Physico-Chemical Characterization of Industrial Wastewater from Ruashi Mining in Kolwezi (DRC)

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Abstract: This study focuses on the physico-chemical characterization of industrial wastewater discharged by Ruashi Mining in Kolwezi, Democratic Republic of Congo. These waters are used daily by local residents for domestic activities, raising serious public health concerns due to the presence of heavy metals. The analysis covered parameters such as turbidity, temperature, total dissolved solids (TDS), electrical conductivity, and heavy metal concentrations. The results reveal significant levels of pollution, highlighting the urgent need for proper treatment before any domestic use.

Keywords: *Characterization, Industrial Wastewater, Heavy Metals, Turbidity, Physico-Chemical Analysis, Ruashi Mining.*

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I. INTRODUCTION

Water is a vital resource whose quality is essential for human health and ecological balance (WHO, 2017). In industrial areas such as Kolwezi, the discharge of untreated wastewater represents a major threat to local populations. Ruashi Mining is a mining company specializing in the production of cathode copper and cobalt salts from ores extracted from its underground mine located in the Kolwezi region of the Democratic Republic of Congo. As in most mining operations, several technical processes are involved in the extraction and processing of ores, among which drainage (pumping and evacuation of groundwater infiltrating mine shafts) constitutes a key step that generates large volumes of wastewater (Chironga, 2013). A portion of the drainage water is reused for internal industrial purposes; another portion is discharged into the natural environment, particularly in areas surrounding the mining site. Local communities living nearby often use this discharged water for domestic purposes (washing, irrigation, or even cooking and drinking), generally without any prior treatment or sanitary control. This situation raises significant environmental and health concerns, as mining effluents may contain metallic residues (Co, Cu, and other chemical pollutants) likely to degrade water quality and pose risks to human health (Lutandula et al., 2020; Winde, 2010).

➢ *Study Objectives:*

- To characterize the physico-chemical quality of industrial wastewater;
- To assess their compliance with World Health Organization (WHO) standards;
- Providing recommendations.

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Fig 1 Location of Ruashi Mining SAS- Musonoi Project

II. METHODOLOGY

➢ *Study Area*

Ruashi Mining/Kolwezi is located in Kolwezi, in Lualaba Province (10°42'S and 25°28'E). The surrounding environment is strongly influenced by mining activities, and wastewater is frequently used by the local population (as illustrated in Figure 1).

➢ *Sampling, Methods, and Parameters Analyzed*

The sampling protocol consisted of collecting several samples each day over a period of eight consecutive days. These samples were combined to form eight representative daily composite samples, on which general physico-chemical tests as well as chemical analyses of heavy metals were performed. The individual composites were analyzed for general physico-chemical parameters, including pH, turbidity, temperature, electrical conductivity, and total dissolved solids (TDS).

All analyses were carried out in accordance with standard procedures recommended by the World Health Organization (WHO). For the chemical analysis of heavy metals and specific ions, the composite samples were examined using spectrophotometric methods (ICP-OES) to determine the concentrations of trace metallic elements (Cu, Pb, Zn, As, Hg, etc.). The results obtained were compared with WHO (2017) guideline values for drinking water quality in order to assess compliance and identify potential sources of contamination.

Samples were collected from several discharge points. They were placed in bottles that had been previously washed, dried, and sterilized, and then transported to the laboratory for analysis. The analytical instruments used included a turbidimeter, a pH meter, a conductivity meter, and an inductively coupled plasma optical emission spectrometer (ICP-OES).

III. RESULTS AND DISCUSSION

➢ *Evaluation Criteria According to WHO Standards*

The World Health Organization (WHO) provides internationally recognized guidelines for assessing drinking water quality. These criteria aim to ensure the safety and acceptability of water intended for human consumption. The standards cover several key categories. For this study, two categories were evaluated and are presented in Table 1 and Table 2.

Table 1 General Physico-Chemical Standards for Drinking Water

No.	Parameters	Units	Indicative Limit Value
1	pH	-	6.5–8.5
2	Temperature	°C	4–25
4	Turbidity	NTU	≤5
5	Suspended Solids (SS)	mg/l	Max 500
8	Conductivity	µS/cm	Max 1000

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Table 2 Concentrations of Heavy Metals and Specific Ions – Guideline Limit Values (WHO)

No.	Substance	Symbol	Indicative Limit Value	Units
1	Copper	Cu^{2+}	< 1.0	mg/l
2	Cobalt	Co^{2+}	< 1.0	mg/l
3	Iron	Fe^{2+}	< 0.1	mg/l
4	Zinc	Zn^{2+}	< 0.1	mg/l
5	Nickel	Ni^{2+}	< 0.05	mg/l
6	Lead	Pb^{2+}	< 0.01	mg/l
7	Cadmium	Cd^{2+}	< 0.01	mg/l
8	Chromium	Cr^{2+}	< 0.05	mg/l
9	Manganese	Mn^{2+}	< 0.1	mg/l
10	Sulfates	SO_4^{2-}	< 250	mg/l
11	Chlorides	Cl^-	0.2 to 1.5	mg/l
12	Arsenic	As	≤ 0.01	mg/l
13	Uranium	U	≤ 0.01	mg/l
14	Mercury	Hg	≤ 0.005	mg/l
15	Selenium	Se	≤ 0.01	mg/l
16	Magnesium	Mg	≤ 0.01	mg/l
17	Aluminium	Al	≤ 0.01	mg/l
18	Antimony (Tin)*	Sb	≤ 0.01	mg/l

- *Presentation of Results*

The concentrations of heavy metals and specific metallic ions measured in the composite water samples (Comp1 and Comp2) are presented below in Table 3, while the physico-chemical results are summarized in Table 4. These values are compared to the limits recommended by the World Health Organization (WHO) for drinking water quality.

Table 3 Metal Concentrations in Ruashi Effluents

Element	Unit (mg/l)	WHO Limit	Comp1	Comp2	Observation / Interpretation
Se (Selenium)	mg/l	≤ 0.01	0.02	0.02	Above WHO limit → possible contamination
Zn (Zinc)	mg/l	< 0.1	0.002	0.001	Within limits
Pb (Lead)	mg/l	< 0.01	0.02	0.018	Exceeds WHO limit → toxic with prolonged exposure
Co (Cobalt)	mg/l	< 1.0	0.043	0.047	Within limits
Mn (Manganese)	mg/l	< 0.1	0.01	0.011	Within limits
Cr (Chromium)	mg/l	< 0.05	0.007	0.007	Within limits
Mg (Magnesium)	mg/l	≤ 0.01	37.968	38.041	Extremely high — likely total hardness or unit mismatch
Ca (Calcium)	mg/l	—	35.114	36.839	Typical for hard water
Ni (Nickel)	mg/l	< 0.05	0.002	0.001	Within limits
Cu (Copper)	mg/l	< 1.0	0.045	0.038	Within limits
As (Arsenic)	mg/l	≤ 0.01	0.02	0.04	Exceeds WHO limit → highly toxic
Al (Aluminium)	mg/l	≤ 0.01	0.309	0.29	Significantly high, above WHO limit
Cd (Cadmium)	mg/l	≤ 0.01	0.007	0.007	Close to limit, requires monitoring
Fe (Iron)	mg/l	< 0.1	0.051	0.049	Within limits
Hg (Mercury)	mg/l	≤ 0.005	0.012	0.019	Above WHO limit, highly toxic
Sb (Antimony)	mg/l	≤ 0.01	0.022	0.012	Slightly above limit
U (Uranium)	mg/l	≤ 0.01	0.036	0.029	Exceeds WHO limit

Table 4 Physico-Chemical Parameters of Ruashi Effluents

No.	Parameter	Method	Unit	WHO Standard	9h00	10h00	11h00	12h00	1h00	4h00	5h00	6h00
1	Turbidity	Nephelometr	NTU	< 5	12.9	27	37.8	18.8	24.8	102	69.5	40.2
2	pH	Potentiometry	–	6.5 – 8.5	7.95	8.17	8.36	7.88	8.06	8.21	8.11	7.92
3	Temperature	Thermometry	°C	4 – 25	19.8	19.5	21.7	19.8	19.7	19.7	21.4	19.6
4	Conductivity	Potentiometry	µS/cm	≤ 1000	438	450	428	436	448	428	444	446
5	TDS	Potentiometry	ppm	≤ 500	219	225	214	218	224	223	232	223

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- *Discussion of Results*

The results of the physico-chemical and heavy metal analyses of the collected water samples reveal variable water quality, influenced by both natural and anthropogenic factors.

From a physico-chemical perspective, most parameters such as pH, temperature, and electrical conductivity fall within the limits recommended by the World Health Organization (WHO). Zinc (Zn) and copper (Cu) concentrations, although below WHO standards, remain indicators of mining influence. However, the high turbidity levels suggest the presence of suspended particles or unfiltered organic matter, indicating a potential risk of microbiological contamination.

In contrast, the analysis of heavy metals and specific ions shows several significant exceedances of WHO standards. High concentrations of lead (Pb), mercury (Hg), arsenic (As), selenium (Se), aluminum (Al), antimony (Sb), and uranium (U) indicate significant metal contamination. This confirms the observations of Lutandula (2020) and Tshanga (2025). The contamination is directly linked to mining activities in Kolwezi.

Uranium concentrations yielded values close to those reported by Tshanga (2025), confirming a cumulative risk associated with geological formations and industrial discharges.

These elements (Pb, Hg, As, Se, Sb, Al, and U) are known for their cumulative toxicity and can cause serious long-term health effects, such as:

- Kidney and neurological disorders (Pb, Hg, Cd),
- Cancers of the skin, lungs, or liver (As, Cr),
- And damage to the nervous system or skeletal system (U, Sb).

The simultaneous presence of multiple heavy metals strongly suggests contamination linked to mining and industrial activities widely developed in the Kolwezi region, which is known for the intensive extraction of copper and cobalt. These activities can lead to the leaching of heavy metals into both groundwater and surface water.

Furthermore, the abnormally high concentrations of magnesium and calcium indicate high water hardness, likely resulting from interactions between rocks and water. Although not toxic, excessive hardness can affect the taste and appearance of water and cause scaling in domestic installations.

In summary, these results highlight the need for regular monitoring of water quality and the implementation of appropriate treatment measures such as filtration, adsorption, or chemical precipitation. Additional microbiological analysis is recommended to fully assess the potability of the water sources studied.

IV. LIMITATIONS DE L'ETUDE

- *This Study has Several Limitations that should be Considered when Interpreting the Results:*

- Scope and duration of sampling: Sampling was conducted over eight consecutive days; however, this may not reflect seasonal variations in water quality.
- Composite sampling : The use of composite samples provides representative averages but may mask short-term fluctuations in pollutant concentrations.
- Analytical techniques: Although spectrophotometric analysis (ICP-OES) is reliable, it may not detect ultra-trace levels of certain contaminants that more sensitive instruments could reveal.
- Lack of microbiological data: This study focused solely on physico-chemical and metallic parameters, without microbiological testing, which limits the comprehensive assessment of water potability.
- Spatial limitation: Sampling was limited to discharge points located near the mining site and does not represent the entire Kolwezi area.

Future research should include seasonal sampling, microbiological assessments, and broader spatial coverage in order to provide a more comprehensive understanding of water quality and potential health risks in mining-affected environments.

V. CONCLUSION AND RECOMMENDATIONS

The analysis of water samples collected at the discharge points of Ruashi Mining in Kolwezi revealed significant variations in water quality. Although most physico-chemical parameters such as pH, temperature, and electrical conductivity remained within acceptable limits defined by the World Health Organization (WHO), turbidity and heavy metal concentrations showed critical exceedances. High levels of toxic elements, including lead (Pb), mercury (Hg), arsenic (As), and uranium (U), indicate metal contamination linked to mining activities and ore processing in the region.

These results highlight a potential environmental and public health concern for nearby communities that depend on these waters for domestic use. The persistence of heavy metals in aquatic ecosystems can lead to chronic health risks due to their cumulative and non-degradable nature.

To mitigate these risks, it is essential to implement continuous monitoring of discharged and surface waters, as well as effective treatment systems prior to any release into the environment. Strengthening environmental regulations, promoting sustainable mining practices, and raising community awareness about water quality are also crucial steps to protect both human health and the Kolwezi ecosystem.

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