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Assessment of Metal Pollution in Drinking Water in Villages Near the Mine of Ity (Côte d'Ivoire)

HE Linda Isabelle[1,*], DAKOUO Semite Jokebed[1,2], GBAGBO Tchapé[2], KPAIBE Sawa André[1,2], AMIN N'cho Christophe[1,2]

[1]Département des Sciences Analytiques et Santé Publique, UFR des Sciences Pharmaceutiques, Université Félix Houphouët-Boigny, Côte d'Ivoire
[2]Laboratoire d'Hygiène, Institut National d'Hygiène Publique, Côte d'Ivoire
*Corresponding author: helinda34@gmail.com

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Abstract Zouan-Hounien is a town in western Côte d'Ivoire, West Africa, and serves as the administrative seat of the Tonkpi region. The following villages are located within a 10 km radius of the town: Biétouo, Floleu, Krozialeu, Meantouo, Ouyatouo, Trogleu, and Ity a hamlet of approximately 1,600 inhabitants that is home to the Ity gold mine. Following a technical incident at the mine, a study was initiated to assess the potential impact of the incident on the physicochemical and bacteriological quality of drinking water in the aforementioned villages. Thirty-six water samples collected from wells, and boreholes equipped with hand pumps were analyzed using AFNOR methods. The results revealed a marked and multifaceted deterioration in the quality of water from hand-operated pumps and traditional wells. The physico-chemical parameters showed significant acidification (pH 4.1–6.5), high turbidity (up to 89 UNT), and high levels of ammonium and organic matter, reflecting a massive intake of particles and contaminants. The microbiological analyses revealed severe fecal contamination, with loads of total coliforms, E. coli, and Enterococcus faecalis well above the standards, making the water unfit for consumption. Heavy metal concentrations, particularly for lead (up to 95.54 µg/L) and cadmium (up to 45.4 µg/L), were well above international potability standards, indicating acute contamination compatible with a mine tailings release or an acid mine drainage event. The presence of cyanides at significant levels, although below regulatory limits, confirmed the direct influence of cyaniding activities. All the results highlight a mixed contamination of mining and environmental origin, affecting more strongly the wells than the manual pumps. These observations highlight the need for urgent health risk management, water treatment and environmental remediation measures, as well as enhanced analytical monitoring to prevent long-term impacts on riparian populations.

Keywords: *drinking water potability,mining pollution,heavy metals*

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1. Introduction

The water supply to rural communities relies heavily on groundwater from wells and hand-pumped pumps, especially where safe alternatives are limited [1,2,3].

In mining areas, this resource becomes particularly vulnerable, as extraction activities, discharges, runoff, and infiltration can simultaneously alter the physicochemical, metallic, and microbiological parameters of water [4,5,6].

Several studies also show that poorly protected structures, particularly hand-dug wells, are more exposed to contaminant transfers and may have an unsafe quality for consumption [3,4].

Microbiological contamination is a second major signal in these contexts. Thermotolerant or total coliforms regularly exceed the zero norm in rural catchments, and several studies in mining areas describe a coexistence between bacterial pollution and metal contamination, with a risk often more marked for children [1,7].

This microbiological vulnerability, frequently observed in rural areas and further accentuated in the mining context, highlights the importance of carefully examining water sources used by populations. It falls within a particular territorial framework: that of Zouan-Hounien, a locality in western Côte d'Ivoire comprising several villages including Biétouo, Floleu, Krozialeu, Méantouo, Ouyatouo, Trogleu and Ity, the latter being home to the industrial gold mine of Ity. In these communities dependent on wells and boreholes for their drinking water supply, the technical incident at the mine has legitimately raised concerns about a possible deterioration of these essential resources, in a context where gold-bearing activities can rapidly modify the physico-chemical and microbiological balance of waters.

The objective of this study is to assess the impact of the incident on the quality of drinking water by analyzing the physico-chemical and microbiological parameters of the main water sources, to detect any contaminants related to gold-mining activities and assess the health risks in order to guide environmental protection and monitoring measures.

2. Materials and Methods

2.1. Equipment and Supplies

The analyses were carried out using a set of analytical quality laboratory equipment. The main device included an Agilent 55 AA atomic absorption spectrometer associated with an Agilent VGA 77 hydride generator. The physico-chemical parameters were measured using an Hanna® probe pH meter (United Kingdom), a WAGTECH 7100 Se® photometer (United Kingdom), a TURB 430 IR® turbidity meter (France), an HACH HQ 11d® pH meter (France) and an HACH HQ 14d® conductivity meter (France).

The filtration operations were carried out using a SARTORIUS Goettingen® (Germany) filtration ramp, while the drying and conditioning steps of the samples were carried out in a LABNET® oven (United States).

All the glassware used was of analytical quality, ensuring measurement reliability and accuracy.

2.2. Reagents

All reagents used were of analytical quality. The solutions and chemicals included distilled water, concentrated nitric acid (65%), concentrated hydrochloric acid (37%) and stock standard solutions of Hg, Pb, Co, As and Cd at a concentration of 1000 mg/L.

For the determination of nitrates, nitrites and ammonium, Nitratest, Nitricol, Ammonia No. 1 and Ammonia No. 2 tablets, as well as zinc powder were used; these were Wagtech® reagents (United Kingdom).

The microbiological analyses were carried out using Bio Rad® culture media (France), notably Rapid E. coli 2 agar for coliform detection, Bile Esculine Azide agar (BEA) for the isolation of *Enterococcus faecalis*, and cetrimide agar for the culture of *Pseudomonas aeruginosa*.

2.3. Sampling

A total of 36 water samples were collected in villages around the Ity mining area: 30 wells and 6 hand -operated pumps.

-Physico-chemical and microbiological analyses

For each site, two types of samples were taken:

- a 1,000 mL Pyrex® glass bottle, filled to the brim, intended for physico-chemical analyses;
- a 500 mL Pyrex® glass vial, filled three-quarters full, intended for microbiological analysis.

The samples were taken in accordance with AFNOR standard FD T90 520 (2005), which defines the conditions for sampling, conservation, and transport of water. The vials were immediately placed in a cooler, protected from light, and transported under cold chain (4–8°C) using ice blocks to limit microbial growth.

Upon arrival at the laboratory, the samples were either analyzed directly or stored in a refrigerator (4–8°C) until processing.

-Metal analyses

For the determination of metals, samples were collected in 1 L polyethylene containers. In situ stabilization was carried out by addition of 10 mL of concentrated nitric acid (HNO 3), to prevent any physico-chemical modification before analysis.

2.4. Methods

The physico-chemical parameters (pH, electrical conductivity, turbidity) were determined according to the AFNOR standardized methods [8,9,10,11]. Concentrations of nitrates, nitrites, ammonium, chlorides, manganese, aluminum, fluorides, organic matter and iron were measured by photometry. For each analysis, 10 mL of sample was introduced into a tube and then a specific reagent pellet was added. After complete dissolution of the reagent by stirring with a glass rod, the tube was placed in the photometer and the program corresponding to the studied parameter was selected. The absorbance was measured at 520 nm.

The microbiological analysis focused on total coliforms, *Escherichia coli*, *Enterococcus faecalis* and *Pseudomonas aeruginosa*. The samples were membrane filtered, then the membranes were deposited on suitable culture media. After incubation for 18-24 h, characteristic colonies were enumerated according to reference protocols [11,12].

The data obtained were subjected to statistical analysis using methods described in the literature [12].

The metal parameters total mercury, arsenic, lead, cadmium, cobalt, and total cyanide were quantified by atomic absorption spectrometry. The results were compared to current drinking water quality standards.

3. Results

Table 1 and Table 2 show the exact location of drinking water collection points in villages located near the Ity mine, as well as the type of source associated with each site.

Table 3 lists the minimum and maximum values of physicochemical and bacteriological parameters for drinking water in the villages located near the Ity mine.

From a physicochemical point of view, the waters showed high turbidity, particularly in the wells. Temperatures were consistently above 25°C. The acidic pH was more pronounced in the wells (4.1–5.4). Several nitrogen, nitrite, and ammonium parameters exceeded the required standards. Iron and fluoride levels also exceeded the recommended limits.

Total coliforms, Escherichia coli and Enterococcus faecalis reached very high levels. The absence of Pseudomonas aeruginosa was the only compliant parameter.

Table 1. Samples water of hand-operated pumps from villages near the mine of Ity

Number	Sample localisation	Water sources	Sample Name	GPS Localisation Longitude	GPS Localisation Latitude
1	Village Ouyatouo	Hand -operated pump	HOP1	06°53’50.32"	08°07’52.74"
2	Village Floleu	Hand -operated pump	HOP2	06°50’43.49"	08°07’33.98"
3	Village Floleu	Hand -operated pump	HOP3	06°50’42.02"	08°07’40.66"
4	Village Kroziale	Hand -operated pump	HOP4	06°51’13.24"	08°09’04.13"
5	Village Ity	Hand -operated pump	HOP5	06°53’29.82"	08°08’05.36"
6	Village Trogleu	Hand -operated pump	HOP6	06°53’11.29"	08°08’57.75"

Table 2. Samples water of wells from villages near the mine of Ity

Number	Sample localisation	Water sources	Sample Name	GPS Localisation Longitude	GPS Localisation Latitude
7	Village Bieutouo	Well	WH1	06°54’06.44"	08°07’44.49"
8	Village Bieutouo	Well	WH2	06°54’03.66"	08°07’43.13"
9	Village Bieutouo	Well	WH3	06°54’09.94"	08°07’40.99"
10	Village Bieutouo	Well	WH4	06°54’08.87"	08°07’35.56"
11	Village Ouyatouo	Well	WH5	06°53'33,66"	08°07'34,72"
12	Village Ouyatouo	Well	WH4	06°53'32,14"	08°07'36,15"
13	Village Ouyatouo	Well	WH5	06°53'30,28"	08°07'39,28"
14	Village Ouyatouo	Well	WH6	06°53'32,14"	08°07'39,43"
15	Village Ouyatouo	Well	WH7	06°53'36,76"	08°07'41,59"
16	Village Ouyatouo	Well	WH8	06°53’42.74"	08°07’45.95"
17	Village Floleu	Well	WH9	06°50’48.97"	08°07’31.79"
18	Village Floleu	Well	WH10	06°50’50.78"	08°07’31.79"
19	Village Floleu	Well	WH11	06°50’48.37"	08’07’22.78"
20	Village Floleu	Well	WH12	06°50’41.06"	08°07’38.78"
21	Village Floleu	Well	WH13	06°50’23.99"	08°07’07.55"
22	Village Meantouo	Well	WH14	06°53’04.63"	08°08’39.44"
23	Village Meantouo	Well	WH16	06°52’54.77"	08°08’36.07"
24	Village Kroziale	Well	WH17	06°51’,21.98"	08°90’03.65"
25	Village Kroziale	Well	WH18	06°51’16.64"	08°09’06.03"
26	Village Kroziale	Well	WH19	06°51’21.53"	08°08’58.67"
27	Village Ity	Well	WH20	06°53’31.67"	08°08’06.66"
29	Village Ity	Well	WH21	06°53’30.76"	08°08’09.32"
30	Village Ity	Well	WH22	06°53’34.60"	08°07’57.35"
31	Village Trogleu	Well	WH23	06°53’09.17"	08°08’52.99"
32	Village Trogleu	Well	WH24	06°53’07.05"	08°08’52.64"
35	Village Trogleu	Well	WH25	06°53’08.53"	08°08’57.08"
36	Village Trogleu	Well	WH26	06°53’14.21"	08°08’58.46"

Table 3. Results of physicochemical and bacteriological parameters for drinking water from villages near the mine of Ity

Parameter	Norme	Hand-operated pumps	Wells
Turbidity	≤ 1 UNT	0.1-12.9	1.74 -89.4
Temperature	≤ 25	26.2-28	26.8-28.8
pH	6.5-8.5	5.2- 6.5	4.1-5.4
Nitrites	≤ 0.1 mg/L	0-0.32	0 - 0.23
Nitrates	≤ 50 mg/L	0.24 -1.12	0.42 - 20.5
Ammonium	≤ 1.5mg/L	0.46 - 8.45	0 -1.92
Organic matter	≤ 5 mg/L	0.86-18.26	2.98 -19.64
Iron	≤ 0.3mg/L	0.05 - 3	0 - 1.96
Manganese	≤50 mg/L	0.004 -0.028	0.010 -0.04
Fluorides	≤1,5 mg/L	0 - 2	0 – 1.4
Total coliforms	0 CFU/100 mL	0 - 2850	0-6350
Escherichia coli	0 CFU/100 mL	0	0-1750
Entercoccus faecalis	0 CFU/100 mL	0	0-1200
Pseudomonas aeruginosa	0 CFU/100 mL	0	0

Table 4. Results of heavy metal concentrations in drinking water from for drinking water from villages near the mine of ity

Heavy metals	Norme	Hand-operated pumps	Wells
Hg	6µg/L	<0.3	<0.3
As	10µg/L	0.0562 - 3.4553	0.2431- 2.2643
Pb	10µg/L	<1 - 80.7	<1- 95.54
Cd	1µg/L	<1 - 35.5	<1- 45.4
Co	2mg/L	<0.001 - <1	<0.001 - 0.3024
Cyanures totaux	50µg/L	9 - 31	6 - 43

Mercury and arsenic were generally compliant with potability standards, with very low concentrations of mercury (<0.3 µg/L) and arsenic levels well below the 10 µg/L limit in all sources. By contrast, lead and cadmium showed significant exceedances, reaching 80.7 µg/L and 35.5 µg/L in pumps, and up to 95.54 µg/L and 45.4 µg/L in wells, respectively. Cobalt remained low overall, well below the 2 mg/L standard. Total cyanides, although below the 50 µg/L limit, had significant values (6–43 µg/L).

4. Discussion

The analysis of physicochemical and microbiological parameters of drinking water from villages located near the Ity mine reveals a marked deterioration in their quality, particularly in traditional wells. The water has high turbidity, which makes it less drinkable because it reflects suspended particles from sediments, runoff, organic matter or metal hydroxides [13,14].

Indeed, highly turbid water can harbour germs or report other contaminants, which increases the health risk [15,16,17].

Several studies report exceedances of drinking water thresholds, for example 6.40 FTU in mining drainage areas, up to 9.99 NTU in some boreholes, and 61.54% of samples above the WHO limit in Ethiopia [18,19,20].

Regarding the pH, it should be noted that it affects potability because an abnormal pH alters the taste, corrosiveness, and chemical behavior of contaminants [16,21].

In a mining context, a pH of 7 often indicates acidity related to acid mine drainage [19].

Acidic waters were observed with averages around 5.34 to 5.48 in Chad, while other sites remained within the 6.5–8.0 interval compatible with drinking water [16,22].

The pH also controls the solubility of metals; several analyses show that its relationship with water quality changes when metals and suspended solids are taken into account [21,23].

The high value of total coliforms with the presence of E. coli and Enterococcus faecalis in the wells; indicated fecal contamination and a risk of pathogens [24].

In groundwater, 93.71% of samples exceeded the standard for total coliforms and 47.17% for E. coli [25].

Even when the chemical parameters comply with standards, contamination by E. coli and faecal coliforms may persist [26].

Hand-operated pumps water is not automatically safe; in Mali, microbial contamination during the rainy season has made this water unsuitable without treatment [27].

Lead and especially cadmium levels have exceeded the standards very sharply in both pumps and wells. This result is consistent with recent mining studies showing that Pb, Cd, As, and Hg are the metal contaminants most often linked to drinking water health risks [4,28,29].

Values of Pb up to 95.54 µg/L and Cd up to 45.4 µg/L suggested a severe contamination. In mining areas, metal concentrations are often higher in groundwater near active sites, and the contribution of mine drainage to metal loadings may be predominant[4,29].

Some mining areas remain heterogeneous; elsewhere, arsenic has remained below thresholds in most scenarios despite high Fe and Mn [6].

The most constant exceedances concern iron and manganese in several mining contexts [31,32,33].

Lead and cadmium also regularly exceed drinking water limits in some mining areas, sometimes with toxic levels or measurable health risks [19,34,35].

Total cyanide is consistent but their significant presence is consistent with gold-bearing activity (cyanidation).

Indeed, gold cyanidation is a well-established source of cyanide in effluents, tailings, and water from gold mining sites [36,37,38,39].

5. Conclusion

The analyses carried out after the mining incident show a significant deterioration in water quality in the villages near Zouan Hounien. Well and borehole water shows marked acidification, high turbidity, as well as significant fecal pollution, making it unfit for consumption. High concentrations of lead, cadmium and cyanides indicate a direct influence of mining activities, probably related to a leaching of residues or an acidic mine drainage. These results highlight a mixed contamination, more pronounced in the wells, and require urgent measures of health protection, water treatment and enhanced environmental monitoring to protect riparian populations.

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