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Physico-Chemical and Microbiological Study of the Water from the Boreholes in the Camp Massard District (Kolwezi, DRC)

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Abstract: The objective of this study is to assess the physico-chemical and microbiological quality of borehole water in Camp Massard district, located in the Manika commune of Kolwezi city, southeastern Democratic Republic of Congo (DRC). The aim is to determine whether this water is suitable for drinking according to World Health Organization (WHO) standards. Three water samples were collected three times of the day (morning, noon, and evening) once a week for four weeks from six boreholes. Analyses were conducted in CRAA and LAE laboratories using standardized methods for organoleptic, physico-chemical, and microbiological parameters. Results show that 80% of samples exceeded acceptable limits: acidic pH (5.9–6.3), high conductivity (513–590 µS/cm), elevated chloride ions (383–465 mg/L), and high heavy metal concentrations (Fe: 5.763–7.194 mg/L; Mn: 0.341–0.551 mg/L; Pb: 0.038–0.042 mg/L; Cr: 0.407–0.429 mg/L; Cd: 0.034 mg/L). Microbiological analysis revealed the presence of pathogenic staphylococci, total coliforms, and aerobic germs, indicating fecal contamination. These findings demonstrate that borehole water is unsafe for human consumption and requires appropriate treatment before use.

Keywords: *Groundwater, Borehole, Potability, Pollution.*

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I. INTRODUCTION

Drinking water is an essential resource for health and socio-economic development; the health and well-being of populations and ecosystem sustainability depend directly on its quality (WHO, 2017).

In many cities in the DRC, including Kolwezi, water supply relies heavily on private boreholes, often operated without sanitary control. Similar observations have been made in other African contexts, where reliance on private boreholes exposes populations to chemical and microbiological risks (Abila et al., 2012).

Camp Massard district illustrates this issue, with reported metallic taste, unpleasant odor, brown coloration, and frequent waterborne diseases (diarrhea, typhoid, parasitic infections).

➢ *This Study Aims to:*

- Characterize borehole water physico-chemically and microbiologically;
- Compare results with international drinking water standards;
- Propose technical and health recommendations.

This study is carried out within the framework of the United Nations Sustainable Development Goals (SDG 6), which aim to ensure universal access to safe drinking water and sustainable water management.

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II. METHODOLOGY

➢ *Study Area*

The Camp Massard district is located in central Kolwezi (10°42'S, 25°31'E), at an average altitude of 1,480 m. The region is characterized by a humid tropical climate, with an average annual rainfall of 1,200 mm and a rainy season extending from November to April.

The soils are lateritic and rich in metal oxides, which influences the chemical composition of groundwater.

➢ *Sampling, Methods, and Parameters Analyzed*

Six representative boreholes were selected using systematic spatial sampling based on their GPS coordinates:

F1	Av Camp Massard	-10.7056030° S	25.5298682° E
F2	Av Lufira	-10.7027975° S	25.5305146° E
F3	Av Kazembe	-10.7016474° S	25.5260880° E
F4	Av Ndegwe	-10.7027975° S	25.5260773° E
F5	Av Mwant Yav	-10.7036771° S	25.5250335° E
F6	Av Mwant Yav	-10.7013831° S	25.5233578° E

A total of 72 water samples were collected from the six selected boreholes, at a rate of three samples per day (morning, noon, and evening), once per week and per borehole over a four-week period (between August and September 2025), in order to account for daily thermal and hydrogeological fluctuations.

The samples were stored in sterile 600 mL bottles, placed in a cooler at 4 °C, and transported to the analysis laboratories within 24 hours.

➢ *Organoleptic Analyses*

The organoleptic parameters, namely appearance, color, taste, and odor, were assessed through direct observation and sensory evaluation in accordance with the guidelines of the World Health Organization (WHO, 2017) for drinking water quality. This approach makes it possible to detect any perceptible alteration in water that may indicate contamination or quality degradation.

Fig 1 Map Location of the Study Area

The analysis was carried out by a selected panel under controlled conditions to ensure the reliability of sensory perceptions. Although subjective, these criteria play an essential role in the acceptability of water by users and vguide further investigations toward more in-depth physico-chemical or microbiological analyses.

➢ *Physico-Chemical Analyses*

The physico-chemical analyses were carried out in accordance with the recommendations of the World Health Organization for the assessment of drinking water quality (WHO, 2017), and the determination of heavy metal concentrations was performed using atomic absorption spectrometry, a recognized method for evaluating

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environmental risks associated with mining activities (UNEP, 2022).

The parameters analyzed include:

- pH (hydrogen potential): measured using an electronic pH meter.
- Electrical conductivity (EC): measured at 25 °C in µS/cm.
- Turbidity: determined using a turbidimeter (NTU).
- Chloride ions (Cl^-) concentration: determined by argentometric titration using the Mohr method.
- Heavy metals (Fe, Mn, Pb, Cr, Cd): determined by atomic absorption spectrometry (AAS).

The obtained values were compared with the World Health Organization (WHO, 2017) standards for drinking water quality.

➢ *Microbiologic Analysis*

The microbiological tests targeted:

- Total and fecal coliforms (multiple-tube method);
- Pathogenic staphylococci (culturing on Chapman agar);
- Mesophilic aerobic bacteria (culturing on Plate Count Agar, PCA).

III. RESULT AND DISCUSSION

In general, the results obtained indicate a significant deterioration in the physico-chemical and microbiological quality of borehole water in the Camp Massard district, compromising its potability according to the criteria established by the World Health Organization (WHO).

➢ *Organoleptic Parameters*

The organoleptic parameters collected from the six boreholes are presented in Table 1.

Table 1 Organoleptic Parameters of Borehole Water in Camp Massard

Sample	Color	Odor	Taste	Appearance
FR1	Slightly colored	odorless	bitter	Presence of particles
FR2	Colorless	odorless	bitter	clear
FR3	colorless	Slight odor	clear	clear
FR4	Slightly colored	odorless	clear	clear
FR5	colorless	odorless	Salty	clear
FR6	colorless	Slight odor	a bit bitter	clear

The observations showed that 67% of the samples exhibited a slightly yellowish to brownish color, accompanied by a metallic taste and a ferruginous odor.

According to WHO standards, drinking water should be colorless, odorless, and clear, criteria that are not met by any of these boreholes.

➢ *Physico-Chemical Parameters*

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. The average values of the results are presented in Table 2.

Table 2 Results of Physico-Chemical Parameters in Borehole Water from Camp Massard

Parameters	FR1	FR2	FR3	FR4	FR5	FR6	Norma
pH	6.2	6.3	6.3	6.0	5.9	6.1	6.5-9.5
Conductivity	590	548	583	584	513	566	250 µs
TDS	44	42	43	42	42	41	<300 mg/l
Total hardness	47	47	45	48	44	45	100 mg/l
Chloride iron	383	383	414	388	429	465	250 mg/l

Rom a physico-chemical perspective, the slightly acidic pH values (5.6–6.2) indicate a marked acidity of the groundwater. This acidity can be explained by the lateritic nature of the soils in the Camp Massard area, which are rich in metal oxides, promoting mineral dissolution and the mobilization of metals into the groundwater, as documented in several studies conducted in regions with intense copper and cobalt mining activities, particularly in Kolwezi (Tshanga et al., 2025).

This study notes that an acidic pH is likely to increase the solubility and toxicity of certain heavy metals, thereby exacerbating health risks.

High turbidity levels were also observed, suggesting the presence of suspended particles or unfiltered organic matter, thus indicating a potential risk of microbiological contamination (WHO, 2017).

Table 3 Results of Metal Concentrations in Borehole Water from Camp Massard

Elements (mg/L)	Norme	FR1	FR2	FR3	FR4	FR5	FR6
Fe	0.30	6,05	6,09	7,19	6,96	6,35	5,76
Cu	2.00	0,70	0,68	0,76	0,78	0,81	0,72

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Co	-	0,34	0,41	0,78	0,41	0,40	0,37
Ni	0.07	1,08	2,78	2,82	0,75	0,71	2,73
Mn	0.04	0,37	0,37	0,40	0,57	0,34	0,55
Zn	3.00	2,92	2,47	2,15	2,02	2,04	2,02
Pb	0.01	0,04	0,04	0,04	0,04	0,04	0,04
Hg	0.006	0,00	0,00	0,00	0,00	0,01	0,00
Cr	0.05	0,43	0,41	0,42	0,42	0,43	0,41
Cd	0.003	0,03	0,03	0,03	0,03	0,03	0,03
As	0.01	0,00	0,00	0,00	0,00	0,00	0,00
Se	0.01	0,01	0,01	0,01	0,01	0,01	0,01

The results of the heavy metal and specific ion analyses are presented in Table 3. They show several significant exceedances of WHO standards for Fe, Ni, Cr, Cd, and Pb concentrations in the Camp Massard boreholes. These findings are consistent with previous studies conducted in the Congolese Copperbelt. The high levels of Fe (5.7–7.2 mg/L) and Mn (>0.4 mg/L) align with observations by Kayembe et al. (2018), who reported organoleptic alterations (metallic taste and discoloration) in water from Lubumbashi and Kolwezi, linked to the weathering of copper-cobalt ores.

Extreme exceedances of Ni (up to 2.8 mg/L, i.e., 40 times the WHO standard) are consistent with findings by Atibu et al. (2013) and Nkulu et al. (2018), who highlighted chronic contamination of water and local populations by Ni and Co in artisanal mining areas of Katanga.

Pb (≈0.04 mg/L) and Cd (≈0.03 mg/L) concentrations exceed WHO limits by approximately 4 and 10 times, respectively. These results corroborate studies by Lufungula et al. (2019) and UNEP (2011), which documented neurotoxic and renal risks associated with chronic exposure to heavy metals in Kolwezi's water sources.

Cr concentrations (≈0.42 mg/L) are about 8 times higher than the WHO threshold, confirming the observations of Boujghad (2023) on chromium mobility and speciation in mining waters, with a recognized carcinogenic risk.

The simultaneous presence of multiple heavy metals strongly suggests mixed contamination sources, both geogenic and anthropogenic, heavily influenced by intensive mining and industrial activities in Kolwezi. This is consistent with studies on the Kafubu River and the Ruashi area (Lubumbashi) by Drapeau (2018) and Geenen & Radley (2014), which demonstrated the combined impact of industrial discharges and artisanal mining on groundwater quality.

Furthermore, abnormally high concentrations of magnesium and calcium indicate high water hardness, likely due to interactions between rock formations and water. Although not toxic, excessive hardness can affect water taste and appearance and cause scaling in domestic installations (WHO, 2011).

➢ *Microbiological Analysis*

The results of the microbiological analyses are presented in Table 4. From borehole 3 to borehole 6, all these water samples show significant microbiological contamination by pathogenic staphylococci, total coliforms, and aerobic bacteria, rendering the water non-compliant with WHO standards.

Studies of Kayembe et al. (2018) and Shutcha et al. (2010) have shown that urban borehole water often exhibits microbiological contamination due to the lack of sanitary control and proximity to latrines or waste disposal sites. Similarly, in the Katanga Copperbelt, Atibu et al. (2013) and Nkulu et al. (2018) highlighted that microbiological pollution adds to metal contamination, thereby increasing health risks.

In Kolwezi, Lufungula et al. (2019) reported high levels of total coliforms and aerobic bacteria in private boreholes, explaining the frequent occurrence of waterborne diseases such as diarrhea and typhoid. Finally, studies conducted in sub-Saharan Africa (WHO/UNICEF, 2017) indicate that microbiological contamination of groundwater is common in rapidly growing urban areas, mainly due to inadequate sanitation infrastructure.

Table 4 Results of the Microbiological Analysis of Borehole Water in Camp Massard

Parameters	**FR1**	**FR2**	**FR3**	**FR4**	**FR5**	**FR6**	**Permissible limit**	**C/CN**
Macroscopic analysus	Clair	Clair	Clair	Clair	Clair	Clair	-	-
Direct exam	RAS	RAS	RAS	RAS	RAS	RAS	-	-
Microscopic exam	RAS	RAS	RAS	RAS	RAS	RAS	-	-
Salmonella	0	0	0	0	0	0	0 UFC/ml	C
Pathogenic staphylococci	0	0	1000	1000	3500	3500	0 UFC/100 ml	C
Total coliforms	0	0	900	900	1900	1900	0 UFC/100 ml	C
Fecal coliforms	0	0	0	0	0	0	0 UFC/100 ml	C
Fecal streptococci	0	0	0	0	0	0	0 UFC/100 ml	C
Thermotolerant coliforms	0	0	0	0	0	0	0 UFC/100 ml	C
Anaerobic spore-forming bacteria	0	0	0	0	0	0	0 UFC/20 ml	C
Aerobic bacteria at 22°C and	0	0	2500	2500	5500	5500	100 UFC/ml	C

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37°C (revivable counts)								
Aerobic bacteria at 30°C	0	0	0	0	0	0	20 UFC/ml	C
Pseudomonas aeruginosa	0	0	0	0	0	0	0UFC/100 ml	C

In summary, boreholes FR1 and FR2 comply with WHO standards (absence of pathogenic microorganisms). In contrast, boreholes FR3 to FR6 are unsuitable for consumption due to the presence of pathogenic staphylococci, total coliforms, and aerobic bacteria in very high quantities.

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. The non-compliance observed in nearly 80% of the analyzed samples reflects a persistent issue related to the vulnerability of groundwater in this urban area under high anthropogenic pressure.

IV. STUDY LIMITATIONS

➢ *This Study has Several Limitations that should be taken into Account when Processing and Interpreting the Results:*

- *Limited Spatial Coverage:*

The study focused on only six boreholes, which may not reflect the full range of hydrogeological conditions in the Camp Massard district or surrounding areas.

- *Limited Temporal Scope:*

Sampling was conducted over a four-week period, which does not allow for the assessment of seasonal variations, particularly between the dry and rainy seasons.

- *Partial Microbiological Analysis:*

The microbiological analysis was limited to general indicators of contamination, without identifying specific pathogens.

- *Lack of Detailed Hydrogeological Analyses:*

The absence of comprehensive hydrogeological investigations does not allow for a precise distinction between geogenic and anthropogenic sources of metal contamination.

- *Subjective Evaluation of Organoleptic Parameters:*

The assessment of organoleptic parameters relied partly on human perception, introducing variability despite controlled conditions.

Future research should include seasonal sampling, advanced microbiological assessments, and broader spatial coverage to provide a more comprehensive understanding of water quality and potential health risks in areas such as the one studied.

V. CONCLUSION AND RECOMMENDATIONS

The present study aimed to assess the physico-chemical and microbiological quality of borehole water in the Camp Massard district, located in the Manika commune of Kolwezi, in order to determine its potability according to the standards established by the World Health Organization (WHO). The results obtained show that 80% of the analyzed samples exhibit major non-compliances, indicating a significant degradation in the quality of groundwater used for human consumption.

From a physico-chemical perspective, the studied waters are characterized by an acidic pH, high electrical conductivity, excessive chloride ion concentrations, and elevated levels of heavy metals such as iron, manganese, lead, chromium, and cadmium, exceeding recommended drinking water limits. These findings indicate a high degree of mineralization and concerning metal contamination, likely related to both local geological conditions and anthropogenic activities, particularly mining, which is dominant in the Kolwezi region.

From a microbiological standpoint, the presence of total coliforms, pathogenic staphylococci, and mesophilic aerobic bacteria indicates contamination of fecal origin, confirming a high risk of waterborne diseases for the consuming populations. The combination of chemical and microbiological contamination demonstrates that the borehole water in Camp Massard is unsuitable for human consumption without prior treatment and constitutes a major public health concern.

In light of these findings, it is essential to implement systematic water treatment before consumption, combining filtration to reduce turbidity, appropriate processes for heavy metal removal (such as adsorption or chemical precipitation), and effective disinfection to minimize microbiological risks. Furthermore, the establishment of a regular water quality monitoring program, including physico-chemical, metallic, and microbiological parameters, is crucial.

It is also recommended to strengthen the sanitary protection of boreholes by establishing safety perimeters and ensuring adequate distance from potential sources of contamination. Raising awareness among local communities about the risks associated with consuming untreated water is equally important. The implementation of these measures will contribute to sustainably improving access to safe drinking water and reducing health risks in the Camp Massard district.

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