water that are commonly used. The Total Hardness of the upstream water samples in this study ranged from 45.9 to 58.26 mg / L. Similarly, the Total Hardness values of downstream water ranged from 92.98 to 97.21 mg / L. The Total Hardness ranged from 89.90 to 96.31 mg / L in water samples taken near industrial effluent point. It has been observed that there is a substantial increase in the Total Hardness value of the samples collected from RBF wells ranging from 180.01 to 184.87 mg / L.

Sodium concentrations in surface water normally range from 1 to 300 ppm, depending on the geographical area. The concentration of sodium at upstream water samples were found to be in the ranges of 19.99 to 24.21 mg / L. Water samples collected at downstream and industrial effluent disposal point, varied from 22.1 to 28.2mg / L and 39.77 to 56.3 mg / L, respectively. The sodium values are observed higher in the water samples collected from RBF wells.

The potassium pollution to be caused by the effluent discharge from the industry and due to the application of excessive fertilizers. The concentration of potassium in the surface water samples varies from 4 to 23 mg / L and ranged between 20.88 to 21.4 mg / L.

Excessive Nitrogen and Phosphorous contamination leads to eutrophication of river waters. In the river water samples TN and TP were found to be in the range of 6.66 to 11.23 mg / L and 2.48 to 5.95 mg / L respectively. It has been observed that there is a decrease in Total Nitrogen values and increase in the Total Phosphorous values in the water samples collected from the RBF wells.

The widespread use of soil conditioners is the major cause for the high sulphate concentration in river water. Sulphate concentrations in upstream water samples measured in the range from 10 to 13 mg / L. The concentration of sulphate in the water sample taken near the effluent discharge locations ranged very high from 163 to 240 mg / L. All of the readings including the samples of RBF values were found to be within the acceptable range.

Iron is an essential element required for human body. According to WHO guidelines, If the concentration exceeds 0.3 mg/L in drinking water is harmful. The Iron level of the water samples evaluated in this study was found to be higher above the allowed limits. These readings range from 0.77 to 1.24 mg / L, indicating that the effluent contains more iron as a result of the usage of chemical compounds in industrial processes.

Table 3. Water quality parameters observed in selected study area of about 40 km stretch of River Tungabhadra

Parameters	S1	S2	S3	S4	S5	S6
pH	7.47	7.63	8.14	8.1	8.5	8.56

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Temp "C	30.1	29.6	30.3	30.1	29.8	29.3
TDS, mg/L	119.6	161.9	254	252	319	329
EC, mS/cm	290	389	597	583	723	732
DO, mg/L	8.1	7.5	4.9	5.7	7.4	7.7
BOD, mg/L	4.22	6.61	7.11	6.02	4.1	3.87
TH, mg/L	45.9	58.26	89.09	96.31	92.98	97.21
Ca, mg/L	29.09	38.77	59.32	67.32	65.89	68.52
Mg, mg/L	16.81	19.49	29.77	28.99	27.09	28.69
Na, mg/L	19.99	24.21	56.3	39.77	28.2	26.56
K, mg/L	4	5	23	19	16	16
TA, mg/L	126	142	188	172	167	162
TN, mg/L	6.66	8.71	11.23	9.71	10.77	10.71
TP, mg/L	2.48	3.1	5.32	5.44	5.95	5.22
SO_4^2,mg/L	10	13	240	163	147	139
Fe, mg/L	0.77	0.94	1.24	0.88	0.75	0.78
Cu, mg/L	0.03	0.05	0.07	0.06	0.05	0.05
Zn, mg/L	0.17	0.25	1.95	1.12	0.8	0.69
Co, mg/L	0.04	0.05	0.45	0.39	0.36	0.32
Ni, mg/L	0.06	0.08	0.39	0.32	0.26	0.23

Table 4. Water quality parameters observed in surface water and RBFs located on the bank of River Tungabhadra at Somlapur

Parameters	S7	RBF1	RBF2	IS Desirable Limit
pH	8.49	7.38	7.14	6.5 to 8.5
Temp "C	27.3	29.6	31.6	-
TDS, mg/L	370	413	549	500
EC, mS/cm	790	925	1255	-
DO, mg/L	8.2	6.5	6.9	-
BOD, mg/L	3.34	0.55	0.74	30-100
TH, mg/L	96.66	180.01	184.87	300
Ca, mg/L	67.88	132.33	145.54	75
Mg, mg/L	28.78	47.68	39.33	30
Na, mg/L	22.1	42.22	39.92	50
K, mg/L	14	20.88	21.4	-
TA, mg/L	160	223	238	200
TN, mg/L	10.61	6.55	6.7	45
TP, mg/L	4.29	5.9	5.2	-
SO_4^2,mg/L	131	123	134	200
Fe, mg/L	0.77	0.96	1.08	0.3
Cu, mg/L	0.04	0.01	0.01	0.05
Zn, mg/L	0.46	0.13	0.15	5
Co, mg/L	0.28	0.21	0.20	-
Ni, mg/L	0.19	0.11	0.14	0.02

Copper is a vital component of the human body, but excessively high quantities can cause health problems. Copper concentrations in river water may increase as a result of discharge of industrial effluent. Copper concentrations near industrial effluent disposal points reached a high of 0.07 mg / L in this study.

Zinc is an important element and its deficit to humans may leads to several diseases. The high concentration in river water is largely due to pollution from industrial sources. Zinc concentrations in the river stretch varied from 0.17 to 1.95

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mg / L. The higher value is observed near industrial effluent disposal point. The observed values are far below the regulatory limits.

Cobalt is vital in trace amounts for humans because it's a crucial part of the vitamin B12 complex. It is harmful to humans and aquatic animals if it is present in higher concentrations. Concentrations of cobalt measured in the river water samples range from 0.04 to 0.45 mg / L. The higher concentration is observed near industrial effluent disposal point.

Human activities, such as discharge of industrial effluents, sewage, pesticides and phosphate fertilizers are causing nickel concentrations to increase in river water. The Nickel concentration in all the collected samples was above the acceptable limit.

Water Quality Index

The water quality index (WQI) is a rating that reflects the combined impact of several water quality factors. It also makes it simple to summarize all of the data on water quality. The water quality measure created for river water samples shows no significant differences across stations. The study's goal was to determine the WQI in order to analyse the area's water quality for public use, irrigation, and other uses. The surface water quality of the selected stretch of the Tungabhadra river was primarily classified as poor, according to the NSF, because the value was between 35 and 45. But the water quality of the samples collected from RBF wells were classified as medium according to the NSF, because the value was above 50, as shown in table 5. Hence it is evident that the polluted river water underwent purification and the quality of the water gets improved through the River Bank Filtration Wells located at Somlapur Village.

Table 5. Water Quality Index of Water samples collected at the study area

Code	Description)	WQI	Quality
S1	Tungabhadra New bridge in Harihara	44	Bad
S2	Harihara bridge (old) in Harihara	41	Bad
S3	Nadiharalalli	35	Bad
S4	Airani Mata	37	Bad
S5	Hirebidri	35	Bad
S6	Konantambige	36	Bad
S7	Somlapur	38	Bad
RBF1	1st Riverbank filtration well at Somlapur	51	Medium
RBF2	2nd Riverbank filtration well at Somlapur	50	Medium

RBF well Yield and its characteristics

The table 2 summarizes the well yield values observed during a monitoring period. Pumping tests were conducted monthly from January 2023 to December 2023, with the average yield recorded at 20 m³/hr for RBF well-1 and 19 m³/hr for RBF well-2. From the pumping tests, it was observed that the well yield was highest during the monsoon season (August and September), reaching 20.5 m³/hr for both wells. However, a slight decrease in yield was noticed in October, despite higher river flow during that period. The lowest river discharge occurred during the summer months, which was reflected in a reduced yield. On average, the yield during the monsoon was 20.5 m³/hr, while in the post-monsoon season, it was slightly lower at 19.5 m³/hr. Over the entire observation period, the average yield from both wells was found to be 20 m³/hr.

Table 2. Results of variation of Well Yield and River discharge

Sl. No.	Month	Yield of well m^3/hr	River Discharge m^3/s
1	January	19.46	10.56
2	February	19.51	0.00
3	March	19.54	0.00
4	April	19.46	0.00
5	May	19.46	41.25
6	June	19.43	270.85

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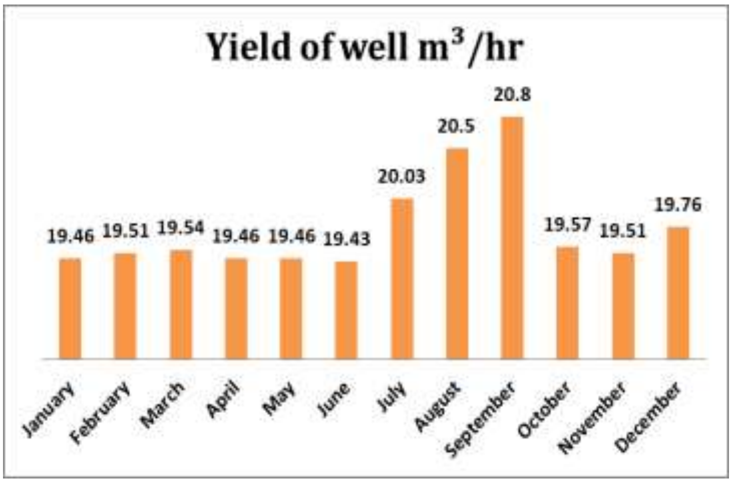
7	July	20.03	878.1
8	August	20.5	1272.2
9	September	20.8	180.57
10	October	19.57	112.65
11	November	19.51	38.56
12	December	19.76	13.68



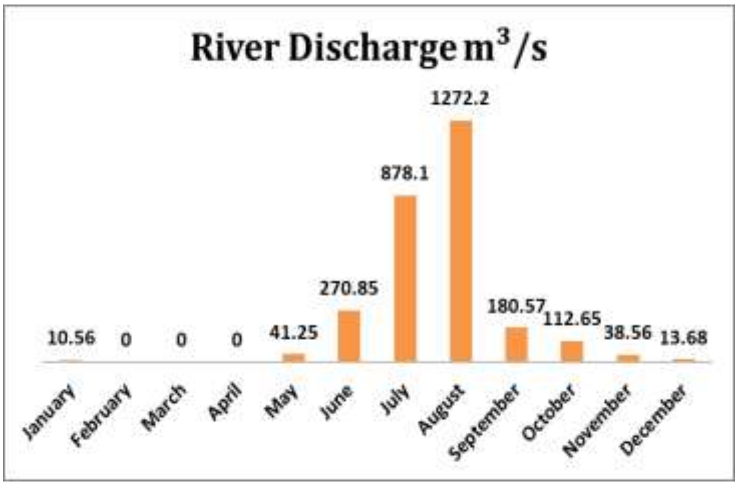


Figure 5. Month wise Variations of Yield of well and River Discharge observed

A comparison between the river discharge and well yield throughout the monitoring period shows a consistent water yield of approximately 20 m^3/hr, despite fluctuations in river flow. The average water production from RBF well-1 was about 0.48 Million Litres per Day (MLD), which is sufficient to meet the needs of around 3,555 people, assuming an average consumption of 135 Litres Per Capita Per Day (LPCD). Given that the population of Somlapura village, according to the 2011 census, is approximately 1,484, the available water supply of 0.48 MLD is more than adequate to meet water demand which stands at around 0.370 MLD.

Geographical Information System

The resulting water quality parameters, indices and clusters were then displayed by drawing themed maps of the Tungabhadra River using Geographical Information System software MapInfo Professional, making GIS a decision support system. As demonstrated in Figure 6, the produced maps may aid decision makers in managing and mitigating pollution in the Tungabhadra River.

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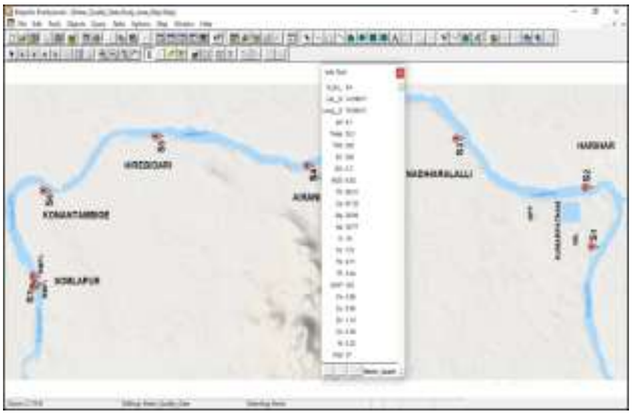

Fig. 6 Stretch of River Tungabhadra [GIS Tool Map Info Professional]

5. Conclusion

The present study reveals that, following a detailed examination of chemical characteristics of river water at several locations along the Tungabhadra River, it has been determined that there is a significant ecological imbalance in the river Tungabhadra as a result of the discharge of industrial effluents. Before they are released from the factories, more dilution and treatment are extremely desirable. The river Tungabhadra is badly contaminated near the HPF and GRASIM industries outfalls, and the pollution extends downstream for 500 meters. In the river stretch, in terms of quality, the water is not potable, and also high in chemical contamination near the discharge point. As a result, the water in this area is suitable for irrigation but not for household or drinking use. However the increasing DO values and decreasing BOD values downstream shows the significant self-purification of Tungabhadra river but as per the WQI, the quality of the river water is determined as bad. Based on the findings, it is possible to conclude that a proper environmental management plan may be implemented to reduce pollution, which is mostly produced by the discharge of industrial effluent. According to the WQI, the purification of river water is observed through installed RBF wells at Somlapur, and the quality of river water has improved significantly from bad to medium. As a result, it is recommended that RBF wells to be installed in nearby villages along the banks of the river Tungabhadra. Else, it will have a substantial negative impact on humans. Further, Geographical Information System software MapInfo Professional is helpful for decision makers in managing and mitigating pollution in the Tungabhadra River.

References

1. APHA, standard methods for the examination of water and waste water, 18th Edition: American Public Health Association, Washington D.C
2. B. Suresh (2015) "Multiplicity of phytoplankton diversity in Tungabhadra River near Harihar, Karnataka (India)" International Journal of Current Microbiology and Applied Sciences, ISSN: 2319-7706, 4(2), pp. 1077-1085
3. B. Suresh, S. Manjappa and E. T. Puttaiah. (2013). "Dynamics of phytoplankton succession in Tungabhadra River near Harihar, Karnataka (India)". Journal of Microbiology and Antimicrobials, ISSN 2141-2308, 5(7), pp. 65-71.
4. Basavaraj M. Kalshetty, Shobha.N, M.B.Kalashetti and Ramesh Gani (2014). "Water Quality of River Tungabhadra due to the Discharge of Industrial Effluent at Harihar, District Davanagere, Karnataka State, India" American Journal of Advanced Drug Delivery, ISSN 2321-547X, 2(1) pp. 120-132.
5. Chitaranjan Dalai and Ramakar Jha. (2014). "Review on Water Treatment Techniques Used for Riverbank Filtration"
6. International Journal of Civil Engineering Research ISSN 2278-3652, 5(3), pp. 221-226.
7. D. Siddaramu, K. Harish Babu, S. Prakash Naik and E.T. Puttaiah (2009). "Heavy Metal Concentration in Surface and Sub Surface Waters Along Tungabhadra River in Karnataka, India" Nature Environment and Pollution Technology, 8(4), pp. 649-655.
8. Gopal Krishan, Surjeet Singh et.al. (2016). "Assessment of Water Quality for River Bank Filtration along Yamuna River in Agra and Mathura" International Journal on Environmental Sciences, ISSN: 0976-4534, 7 (1) pp. 56-67.
9. Marcela Jaramillo. (2011). "Riverbank Filtration: An Efficient and Economical Drinking-Water Treatment Technology" Medellin, ISSN 0012-7353, 79(171), pp. 148-157.
10. Nagraj S. Patil, Madhu Dodawad, Vijaykumar, H. and Nataraja, M. (2020). "Site Suitability for RBF Using Geospatial Technology in Tungabhadra Sub-basin, India" Journal Geological Society of India. ISSN 0016-7622, 96, pp.180-188.
11. Pradeep Kumar, Indu Mehrotra, Ankush Gupta, Soma Kumari. (2018). "Riverbank Filtration: A Sustainable Process to Attenuate Contaminants during Drinking Water Production" Journal of Sustainable Development of Energy, Water and Environment Systems, 6(1), pp 150-161.
12. Rashmikant G. Shah and Dr. Nanak Pamnani. (2018). "Effect of Riverbank filtration and infiltration in Mahi River" International Journal of Research in all Subjects in Multi Languages ISSN: 2321 – 2853, 6(4) pp.1-6.
13. S. Ranjith, Anand V. Shivapur, P. Shiva Keshava Kumar, Chandrashekarayya G. Hiremath, Santhosh Dhungana. (2019). "Utilization of Water Quality Modeling and Dissolved Oxygen Control in River Tungabhadra, Karnataka (India)" Open Access Library Journal, ISSN: 2333-9721, 6, pp. 1-17.
14. S.Ranjith , Anand.V. Shivapur, P. Shiva Keshava Kumar, Chandrashekarayya.G. Hiremath, Santhosh Dhungana (2019). "Water

10.48047/jocaaa.2024.33.08.214

Quality Evaluation in Term of WQI River Tungabhadra, Karnataka, India" International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, 8(9), pp. 247-253.

15. T M Vinay. (2017). "Water Quality Analysis of River Tungabhadra near Harihar". IJARIIE, ISSN(O):2395-4396, 3(2) pp. 3683–3686.
16. T. B. Boving, B. S. Choudri, P. Cady, A. Cording, K. Patil, Veerabaswant Reddy (2014). "Hydraulic and Hydrogeochemical Characteristics of a Riverbank Filtration Site in Rural India" Water Environment Research, 86(7), pp.636-648.
17. T.B. Boving, K. Patil, F. D'Souza, S.F. Barker, S.L. McGuinness, J. O'Toole, M. Sinclair, A.B. Forbes and K. Leder. (2019). "Performance of Riverbank Filtration under Hydrogeologic Conditions along the Upper Krishna River in Southern India" Water, 11(12), pp. 1-17.
18. Thi Ngoc Anh Hoang, Gustavo Covatti1 · Dan Van Nguyen2 · Hilmar Börnick3 · Thomas Grischek. (2024). "Feasibility of riverbank filtration in Vietnam" Sustainable Water Resources Management, 10:174, https://doi.org/10.1007/s40899-024-01143-x.