

Research Article

Chemical Impact of Borehole Water Quality on the Operation of Equipment at the Atinkou Thermal Power Plant (Côte d'Ivoire)

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Abstract

The quality of borehole water can significantly impact the operation of equipment at the Atinkou Thermal Power Plant in Côte d'Ivoire. Borehole water often contains various minerals and chemicals, such as calcium, magnesium, iron, and manganese. These can lead to scaling and corrosion in the power plant's equipment. Industrial activities can introduce pollutants into groundwater, including nitrates, sulfates, and chlorides. These pollutants can affect the chemical balance of the water, leading to operational challenges. The aim of this study is to determine the chemical quality of the borehole water supplying Atinkou thermal power plant in order to assess its impact on the operation of the plant's equipment. Selective physico-chemical analyses were carried out on Atinkou borehole water in 2019 and 2024. The Chemical Water Quality Index (CWQI) method was used to determine the classes quality of the borehole water, and the Ryznar Index was used to highlight the impact of the water on the plant's equipment. Water chemical quality index (IQCE) value of 0.70 obtained in 2019 indicates that the plant's borehole water was of acceptable quality, requiring moderate treatment for use in the plant. On the other hand, in 2024, the IQCE value of 0.05 indicates that the borehole water is of poor quality and requires full treatment before use. The Ryznar Index of 14.67 in 2019 and 14.83 in 2024 indicate a risk of extreme corrosion of equipment by borehole water in both years.

Keywords

Chemical Risk, Thermal Power Plant, Borehole Water, Corrosion

1. Introduction

Water is an essential element for the proper functioning of electric thermal power plants [1-4]. Indeed, thermal power

plants require water volumes of about 0.03165MWh for steam condensation and 0.633MWh for cooling turbines and boilers

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[5, 6]. In addition to these large quantities of water, the quality requirements are required for the cooling water because the water booster, sometimes highly mineralized and contaminated biologically can cause problems of corrosion, of entanglements and contamination of biological materials [7, 8]. As a result, the use of good chemical and microbiological water in thermal power plants becomes a necessity to maintain the effectiveness of turbines and prolong their lifetime of life [9]. The groundwater is generally less polluted than surface water, are increasingly used to supply power plants because they do not undergo treatment before their uses [10]. They represent approximately 4% of water samples for the supply of thermal power plants [11]. In Côte d'Ivoire, the Atinkou thermal power station, located in Jacqueville, must be powered by drilling water. However, very few studies relating to the quality of drilling water intended for use in thermal power plants have been carried out while corrosive cooling water could cause the progressive destruction of building materials and when it is clogging, would produce tarters [12]. It is therefore important to know the chemical characteristics of the Atinkou borehole water in order to assess its impact on the plant's equipment.

2. Materials and Methods

2.1. Presentation of the Zone of Study

The thermal power station of Atinkou is located in 1km in the southeast of the village of Taboth, in the prefecture of Jacqueville, in about 30 km on the West from Abidjan the capital of Côte d'Ivoire. It is between degree of longitude $4^{\circ} 19.94''$ West and degree of latitude $5^{\circ} 14' 44.86''$ North. The zone of study (Figure 1) is influenced by an equatorial climate characterized by two seasons of rains and two dry seasons with medium temperatures about 27°C , a relating humidity wobbling between 80% and 90% and an annual pluviometry vary mm between 1500 and 2000 [13]. The relief is mainly flat to slightly wavy, typical of the coastal areas of Côte d'Ivoire. The altitude generally varies from 0 to 100 meters above sea level. The coastal plains dominate the region with sandy and alluvial soils, favorable to agriculture and forestry [14]. The hydrographic network is dominated by the Ebrié lagoon and the Atlantic Ocean.

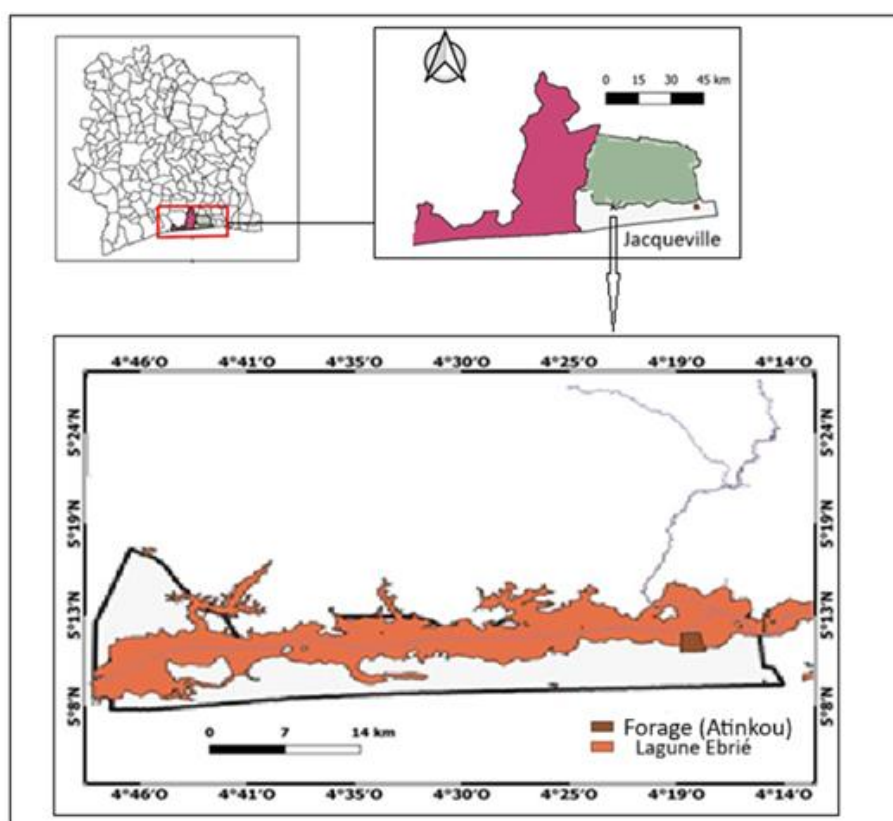


Figure 1. Location of the study area and sampled drilling.

2.2. Sampling and Analysis of Drilling Water from the Atinkou Thermal Power Station

The drilling has been the subject of two samples (one in

2019 and the other in 2022). The water samples from boreholes were taken directly to the valve of the system equipment of the drilling in polyethylene bottles of 500 mL previously washed and labeled. All these samples were then stored away

from light in coolers containing packs refrigerants (4 °C) and then, transported to the laboratory for the different analyses. In the field, pH, temperature, conductivity, dissolved oxygen, and total dissolved solids (TDS) were measured using a multi-parameter HANNA (Hi 9829). Turbidity was measured with a HANNA turbidity meter (Hi 98703). In the laboratory, the analysis of iron, sulphates, zinc, copper, silica, chloride was carried out with the DR 6000 HACH molecular absorption spectrophotometer (SODIMEL, France). Alkalinity and hardness were measured by volumetric and titrimetric methods, respectively.

2.3. Statistical Data Processing and Analysis

2.3.1. Index of Chemical Quality of the Waters of the Drilling of the Thermal Power Plant of Atinkou

The chemical water quality index (IQCE) is a reliable assessment and communication tool, which provides useful and effective information on the overall quality of water [15]. It is determined in six (6) stages that are the choice of parameters, the definition of the quality thresholds of parameters, the normalization of parameters, the balance of parameters and the estimate of the total indication of the quality of water.

Choice of Parameters and Quality Thresholds

The choice of parameters was based on those responsible for corrosive character or and entartrant some water [16]. As a

result, pH, hardness, turbidity, chlorides, sulfates and copper and zinc have been retained. The values guide each parameter as a function of industrial use and technical recommendations specific to thermal power plants have been retained and are recorded in Table 1.

Normalization of Parameters

The normalization of parameters consists in converting stocks measured in normalized scores (between 0 and 1) by using equations of following normalization:

$$Score\ i = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad (1)$$

With x : value measured by parameter;

X_{min} and X_{max} : minimum and maximum concentrations acceptable respectively.

Weighting Parameters

This step was to assign weights to each parameter in terms of its effect on the cooling of thermal power plants. The sum of the weights must be equal to 1. In the case of this study, the corrosion is the major problem, chlorides, and pH have registered the weight of the most high (Table 1) [17].

Calculation of the Overall Index of Chemical Quality of the Water

Calculation of the overall chemical quality index combines normalized (score i) scores (weight I) (equation 2) (Table 2)

$$IQCE = \sum_{i=1}^n Score_i * Poids_i \quad (2)$$

Table 1. Acceptable limit and weight parameters as a function of its relative importance [18].

Parameters	Units	Acceptable Limit	Weights	Sources
pH	-	6.5- 8.5	0.2	[16]
Conductivity	µS/cm	<2000	0.2	[19]
TDS	mg/L	<500	0.15	[20]
Hardness	mg/L	<200	0.15	[7]
Silice	mg/L	<25	0.1	[21]
Chlorures	mg/L	<250	0.2	[19]

Table 2. Classification and possible usage of water according to IQCE of American Society of Mechanical Engineers [18].

Water chemical quality index (IQCE)	Water quality	Industrial Use	Measures Required
0.90 - 1.00	Excellent	Water of very high quality, tailored without additional processing	No necessary treatment
0.75 - 0.89	Good	Good water quality, and can be used with treatments minimum	Regular surveillance, light treatment if necessary
0.50 - 0.74	Acceptable	Water of medium quality, requiring a moderate treatment	Moderate treatment (filtration, softening, demineralization)

2.3.2. Estimate of the Indication of Ryznar of Waters of Boring of the Thermal Power Station of Atinkou

The indication of Ryznar (IR) is acquired from following equation [22]:

$$Ir = 2 \text{ pHeq} - \text{pH real} \quad (3)$$

pHeq: pH of equilibrium

pH real = pH measured by some water

With

$$\text{pHeq} = (9.3 + A + B) - (C + D) \quad (4)$$

$$A = \log_{10}(\text{TDS}) - 1 \quad (5)$$

$$B = 13.12 \log_{10}(\text{Temperature} (^{\circ}\text{C}) + 273) + 34.55 \quad (6)$$

$$C = \log_{10}(\text{Alcalinity}) \quad (7)$$

$$D = \log_{10}(\text{Hardness}) \quad (8)$$

Table 3. Classification and possible usage of water according to the indication of Ryznar [19].

Ryznar Index	Description of Quality	Implication for Industrial Use	Measures Required
4.0 - 5.0	Lightly entartrant	Minimal risk of scaling	Regular surveillance, minimal treatment if necessary
5.0 - 6.0	Stable	Weak risk of furring-up or of corrosion	Regular surveillance
6.0 - 7.0	Lightly corrosive	Weak risk of corrosion	Regular monitoring, treatment, corrosion-resistant, lightweight
>7.0	Very corrosive	Well brought up risk of corrosion	Treatment anticorrosion intensive requested

3. Results

3.1. Physico-chemical Characteristics of the Water of Drilling of the Thermal Power Plant of Atinkou

The descriptive statistics of physicochemical parameters is introduced in the Table 4. The stocks of the temperature, the pH, turbidity, conductivity, TDS and the oxygen dissolved by some water of boring of Atinkou acquired in 2019 and in 2024 are respectively 25.6 and 29.2 °C, 5.8 and 5.04, 3.85 and 0.66

UTN, 44.2 and 64.2 μS/cm, 26.4 and 25.7 mg/L and 6.2 and 6.9 mg/L. The average values of total hardness, TAC, total iron, copper and zinc are successively 12 ± 4.24 mg/L (CaCO₃), 5.6 ± 0.35 mg/L (CaCO₃), 0.27 ± 0.09 mg/L, 0.02 ± 0.01 and mg/L, 0.01 ± 0.01 mg/L. Chloride, sulfate and silica recorded in 2019 and 2022, they range from 3.2 to 4.6 mg/L for chloride, from 0 to 2 mg/L for sulfates and from 0.8 to 9 mg/L for silica. On the whole, only the average values of the pH (4.75 ± 0.21), turbidity (1.77 ± 0.79 UTN) and dissolved oxygen (6.55 ± 0.25 mg/L) do not conform to the acceptable guid values of 6.5-8.5 for pH, 1 UTN for turbidity and 0.1 mg/L for dissolved oxygen.

Table 4. Descriptive statistics of the physicochemical parameters of the water of boring of the thermal power station of Atinkou.

Parameters	Unity	Guide values	Source	Years		Average	Ecartype
				2019	2024		
Temperature	°C	<50	APHA, AWWA	25.6	29.2	27.4	1.27
pH	-	7.0-9.0	APHA, ASTM	4.46	5.04	4.75	0.21
Turbidity	NTU	<1.0	APHA, AWWA	2.89	0.66	1.77	0.79
Conductivity	μS/cm	<2000	APHA, ASTM	44.2	67.2	55.7	8.13

Parameters	Unity	Guide values	Source	Years		Average	Ecartype
				2019	2024		
TDS	mg/L	<500	APHA, ASTM	26.4	25.7	26.05	0.25
Dissolved Oxygen	mg/L	<0, 1	ASTM, APHA	6.2	6.9	6.55	0.25
Total Hardness	mg/L (CaCO ₃)	<200	AWWA	6	18	12	4.24
TAC	mg/l (CaCO ₃)	20-200	APHA, AWWA	6.1	5.1	5.6	0.35
Total Iron	mg/L	<0.3	APHA, AWWA	0.4	0.14	0.27	0.09
Copper	mg/L	<0.05	ASTM	0	0.04	0.02	0.01
Zinc	mg/L	<0.1	APHA, ASTM	0	0.02	0.01	0.01
Chloride	mg/L	<250	APHA, ASTM	3.2	4.6	3.9	0.49
Sulfates	mg/L	<250	APHA, ASTM	0	2	1	0.71
Silica	mg/L	<25	European Direction	0.8	9	4.9	2.90

3.2. Index of the Chemical Quality of Borehole Water Intended to Supply the Cooling Circuit of the Atinkou Thermal Power Plant

The value of the index of the chemical quality achieved in 2019 is the 0.70 (table 5). It indicates that the water quality of

drilling Atinkou is acceptable for its use in the thermal power plant. However, it requires a slight processing (filtration, softening, demineralization) for use in the plant. In contrast, in 2022, the water drill has a very poor quality with a value of the quality index of 0.05. It necessarily requires a full treatment before use in the plant (Table 5).

Table 5. Value of the index of the chemical quality of the water of drilling Atinkou.

Parameters	Score		IQCE		Class of water quality		Traitement	
	2019	2022	2019	2022	2019	2022	2019	2022
pH	-0.6	0.98						
Turbidity	3.85	0.66						
Hardness	0.03	0.09						
Chloride	0.01	0.01	0.70	0.05	Acceptable	Very bad	Treatment moderate (filtration, softening, demineralization)	Full treatment required prior to use
Sulfates	0	0.8						
Zinc	0	0.2						

3.3. Impact of the Water of Boring on the Equipment of the Thermal Power Station of Atinkou

Table 6 presents the Ryznar drilling water showing values

recorded in 2019 and 2024. These values are 14.67 (2019) and 14.83 (2024). They indicate that the borehole water of the Atinkou power plant has a high risk of corrosion, which requires intensive anti-corrosion treatment required for use in the plant.

Table 6. Ryznar Showing Value of Atinkou Borehole Water from 2019 and 2024.

Parameters	Valeur		IR		Corrosivity class		Description	
	2019	2022	2019	2022	2019	2022	2019	2022
pHeq	10.23	9.93	14.67	14.83	Very corro- sive	Very corro- sive	Very corrosive, very im- portant deposit	Very corrosive, very im- portant deposit
pH	5.8	5.04						

4. Discussion

The analysis of physico-chemical parameters allowed us to determine the quality of the drilling water from the Atinkou thermal power station. The pH of the measured drilling waters remains acidic (5.8 in 2019 and 5.04 in 2024) during the study period. The acidity of groundwater in Côte d'Ivoire has been proven by numerous studies [22, 23]. The acidity of the groundwater in the humid tropics is mainly linked to the production of CO₂ in the first layers of the soil [24]. The hydration of CO₂ produces carbonic acid (H₂CO₃), whose ionization gives H⁺ ions which are at the origin of the acidity of the water [25]. The conductivity values obtained in the course of our analysis (44.2 µS/cm in 2019 and 67.2 µS/cm 2024), as well as those of TDS (26.4mg/L 2019 and 25.7mg/L in 2024) indicate that the waters are weakly mineralized in the water drilling. This low mineralization characterizes the waters of the sedimentary basin in Côte d'Ivoire, which are poor in silicate minerals. However, silica levels have increased from 0.8mg/L in 2019 to 9mg/L in 2024. According to Thurman [26], this considerable increase in silica in drilling may be related to the erosion of silica-rich rocks or changes in the mineral compositions of aquifers. However, these concentrations remain below the specifications in thermal power plants of 25mg/L. This range of the stocks of silica was noticed in jobs of Smith [27] and Johnson et Brown [28]. From 2019 till 2024, the concentration of sulphates is crossed from 0 to 2mg/L and that some zinc from 0 to 0.02mg/L in 2024. An upward trend was noticed for these chemical elements. Nevertheless concentration of 2mg/L of sulphate will you remain underneath the maximum borders fixed by AASP of 250mg/L. Sulphates can come from natural sources such as the erosion of soil containing sulfatés mineral or from sources anthropiques as industrial rejections and agrarian activities [29]. The possible sources of zinc in water include industrial rejections, domestic effluents and erosion of materials containing some zinc (Jones et al., 2020). In 0.02mg/L, the concentration of zinc in water is well superior on the verge of 0.01mg/L recommended by SAEM. This study gets closer to that of Smith, [27] carrying on concentration of heavy metals in the upper underground water in 0.01mg/L. Concentration of variable SNAP of 0 °F in 2019 and 0, 51 °F in 2024 suggests a weak influence of the processes of dissolution or haste

of carbonates. According to Ward et al. [30], the small change in the TAC indicates that there has been no contributions of significant hydrog énocarbonates which are the main contributors to the alkalinity of the water. However, the slight increase in the TAC may be due to a gradual stabilisation of the water sources. However, the levels of TAC are lower than the standards recommended by APHA in the thermal power plants which is between 20-200mg/L. These results are in agreement with those of Khan et Eghbalbakhtiari [31] who found similar results. The evolution of the IQCE 0.70 (2019) 0.05 (2024) suggests a deterioration of the chemical quality of the waters of drilling for use in the thermal power plant of Atinkou. These values found are consistent with those obtained by the studies of Kumar et Sharma [32], who found similar values. Moreover, the values of the Index, Ryznar of 14.67 (2019) and 14.83 (2024) indicate that the water drill is extremely corrosive which can lead to a rapid degradation of the pipes of the types of heat exchangers, boiler and other metal components. In fact, this corrosivity is due to the acidic pH, which can lead to accelerated corrosion of pipes, boilers, turbines [33]. According to Mateescu et al. [34], corrosion reduces the lifespan of the components of the power station and increases the risks of leaks and failures. Indeed, the economic and operational impacts of corrosion and deposits in heat exchangers claim that corrosion can significantly reduce energy efficiency and increase maintenance costs [35]. These studies are close to those of Jones et al. [36]. According to Fawell et Nieuwenhuijsen [37], water quality indices such as the Ryznar index are essential to anticipate corrosion problems.

5. Conclusion

The results obtained in this study indicate that the water of drilling was acidic and weakly mineralized. The quality of the water is gone from acceptable to bad from 2019 to 2022 and requires a compulsory treatment before its use. The values of the index, Ryznar obtained reveal that the water in the drilling of the central Atinkou remained extremely corrosive during these two years of study. This situation requires treatment measures stringent to prevent damage to the equipment and to ensure an effective operation in the plant.

Abbreviations

IR	Index, Ryznar
CWQI	Chemical Water Quality Index
IQCE	Index of the Chemical Quality of the Water

Author Contributions

Elogne Guessan Zoro: Conceptualization, Validation, Writing - original draft, Writing - review & editing

Aya Nelly Berthe Kouadio: Data curation, Methodology, Formal analysis, Validation, Visualization, Writing - original draft

Namory Mâté Visualization, Writing - review & editing, Validation, Visualization, Writing - original draft, Writing - review & editing

Anderson Kouassi Yao: Data curation, Methodology, Formal analysis, Writing - original draft

Léon Koffi Konan: Methodology, Supervision, Validation, Visualization, Writing - review & editing

Droh Laciné Goné Methodology, Supervision, Validation, Visualization, Writing - review & editing

Data Availability Statement

The data presented in this study can be provided upon request from the corresponding author.

Conflicts of Interest

The authors declare no conflicts of interest.

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