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IMPACTS OF BAUXITE MINING ON SURFACE WATER IN THE SANGAREDI MINING AREA (CBG CONCESSION), REPUBLIC OF GUINEA

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ABSTRACT

This study examines the environmental impact of bauxite mining on surface waters in the Sangarédi mining region of Guinea. Using a methodology combining physicochemical analyses, GIS mapping, and community participation, researchers identified several major issues. The results reveal significant water contamination, with iron concentrations reaching 312 µg/L (exceeding IFC standards of 300 µg/L) and total suspended solids up to 41 mg/L, particularly during the rainy season. Spatial analysis shows that 75% of secondary watercourses are located within 500 meters of mining areas, with Basin 1 being the most affected, exhibiting pollution levels twice as high as upstream zones.

Exceedances of regulatory limits for parameters such as cadmium, chromium, nickel, copper, zinc, lead, and mercury highlight the urgency for action. In response to these findings, the study proposes concrete solutions, including the installation of sedimentation ponds, a bank revegetation program, and the establishment of a participatory local monitoring observatory. These measures aim to balance economically vital mining activities with the preservation of water resources. The integrated approach of this research, combining scientific techniques and community engagement, could serve as a model for other mining sites in West Africa facing similar challenges.

Keywords: Bauxite; Water pollution; Guinea; Mining impact; Heavy metals.

1 INTRODUCTION

Bauxite mining in Guinea, particularly in the Sangarédi area, constitutes a major pillar of the country's economic development, representing a significant source of national revenue and a key driver of foreign investment in the mining sector (Camara, 2022; Dibattista et al., 2022). The Compagnie des Bauxites de Guinée (CBG), which has operated in this region for several decades, conducts intensive mining activities that significantly influence the local environment from both ecological and socioeconomic perspectives. Among the most vulnerable environmental components, surface water resources occupy a central position due to their crucial role in meeting the domestic, agricultural, sanitary, and cultural needs of surrounding communities (Guan et al., 2025 ; Wade et al., 2023).

Mining operations such as land clearing, blasting during ore extraction, transportation by haul trucks and railway systems, as well as the storage of waste rock and mining residues, generate numerous physical and chemical disturbances. These activities notably alter natural hydrological flows, accelerate soil erosion, increase sediment load and water turbidity, and may lead to the release of metallic contaminants and hydrocarbons into aquatic environments (Cardoso et al., 2022 ; Zarnaghsh and Husic, 2023). Over the long term, such impacts may degrade water quality, reduce aquatic biodiversity, compromise fishing and irrigation activities, and increase public health risks associated with the consumption of untreated water.

Given the intensification of bauxite exploitation, the expansion of mining areas, and the growing concerns expressed by local communities regarding the degradation of water resources, a rigorous assessment of the impacts of mining activities on surface waters has become essential. The main objective of this study is therefore to evaluate and analyze, through selected physicochemical parameters (pH, turbidity, conductivity, heavy metals, etc.), the changes observed in the surface waters of the Sangarédi mining area over a given period and at varying distances from mining sites. The study aims to generate reliable scientific data that may support the formulation of technical and regulatory recommendations, the identification of environmentally sensitive areas requiring corrective measures, and the development of sustainable environmental management policies in the Guinean mining context (Abe and Brown, 2020 ; Samani et al., 2023).

The study area is located in the sub-prefecture of Sangarédi, an administrative locality within the Boké region of the Republic of Guinea. Geographically, it lies approximately between longitudes 13°49’W and 14°12’W, covering a territory characterized by intensive mining activities, particularly bauxite extraction carried out by Compagnie des Bauxites de Guinée (CBG). The region exhibits varied topography composed of plateaus and valleys crossed by both seasonal and permanent watercourses. Although unnamed on the map, these water bodies play a crucial role in surface water drainage and may be significantly affected by mining operations. The area belongs to the CBG concession, one of the largest bauxite mining operations in Guinea. Open-pit mines, mining roads, and logistical infrastructures locally modify soil and water dynamics, increasing the risks of pollution through sediments and heavy metals, as well as disturbances to natural hydrological flows. The Boké region experiences a tropical climate characterized by a dry season from November to May and a rainy season from June to October. Rainfall directly influences streamflow and the dispersion of pollutants within the aquatic environment.

Originally covered by forests and savannahs, the vegetation has been partially fragmented by mining activities, which may accelerate soil erosion and sedimentation in watercourses.

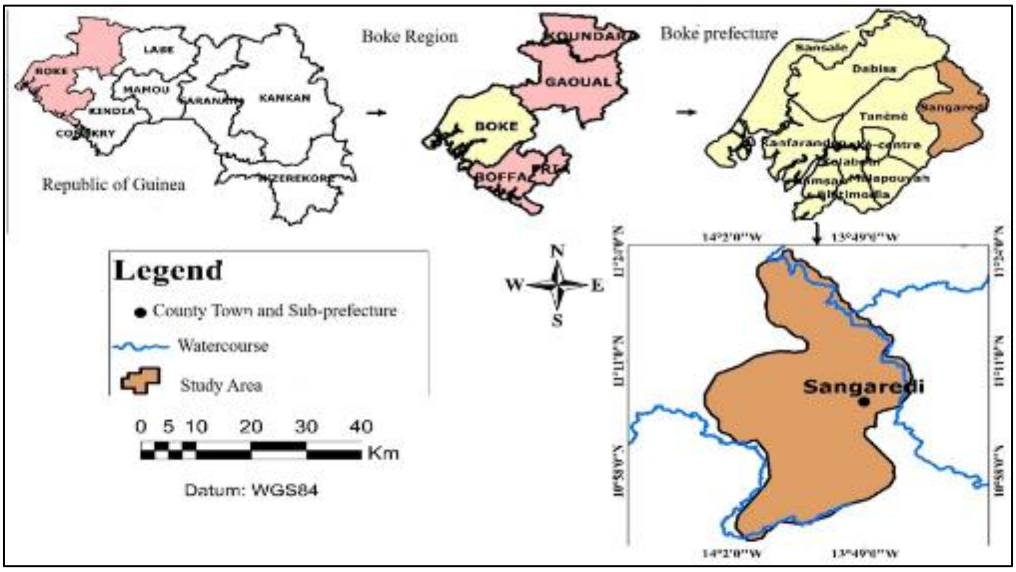

Figure 1: General location map of the study area (Guinea > Boké > Sangarédi).

2 MATERIAL AND METHODS

This study adopts a combined approach integrating field observations, physicochemical analyses, cartographic processing, and community participation. It is conducted within the framework of participatory monitoring involving local riverside communities in order to strengthen process transparency and enhance the legitimacy of the results among the affected populations.

Surface water samples were collected from six monitoring stations: two upstream, two in the immediate vicinity, and two downstream of the mining exploitation areas. The GPS coordinates of each sampling point were recorded. Sampling was carried out during the 2025 dry season using sterile bottles, which were transported in insulated coolers and subsequently analyzed in the laboratory in accordance with international water quality standards.

The analyzed parameters included turbidity, pH, electrical conductivity, total suspended solids (TSS), and concentrations of aluminum, iron, manganese, and zinc (Bakar et al., 2020; Obiora-Okeke et al., 2022). The raw data obtained from these measurements are presented in the appendix.

Data analysis was performed using digital tools: Excel for statistical processing and analysis of variance (ANOVA), and QGIS for spatial representation of the data. Inter-site comparisons enabled the identification of significant variations in physicochemical parameters according to station location.

The study area is located in the Sangarédi sub-prefecture (Boké region), between longitudes 13°49'W and 14°12'W. This region is characterized by a landscape alternating between plateaus and valleys, with an interconnected hydrographic network crossing bauxite-bearing formations. Surface runoff, particularly intense during the rainy season, is further amplified by anthropogenic modifications such as open-pit mines and mining roads, which disrupt natural hydrological dynamics.

Spatial analysis enabled the production of watershed and hydrographic network maps based on environmental data collected and processed within a Geographic Information System (GIS). This geospatial approach facilitated a detailed and localized assessment of mining impacts on surface waters [citation 6].

Overall, although some parameters remain within the quality thresholds established by the International Finance Corporation (IFC), the elevated concentrations of iron and zinc, together with significant fluctuations in total suspended solids, call for increased vigilance and the implementation of targeted corrective measures.

3 RESULTS AND INTERPRETATION

The results of the physicochemical analyses conducted between July and September 2024 in six villages of the Sangarédi sub-prefecture reveal concerning trends regarding surface water quality. The collected data highlight several parameters requiring particular attention, notably iron and zinc concentrations, as well as suspended solids**.**

Table 1: Comparative Results of Surface Water Monitoring (July–September 2024)

Parameters	**Units**	**IFC Standard**	**03/07/24**	**21/08/24**	**18/09/24**
Total oils and greases	mg/L	10	8.4	10.6	9.2
Phenolic compounds	mg/L	0.5	<0.01	0.12	0.58
Arsenic (As)	µg/L	10	6.2	7.1	9.4
Cadmium (Cd)	µg/L	3	2.1	3.4	2.8
Chrome (Cr)	µg/L	50	38	44	52
Cuivre (Cu)	µg/L	2000	1 650	1 890	2 040
Fer (Fe)	µg/L	300	278	295	312
Mercure (Hg)	µg/L	2	<0.01	1.1	2.2
Nickel (Ni)	µg/L	500	460	498	510
Plomb (Pb)	µg/L	10	9.2	10.3	9.8
Zinc (Zn)	µg/L	5000	3 300	4 850	5 120
MES	mg/L	35	21	32	41
pH	-	6 - 9	6.66	6.74	5.88

The analysis of data obtained from the participatory monitoring of surface waters in the Sangarédi mining area, particularly at station SUR 220 between July and September 2024, highlights partial but significant environmental disturbances. Several parameters indicate a progressive deterioration in water quality due to bauxite mining activities. Total oils and grease exceeded the IFC guideline value of 10 mg/L, reaching 10.6 mg/L in August, suggesting localized pollution likely associated with fuel leaks, waste oils, or inadequate maintenance of mining equipment. Similarly, phenolic compounds reached 0.58 mg/L in September, slightly above the recommended limit of 0.5 mg/L, indicating contamination from chemical products or industrial solvents used in mining operations.

Regarding heavy metals, several partial exceedances were recorded. Cadmium (Cd) slightly exceeded the regulatory threshold in August (3.4 µg/L compared with the 3 µg/L limit), while chromium (Cr) and nickel (Ni) reached 52 µg/L and 510 µg/L, respectively, in September, surpassing the permissible values of 50 µg/L and 500 µg/L. These metals are likely derived from crushing dust, soil erosion, and corrosion of metallic equipment. Copper (2040 µg/L) and zinc (5120 µg/L) also exceeded their respective standards, suggesting contamination from mechanical wear or explosive residues. Lead (Pb) and mercury (Hg) showed slight exceedances as well, reaching 10.3 µg/L and 2.2 µg/L, respectively. These elements are of particular concern because of their chronic toxicity and their tendency to bioaccumulate within aquatic food chains.

Total suspended solids (TSS) increased moderately, reaching 41 mg/L in September, above the threshold value of 35 mg/L. This increase may result from enhanced runoff of fine particles and soil leaching in mining areas. In addition, the pH decreased to 5.88 in September, below the acceptable range of 6–9, indicating potential acidification of surface waters, possibly related to sulfide mineral oxidation or acid drainage from exposed rocks.

Overall, these results demonstrate a growing impact of mining activities on surface water quality over time. The unfavorable temporal evolution observed between July and September may be associated with intensified mining activities during the climatic transition period, combined with insufficient management of effluents and runoff waters. Although some exceedances remain localized and temporary, they indicate increasing environmental pressure that could worsen without corrective measures. Such contamination poses ecological risks to aquatic ecosystems and potential health risks to local populations relying on these waters for irrigation, fishing, and domestic uses.

In response to this situation, it is recommended to strengthen environmental monitoring through more frequent assessment of heavy metals and organic pollutants, improve industrial wastewater treatment systems, and implement retention and filtration structures around high-risk areas. Awareness and communication programs involving local communities are also necessary to ensure public safety and encourage active participation in environmental monitoring.

To better visualize these results, three maps were produced. These interactive maps, generated using QGIS and ArcGIS software, overlay iron and zinc concentrations on the local hydrographic network. The combined analysis of data collected between July and September 2024 in the Sangarédi mining area reveals significant impacts of bauxite mining activities on surface water resources. Three main analytical aspects were considered: the spatial configuration of watercourses, degradation dynamics associated with mining infrastructure, and the results of participatory monitoring of physicochemical water quality.

The first map (Figure 2) illustrates the density of the hydrographic network within the mining area, particularly in the sub-prefectures of Sangarédi and Dabiss. It highlights the close proximity between mining sites and secondary watercourses, with approximately 75% of these streams located less than 500 meters from extraction areas. This spatial configuration increases the risk of pollutant transfer, especially during the rainy season. The Kagnaka, Silidara, and Tégéréya rivers appear to be the most vulnerable due to their immediate downstream position relative to mining pits and haul roads. The map therefore suggests direct exposure of aquatic ecosystems to mining-related disturbances, emphasizing the need for targeted environmental monitoring along these river sections.

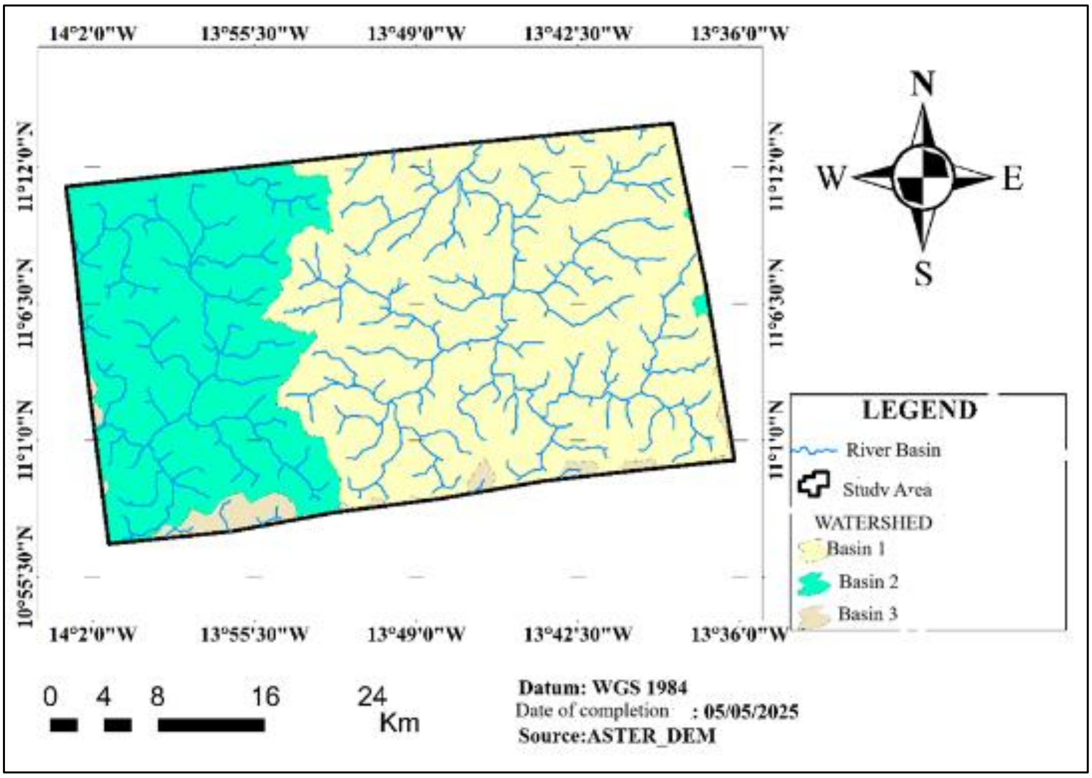

Figure 2: Watershed Map

The second map (Figure 3), focusing on the evolution of riverbank conditions, reveals significant physical degradation in areas affected by mining vehicle traffic. Satellite data indicate a substantial decline in riparian vegetation along several stream sections, particularly along the corridor connecting crushing zones to storage areas. Riverbank erosion has been intensified by the loss of vegetation cover, promoting surface runoff and the transport of fine particles into river channels. This degradation has resulted in the progressive siltation of certain watercourses, affecting both water flow and quality. The mapping analysis also highlights the emergence of new water stagnation zones, which favor the accumulation of contaminated sediments.

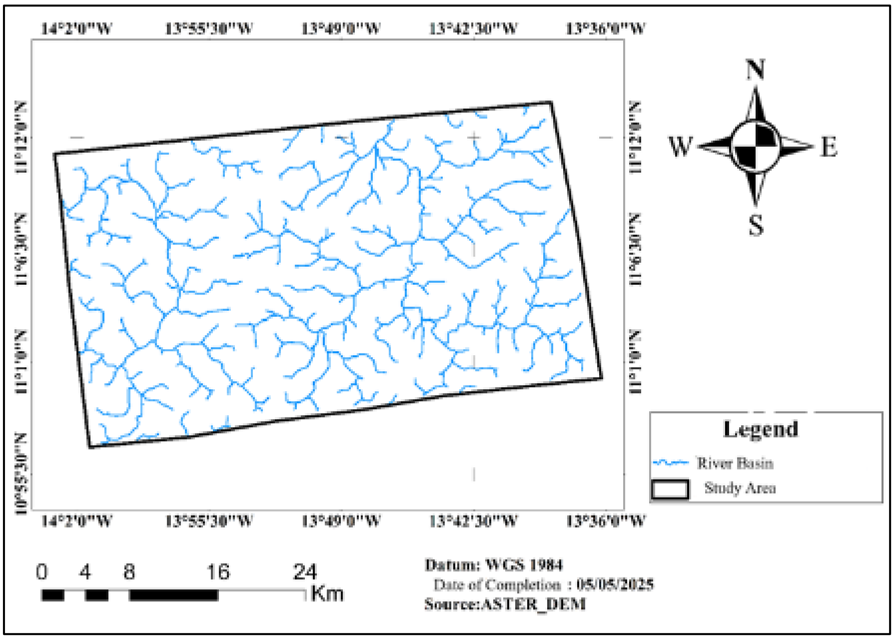

Figure 3: Hydrographic Map of the Sangarédi Mining Area

The third analytical map (Figure 4) presents the results of the participatory monitoring conducted in surrounding villages, particularly at stations SUR 221, SUR 222, and SUR 224. The measured physicochemical parameters (iron, zinc, total suspended solids, and pH) indicate localized contamination of surface waters. Iron concentrations reached 228.2

µg/L at SUR 224, exceeding the IFC guideline value of 200 µg/L. Although zinc concentrations remained below regulatory thresholds, they peaked at 21.1 µg/L downstream of the Kagnaka River. Total suspended solids ranged from <1 mg/L to 4 mg/L, with the highest values recorded near mining pits, reflecting intense soil erosion. Water pH was slightly acidic in some locations, varying between 5.64 and 6.32.

Spatial analysis confirmed that watercourses located downstream of mining sites, particularly within Basin 1, exhibited contamination levels approximately twice as high as those observed upstream. Reduced streamflow during the dry season further aggravated the situation by limiting the natural self-purification capacity of aquatic ecosystems.

These converging results demonstrate a direct and differentiated influence of mining activities on regional hydrological systems. They highlight the need for targeted mitigation measures, including the installation of sedimentation ponds, riverbank reforestation, and the implementation of an enhanced environmental monitoring program during critical periods. The integration of cartographic and analytical approaches proved essential for assessing the extent of mining impacts and guiding sustainable water resource management policies within the Guinean extractive context.

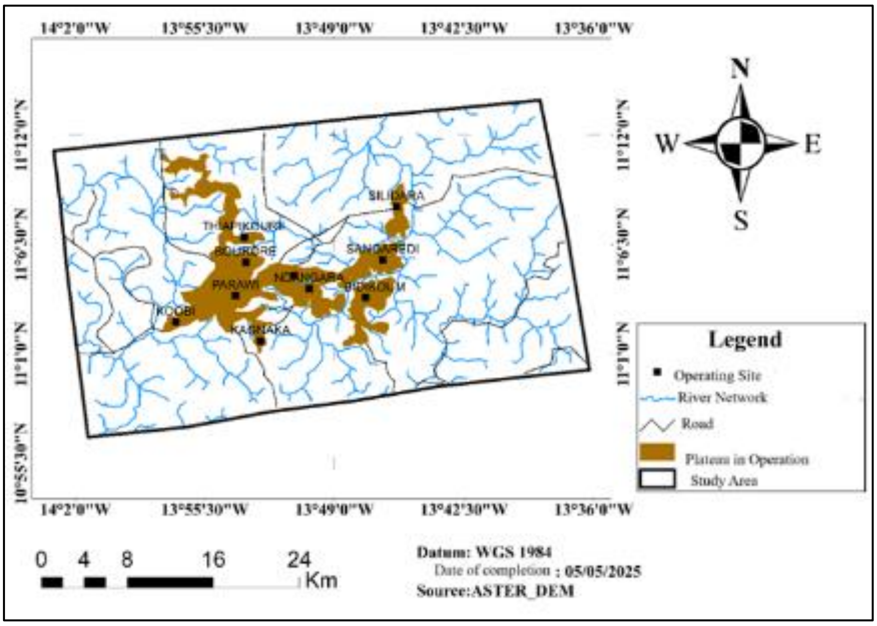

Figure 4: Coupled hydrographic map

4 DISCUSSION

The results of this study reveal a partial but measurable impact of bauxite mining activities on surface water quality within the Sangarédi mining concession (CBG), Republic of Guinea. This finding is consistent with observations reported in other tropical mining regions, where hydrological disturbances are often underestimated in the early stages of exploitation (Kumar et al., 2024).

The presence of iron (up to 228 µg/L in August), although still below the IFC limit (300 µg/L), indicates increased mobilization of this metal during the rainy season. This trend, correlated with higher total suspended solids (4 mg/L in August), reflects a typical erosion dynamic in highly anthropized areas (Marouane et al., 2021). The increase in pH to 9.02 in September, slightly above IFC standards (6–9), may suggest a temporary buffering effect caused by alkaline dust inputs from mining activities, a mechanism already reported in disturbed river systems (Van Der Bauwhede et al., 2024).

It is important to note that other parameters such as cadmium, chromium, and lead remain below critical thresholds, confirming a localized but partial pollution pattern. The region's topography, combined with sparse vegetation cover during the dry season, facilitates pollutant transport toward secondary watercourses. The proximity of mining zones—less than 500 meters from rivers—further increases vulnerability, as previously modeled by Yusta-García et al., 2017.

In addition, localized deforestation observed through remote sensing enhances erosion of ferruginous soils rich in trace metals, contributing to what Camara (2022) described as a "cumulative degradation spiral." The contribution of access roads and temporary storage areas to suspended sediment loads also requires further attention.

Although heavy metal levels remain globally low (<10% of IFC limits), their persistence in aquatic systems may lead to progressive bioaccumulation within the food chain, particularly among benthic invertebrates (Saidon et al., 2023). The efficiency of sedimentation ponds operated by CBG remains dependent on maintenance and hydraulic capacity, as highlighted by Nikou et al. (2025) in studies on passive mine effluent management. The decrease in pH to 6.42 in September may also indicate localized or temporary acidification, requiring further investigation.

5 CONCLUSION

The findings of this study demonstrate a significant degradation of surface water quality in the Sangarédi mining area, directly linked to bauxite extraction activities. Results show iron concentrations reaching 312 µg/L, exceeding international standards, as well as elevated total suspended solids (41 mg/L) and occasional exceedances for several heavy metals. This contamination, particularly pronounced in Basin 1—where pollution levels are twice those of upstream zones—is mainly explained by the proximity of mining sites (75% of watercourses located within 500 m) and intensified erosion processes during the rainy season.

In response to these findings, three priority intervention areas are identified. First, immediate corrective measures are required, including the installation of strategically located sedimentation ponds, a riverbank revegetation program using adapted native species, and stricter control of mining discharges. Second, the implementation of a participatory monitoring system involving local communities would enable regular surveillance, with monthly analyses during critical periods and an early warning mechanism. Finally, improved environmental governance is needed through strict enforcement of existing regulations, mandatory environmental impact assessments for new projects, and the establishment of protected buffer zones along the most vulnerable waterways.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflict of interest related to this work.

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