International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-10, Issue-07, Oct 2024

Assessment of treatment units at Raichur Thermal Power Station and Water Quality Evaluation of the Krishna River, Karnataka, using WQI

Ashwini G, Research Scholar, Guru Nanak Dev Engineering College, Bidar, India, ashwini.giridas@gmail.com

Dr. Basappa B Kori, Professor, Guru Nanak Dev Engineering College, Bidar, India, bbkori@gmail.com

Santosh Kumar, Assistant Professor Navodaya Institute of Technology, Raichur, Karntaka, India, santunmath2112@gmail.com

Abstract **Thermal power plants are the primary energy source in India, meeting 70-80% of the country's total power demand through coal-based generation. These plants use significant amounts of water in various processes, resulting in large quantities of wastewater discharge. This study aims to assess the physico-chemical characteristics of the effluent released from the bottom ash pond (fly ash slurry) at a coal-based power plant near the Krishna River, located 18 km from Raichur city in Deosugur village, Karnataka. Water samples were analyzed from both upstream and downstream points of the river to evaluate the impact of the effluent on water quality. Parameters such as pH, EC, TDS, Hardness (TH), DO, BOD, Alkalinity, and Chlorides were measured. The results showed that while pH, EC, TDS, Alkalinity, and Chlorides were within the acceptable limits set by the BIS, but BOD, DO, and TH exceeded permissible limits due to untreated industrial effluents being directly discharged into the river. Water Quality Index analysis indicated that the effluent alters the river's physico-chemical properties, negatively impacting human and aquatic life. As a result, the river water is deemed unsuitable for drinking, bathing, or supporting fisheries, though it may still be used for industrial and irrigation purposes. The study concludes that primary treatment of the effluent and increased water reutilization are necessary to prevent environmental pollution and minimize health risks.**

***Keywords* —Bottom ash pond, Coal-based power plant, Fly ash slurry, Physico-chemical properties Water pollution, Water Quality Index(WQI) .**

I. Introduction

1.1 General:

Water scarcity and pollution are pressing concerns in India, significantly impacting both humans and the environment. Water pollution refers to the contamination of water bodies such as rivers, lakes, oceans, and groundwater by harmful substances, which can degrade water quality and harm ecosystems, human health, and the environment. Common pollutants include chemicals, industrial effluents, plastics, heavy metals, untreated sewage, and agricultural runoff. Key sources of water pollution are industries, agricultural practices, urban runoff, and domestic waste.

1.2 Industry and its description:

Thermal power plants are among the major industries in India, converting heat energy into electrical energy. In these power stations, heat is used in a steam-generating cycle to boil water in a high-pressure vessel, producing steam that drives a turbine connected to an electrical generator.

This study examines the impact of effluent discharge from the Raichur Thermal Power Station (RTPS) on the Krishna River basin. RTPS is a coal-fired power plant located in Yadlapur, Devsugur, Shaktinagar, Raichur district, Karnataka. Operated by Karnataka Power Corporation Limited (KPCL), it was the first thermal power plant established in the state. RTPS consists of 8 units: 7 units each generate 210 MW of electricity, while 1 unit produces 250 MW, giving the plant a total capacity of 1,720 MW per day. The plant consumes 18,000 to 24,000 tons of bituminous coal daily and meets 40% of Karnataka's electricity demand. The water required for the plant is

 DOI : 10.35291/2454-9150.2024.0375

ISSN : 2454-9150 Vol-10, Issue-07, Oct 2024

sourced from the Krishna River basin. Water treatment processes at RTPS include coagulation using alum and demineralization, ensuring water is free from contaminants. Although coal-based power plants meet significant energy demands, they also pose environmental challenges due to pollutant emissions, making it essential to explore more sustainable practices in power generation and water usage.

The study focuses on understanding the environmental impacts caused by RTPS's effluent on the river ecosystem and water quality.

II. OBJECTIVES OF PRESENT STUDY

1 To study the water treatment unit of RTPS.

2 To identify the source of discharge from RTPS to Krishna River.

3 To study the characteristics of Fly ash & Bottom ash discharge from RTPS.

4 To evaluate Physio -Chemical properties of Krishna River near RTPS Raichur.

5 To compare the results with BIS standards for effluent discharge into the River.

6 To access the water Quality using WQI.

III. MATERIALS & METHODOLOGY

The study was conducted to assess the impacts of effluent discharge from RTPS on the Krishna River basin. Water samples from the river were collected every week over a period of four weeks during the study. The procedure used for sample collection as follow:

A.Sample Collection: Samples were collected to analyze the physico-chemical parameters in fly ash and bottom ash at various points, including outlets, downstream, and upstream locations near the disposal point in the river as shown in figures 3.1 to 3.7 and the respective latitude and longitude is mentioned in table 3.1. Using the grab sampling method, samples were periodically collected during the study period from March 27, 2023, to April 20, 2023. The sampling procedure is as follows:

- Water samples were collected in clean 1-liter plastic bottles. For the Dissolved Oxygen (DO) analysis, water was fixed in specialized DO bottles directly at the sampling point, ensuring no air bubbles were present.
- It was ensured that no floating materials were present at the sampling station.
- Each sample bottle was labeled with the necessary details.
- The samples were carefully transported to the laboratory and kept at a cold temperature.
- Additional samples were taken for laboratory analysis of various parameters mentioned below.

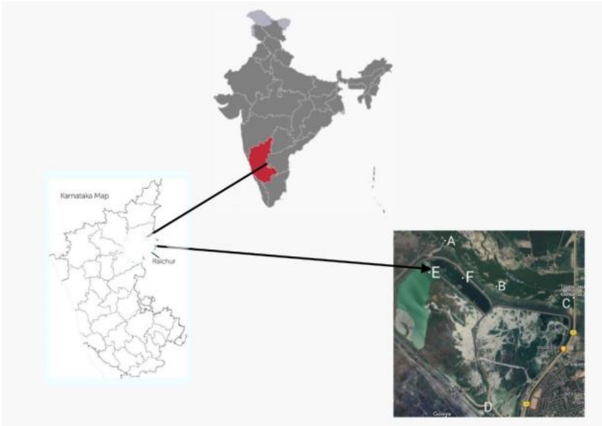

Fig: 1 Location of sample Stations

Table:1 Latitude & longitude of sample stations

Sample Points	Latitude	Longitude
A	16.384˚	77.339
B	16.386˚	77.333
C	16.364˚	77.341
D	16.390˚	77.335
E	16.383˚	77.344
F	16.381˚	77.356

Fig: 2 Station A Upstream

Fig: 3 Station B Downstream

 DOI : 10.35291/2454-9150.2024.0375

ISSN : 2454-9150 Vol-10, Issue-07, Oct 2024

Fig: 4 Station C Clear Water Zone

Fig: 5 Station D Fly Ash

Fig: 6 Station E Bottom ash (Raw water)

Fig: 7 Station F Bottom ash (Clean water)

B. Water Quality analysis: The samples were analyzed for various parameters using standard methods outlined in APHA (2012). The parameters analyzed are as follows:

- pH
- Dissolved Oxygen (DO)
- Biological Oxygen Demand (BOD)
- Alkalinity
- Electrical Conductivity (EC)
- Total Dissolved Solid (TDS)
- Total Hardness (TH)
- Chlorides

The pH and electrical Conductivity were measured in the field during sample collection using a Portable Star Series Orion (USA) meter. The Winkler method was used for the determination of DO and BOD.

IV. RESULT AND DISCUSSION

4.1 Assessment of treatment units:

In a thermal power plant, water plays a crucial role in various stages of power generation such as Steam Generation, cooling systems, Feed water Supply, Flue Gas Cleaning, etc., Water is, therefore, integral to both the energy generation process and maintaining the equipment's efficiency and longevity in a thermal power plant. The unit flow diagram for the water treatment used in RTPS is shown in figure 4.1 and description of different units is explained below.

1. Stilling Chamber

Water from the Krishna River is pumped through a 64 m^3 closed pipe into a cylindrical stilling chamber. The physical and chemical characteristics of this water is presented in the table 4.1 below The water enters near the top, and as it flows through the chamber, its velocity decreases, allowing fine air bubbles to rise. These bubbles are removed by an automatic air vent at the top. The chamber's outlet runs 75 cm above the air release. During the process, chlorine gas is added to disinfect the water, eliminating harmful microorganisms and algae. Care must be taken, as chlorine gas is hazardous to humans.

2. Coagulation-Sedimentation Chamber:

Coagulation is a chemical water treatment process that removes suspended solids by neutralizing their electrostatic charges. Alum solution is mixed with water through a porous pipe, using about 600 tons annually. In the sedimentation tank, the alum-treated water rests for 2-3 days, allowing suspended particles to settle as sludge at the

DOI : 10.35291/2454-9150.2024.0375

bottom. The clarified water is collected from the top and sent for further treatment.

Water inlet pipe

Stilling Chamber

lum solution mixing with water

Sedimentation Tank

Fig 4.1: Unit flow diagram for the water treatment

Strongly Acidic Cation Tank

Weak Base Anion Tank

Strong Base Anion Tank

Mixed Bed Tank

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3. Strongly Acidic Cation Tank

Water from the sand filter is collected in an acidic cation tank containing sulfonic acid-based resin beads. This tank removes positively charged particles like calcium, magnesium, and sodium from the water in about 3 hours. The resin works across the full pH range (0-14) and remains stable even at high temperatures up to 120°C.

4. Weak Base Anion Tank

Water from the strongly acidic cation tank is stored in a weak base anion tank to remove weakly charged anions like chloride, sulfate, and nitrates. The tank uses weakly basic anion exchange resins with amino groups and has a detention time of 3 hours before the water is sent for further treatment.

5. Strong Base Anion Tank:

The Strong Base Anion Tank is used for demineralization, dealkalization, and removal of strong negatively charged ions like Cl, SO_4, HCO_3, and silica. The anions are exchanged with OH^- ions from the resin. This process, which also removes organics like total organic carbon (TOC), takes about 3 hours

6. Mixed Bed Tank:

A mixed bed deionizer is crucial for producing high-purity boiler water, achieving water quality below 1 micro-ohm conductivity. It contains a 40% strong acid cation resin and 60% strong base anion resin mix. After initial treatment through a two-bed deionizer or reverse osmosis, water passes through the mixed bed for 3 hours to polish it to higher purity. The rubber-lined bed allows for resin expansion during backwashing. The treated water is stored and then transferred to the boiler for further use.

4.2 Assessment of water quality parameters:

The physico-chemical properties of water were analyzed over a four-week period. The results are summarized in the following table 4.2 to 4.5, showcasing the variations and trends in parameters such as pH, alkalinity, hardness, chlorides, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), electrical conductivity (EC), and other relevant characteristics. The data provides insight into the water quality across different weeks, highlighting fluctuations in key parameters. This representation offers a clear understanding of how the physico-chemical aspects of water quality evolved over time, serving as a basis for further interpretation and comparison with water quality standards.

Date	Parameter	Units	BIS Standards		Intake	Flyash	Bottom ash	
			Drinking water	Irrigation water			Raw water	Clear water
17-04-2023	pH		6.5-8.5	6.5-8.5	8.3	7.8	8.5	7.23
17-04-2023	EC	µs/cm	300	3000	1426.000	1426.000	2972.000	1250.00
17-04-2023	TDS	mg/L	500	2000	850.34	850.34	1000.5	1056
17-04-2023	DO	mg/L	5	>5	6.3	6.3	5.6	4.5
20-04-2023	BOD	mg/L	5	<10	4.9	4.9	6.3	5.9
17-04-2023	Alkalinity	mg/L	120	150	60	60	70	50
17-04-2023	Hardness	mg/L	300	600	1730	1730	1640	1540
17-04-2023	Chlorids	mg/L	250	1000	139.4	139.4	317.9	381.5

Table 4.1 Physico-Chemical Properties of Water Analyzed at locations intake, flyash disposal point and bottom ash collection point

Date	Parameter	Units	BIS Standards		Station A	Station B	Station C
			Drinking wate	Irrigation water			
27--03-2023	pH		6.5-8.5	6.5-8.5	6.7	7	7.63
27--03-2023	EC	µs/cm	300	3000	1354	1074	1954
27--03-2023	TDS	mg/L	500	2000	900	798	746.4
27--03-2023	DO	mg/L	5	>5	5	4.8	4.6
30-03-2023	BOD	mg/L	5	<10	4.8	4.2	4
27--03-2023	Alkalinity	mg/L	120	150	30	26	20
27--03-2023	Hardness	mg/L	300	600	795.6	786	780.2
27--03-2023	Chlorids	mg/L	250	1000	53.78	50.12	145.3

Table 4.2 Physico-Chemical Properties of Water Analyzed for week 1

Date	Parameter	Units	BIS Standards		Station A	Station B	Station C
			Drinking water	Irrigation water			
03--04-2023	pH		6.5-8.5	6.5-8.5	6.8	7.85	7.9
03--04-2023	EC	µs/cm	300	3000	1782	1733	1713
03--04-2023	TDS	mg/L	500	2000	794	591.08	576
03--04-2023	DO	mg/L	5	>5	5.1	4.7	4.5
06--04-2023	BOD	mg/L	5	<10	4.95	4.5	4.2
03--04-2023	Alkalinity	mg/L	120	150	40	30	32
03--04-2023	Hardness	mg/L	300	600	796	794.2	792.1
03--04-2023	Chlorids	mg/L	250	1000	52.96	52.75	43.85

Table 4.3 Physico-Chemical Properties of Water Analyzed for week 2

Date	Parameter	Units	BIS Standards		Station A	Station B	Station C
			Drinking water	Irrigation water			
03--04-2023	pH		6.5-8.5	6.5-8.5	6.8	7.85	7.9
03--04-2023	EC	µs/cm	300	3000	1782	1733	1713
03--04-2023	TDS	mg/L	500	2000	794	591.08	576
03--04-2023	DO	mg/L	5	>5	5.1	4.7	4.5
06--04-2023	BOD	mg/L	5	<10	4.95	4.5	4.2
03--04-2023	Alkalinity	mg/L	120	150	40	30	32
03--04-2023	Hardness	mg/L	300	600	796	794.2	792.1
03--04-2023	Chlorids	mg/L	250	1000	52.96	52.75	43.85

Table 4.4 Physico-Chemical Properties of Water Analyzed for week 3

Date	Parameter	Units	BIS Standards		Station A	Station B	Station C
			Drinking wate	Irrigation water			
17-04-2023	pH		6.5-8.5	6.5-8.5	7.85	7.95	8.1
17-04-2023	EC	µs/cm	300	3000	1416	1571	1604
17-04-2023	TDS	mg/L	500	2000	801	795	755
17-04-2023	DO	mg/L	5	>5	5.6	5.4	4.8
20-04-2023	BOD	mg/L	5	<10	4.9	3.8	3.4
17-04-2023	Alkalinity	mg/L	120	150	40	30	28
17-04-2023	Hardness	mg/L	300	600	795	785	760
17-04-2023	Chlorids	mg/L	250	1000	52	42.8	39.4

Table 4.5 Physico-Chemical Properties of Water Analyzed for week 4

1. **pH:** The pH of the samples ranged from 6.7 to 8.5, within the permissible BIS limit of 6.5-8.5. The pH variation, influenced by the temperature of slurry waste, may have resulted from the addition of condenser or warm water. All sample points remained within safe limits throughout the study. However, elevated pH levels from effluent discharge into rivers can adversely affect water quality and disrupt aquatic life. Figure 4.2 shows the pH variation at sampling stations A, B, and

 DOI : 10.35291/2454-9150.2024.0375

C.

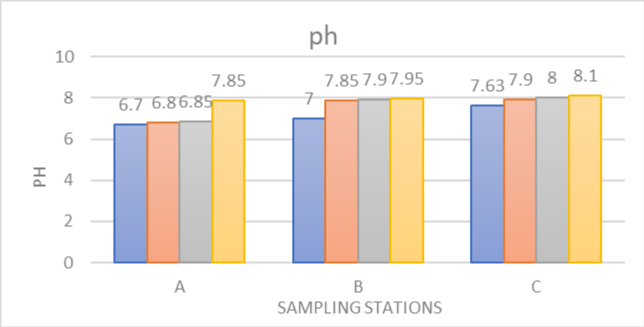

Fig: 4.2 Variation of pH during study period for Sampling Station ABC

2. **DO**: In this study, the Dissolved Oxygen (DO) levels at the industrial effluent discharge point were found to range between 4.8 and 5.9 mg/L during the monitoring period. These values suggest that the river undergoes a natural purification process. However, the lower DO levels at the discharge point are likely attributed to the high influx of inorganic and organic waste, which contributes to oxygen depletion in the water. Figure 4.3 shows the DO variation at sampling stations A, B, and C.

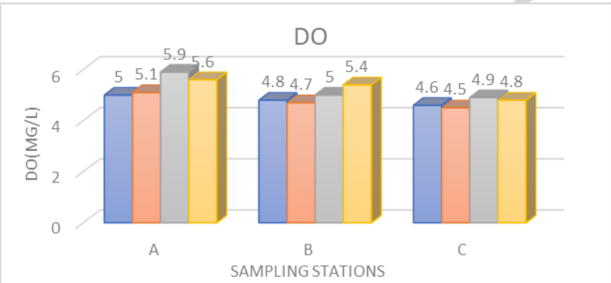

Fig: 4.3 Variation of DO during study period for Sampling Station ABC

3. **BOD**: As a result of the study, the Biological Oxygen Demand (BOD) of water samples collected during the monitoring period at the industrial effluent discharge point ranged between 4 to 6.9 mg/L. These values were within the permissible limits set by BIS standards, which specify a maximum of 5 mg/L for BOD. The observed decrease in BOD, along with an increase in Dissolved Oxygen (DO) levels downstream of the discharge point, suggests the occurrence of natural self-purification processes in the water body. Figure 4.4 shows the BOD variation at sampling stations A, B, and C.

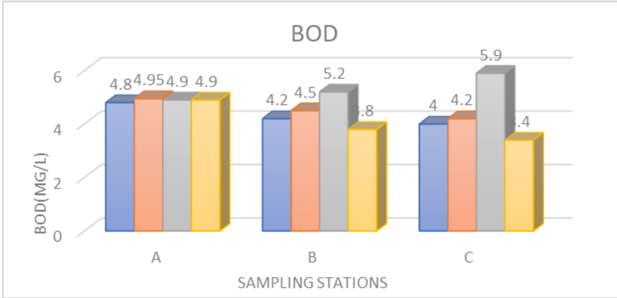

Fig: 4.4 Variation of BOD during study period for Sampling Station ABC

4. **Alkalinity**: In this study, the water samples collected at the disposal point showed total methyl orange alkalinity ranging between 20-80 mg/L. This was within the BIS prescribed limits of 120 mg/L. The alkalinity in the water was primarily due to the presence of carbonate ($CO3^{2-}$), bicarbonate ($HCO3^{-}$), and hydroxide (OH^{-}) ions. Other contributors, such as borates, phosphates, silicates, or additional bases, were also noted if present. Figure 4.5 shows the alkalinity variation at sampling stations A, B, and C.

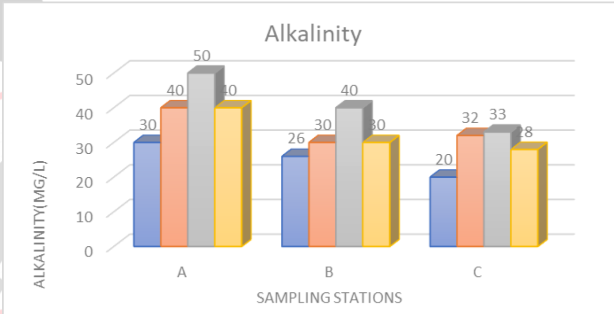

Fig : 4.5 Variation of Alkalinity during study period for Sampling Station ABC

5. **EC**: As a result of the study, the electrical conductivity (EC) values of the water samples collected at the industrial effluent point during the monitoring periods ranged from 1.357 µS/cm to 2.972 µS/cm. Electrical conductivity is a measure of water's ability to conduct an electric current, which is influenced by the presence of electrolytes that dissociate into cations and anions. The EC is an indicator of the water's mineralization, correlating with the total dissolved solids (TDS) and signifying the concentration of dissolved inorganic substances in their ionized form. Elevated EC values indicate a higher presence of total dissolved salts. Figure 4.6 shows the EC variation at sampling stations A, B, and C.

DOI : 10.35291/2454-9150.2024.0375

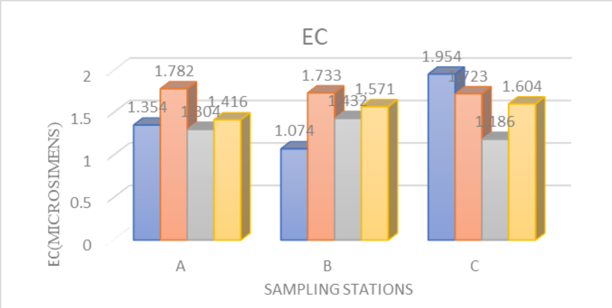

Fig: 4.6 Variation of EC during study period for Sampling Station ABC

6. **Total Dissolved Solid** : The Total Dissolved Solids (TDS) values in this study ranged from 502 mg/L to 1056 mg/L, exceeding the recommended limit of 500 mg/L for drinking water. Although water with TDS levels up to 1500 mg/L can be permitted for domestic use in unavoidable circumstances, the results suggest that the groundwater in the study area contains a high concentration of dissolved solids. This elevated TDS likely results from the discharge of plant effluents, contributing to the increased salinity of the water. Figure 4.7 shows the TDS variation at sampling stations A, B, and C.

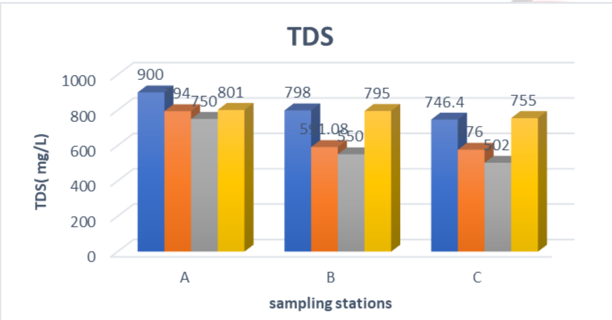

Fig : 4.7 Variation of TDS during study period for Sampling Station ABC

7. **Total Hardness**: In this study, the total hardness of the water was attributed to the presence of divalent cations, such as calcium (Ca) and magnesium (Mg), which are commonly found in water. The analysis of industrial effluent samples revealed total hardness levels ranging from 690 to 796 mg/L. As a result, the water was classified as moderately hard, indicating the need for treatment before it can be used for domestic purposes. Figure 4.8 shows the hardness variation at sampling stations A, B, and C.

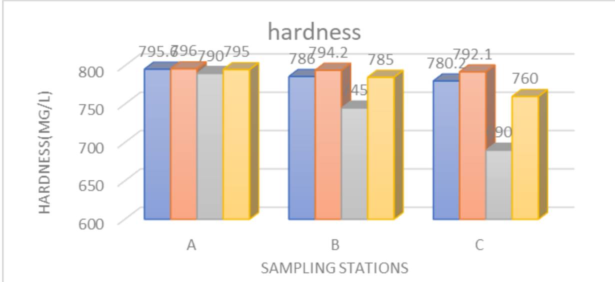

Fig : 4.8 Variation of Hardness during study period for Sampling Station ABC

8. **Chlorides**: The study revealed that chloride concentrations in the water samples ranged from 39.99 mg/L to 459.4 mg/L, with several values exceeding the BIS standard limit of 250 mg/L. Elevated chloride levels are often indicative of contamination from sewage and industrial effluents, which are common sources of pollution in groundwater. Although chloride itself is not highly harmful at moderate levels, concentrations above 250 mg/L can give water a salty taste. Additionally, people who consume water with excessively high chloride levels may experience laxative effects, especially if they are not accustomed to it. The high chloride concentrations observed in this study likely stem from the intrusion of wastewater and industrial discharge into the groundwater, contributing to the contamination. Figure 4.9 shows the chloride variation at sampling stations A, B, and C.

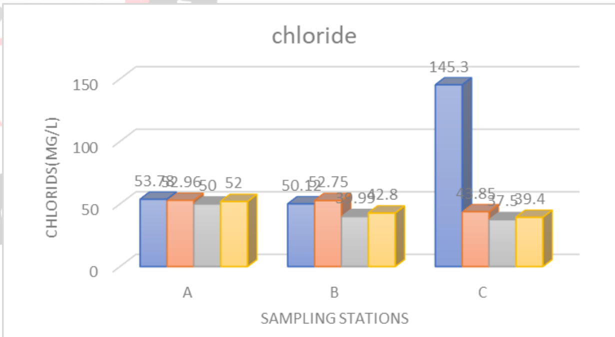

Fig : 4.9 Variation of Chloride during study period for Sampling Station ABC

4.3 Water Quality Index:

Water Quality Index (WQI) is a crucial tool used to assess the overall quality of water by combining multiple water quality parameters into a single numerical score. In the context of this study, WQI provides a comprehensive evaluation of water suitability for various uses, including drinking, recreation, and agriculture.

The WQI is calculated based on several key parameters, such as pH, dissolved oxygen, turbidity, total dissolved solids, and concentrations of contaminants like chloride, nitrates, and heavy metals. Each parameter is assigned a

 DOI : 10.35291/2454-9150.2024.0375

weight based on its relative importance to water quality, and a score is derived that categorizes the water into different quality classes (e.g., excellent, good, moderate, poor, and unsuitable).

In this study, applying WQI allows for an integrated assessment of the water samples, highlighting the impact of excessive chloride levels alongside other pollutants. By quantifying water quality in this way, stakeholders can make informed decisions regarding water management, pollution control, and public health protection. Ultimately, the WQI serves as a valuable indicator of the water's ability to support life and its overall safety for human consumption and use.

The Water Quality Index (WQI) values were calculated for three monitoring stations (A, B, and C) based on the following key water quality parameters: pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Alkalinity, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), and Chlorides. The WQI results were as follows:

Station C: The WQI was 79.79, indicating poor water quality. The water at this station is likely moderately polluted and may require treatment before use.

Station B: The WQI was 102.633, indicating very poor water quality. The water at this station is unsuitable for direct use and requires significant treatment.

Station A: The WQI was 113.78, indicating unsuitable water quality for most purposes, as the pollution level exceeds acceptable limits.

The results tabulated in table 4.6 highlight that Station A has the highest level of water pollution, followed by Station B and then Station C. These findings suggest that water from all stations may not be safe for consumption or other uses without proper treatment, with Station A requiring the most immediate attention.

Parameters	BIS	1/Sn	Sum1/Sn	k=1/Sn	Wn=k/Sn	Vo	Vn(1)	Qn	Qn*Wn	Vn(2)	Qn	Qn*Wn	Vn(3)	Qn	Qn*Wn
pH	7.5	0.133	0.554	1.804	0.241	7	7.05	10	2.405	7.67	134	32.2309	7.65	130	31.26881
EC	300	0.003	0.554	1.804	0.006	0	2.01175	0.6706	0.004	1.452	0.484	0.00291	1.09	0.3633333	0.002185
TDS	500	0.002	0.554	1.804	0.004	0	699.2	139.84	0.505	686.02	137.204	0.49502	657.35	131.47	0.474336
DO	5	0.200	0.554	1.804	0.361	14.6	4.65	103.65	37.395	5.075	99.21875	35.7975	4.3	107.29167	38.71019
BOD	5	0.200	0.554	1.804	0.361	0	5.137	102.74	37.068	4.425	88.5	31.9303	5.7	114	41.13051
Alkalinity	120	0.008	0.554	1.804	0.015	0	54	45	0.676	38.5	32.08333	0.48231	45	37.5	0.563741
TH	300	0.003	0.554	1.804	0.006	0	794.1	264.7	1.592	778.57	259.5233	1.56057	755.55	251.85	1.514433
Chloride	250	0.004	0.554	1.804	0.007	0	52.18	20.872	0.151	46.41	18.564	0.13396	42.26	16.904	0.121977
		0.554			1.000			ΣWQn=	79.795		ΣWQI=	102.633		ΣWQI=	113.7862
								WQI=	79.795		WQI=	102.633		WQI=	113.7861

Water Quality Range (brown et.al.1970)

WQI	WQS	Possible usage
0.0-25	Excellent	Drinking,Irrigation
26-50	Good	Drinking,Irrigation
51-75	Poor	Irrigation&Industrial
76-100	Very Poor	Irrigation
>100	Unsuitable for drinking	Treament Required

site	WQI	WQS	Possible Usage
SS1	79.745	poor	Irrigation and industrial
SS2	102.633	poor	Irrigation
SS3	113.786	poor	Irrigation

Table 4.6: Water Quality Index (WQI) Values for Different Water Quality Parameters

V. Conclusion

The water treatment units of the Raichur Thermal Power Station (RTPS) were studied in detail, focusing on their role in maintaining water quality. The treatment process was found to be essential in ensuring that the water meets the necessary standards for use in the power plant and

 DOI : 10.35291/2454-9150.2024.0375

reducing the environmental impact of wastewater discharge. The study highlighted the effectiveness of the various treatment stages, including coagulation, ion exchange, and demineralization, in removing contaminants and ensuring the water quality is suitable for industrial use. However, the findings also emphasize the need for ongoing monitoring and improvements to optimize the treatment efficiency and address any potential sources of pollution in the surrounding water bodies.

The major sources of river pollution in the study area were identified as industrial waste, agricultural runoff, and sewage. By reviewing relevant literature, key water quality parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Total Hardness (TH), Alkalinity, and Chlorides were selected for analysis. Water samples were collected over four weeks (mid-March to mid-April) through grab sampling, and the results were compared with BIS standards to assess water quality.

The Water Quality Index (WQI) values ranged from 79.79 to 113.78, indicating very poor water quality in areas near the industrial zone and power plant, with pollution worsening at downstream sites. The findings highlight a critical need for appropriate treatment methods to improve surface water quality around the plant. The application of WQI in this study has proven to be an effective tool for assessing and comparing the overall water quality across different sampling stations.

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 DOI : 10.35291/2454-9150.2024.0375