Gold mining, discourses, and threats: What is really damaging the fluvial hydrosystem of the Faleme River?

El Hadji Serigne Top [a1]

Mouhamadou Lamine Diallo [b]

Gilles Arnaud-Fassetta [c]

Géraud Magrin [d]

[a,c] Université Paris Cité, France

[b] Université Cheikh Anta Diop, Senegal

[d] Université Paris 1 Panthéon-Sorbonne, France

Abstract

The gold rush in the Faleme catchment between Senegal and Mali involves artisanal miners from the sub-region, European and American multinationals, and medium-sized Chinese companies. These miners, with their disproportionate financial and material resources, practise three types of gold mining (artisanal, industrial and semi-industrial) involving the Faleme River. The mining techniques used by these operators are now a major source of damage to the river. This damage is mainly water pollution, the destruction of riverbanks, and the disappearance of aquatic fauna and agro-pastoral activities. The level of degradation is a source of speculation. Attempts are made to emphasize that artisanal exploitation is the main activity degrading the river. This article deconstructs these arguments with evidence showing that, in addition to artisanal gold mining, industrial and semi-mechanical mining activities are major contributors to the degradation of this river.

Keywords: Gold mining, threats, discourse analysis, environmental impact, Faleme River, Senegal catchment, Mali, Senegal

Résumé

La ruée vers l'or dans le bassin versant de la Falémé, entre le Sénégal et le Mali, implique des mineurs artisanaux de la sous-région, des firmes multinationales européennes et américaines et de moyennes entreprises chinoises. Ces mineurs, aux moyens financiers et matériels disproportionnés, pratiquent trois types d'exploitation de l'or (artisanal, industriel et semi industriel) impliquant la rivière Falémé. Les techniques d'exploitation utilisées par ces opérateurs constituent aujourd'hui une source majeure de dégradation pour la Falémé. Les dommages concernent principalement la pollution de l'eau, la destruction des berges, la disparition de la faune aquatique et les activités agro-pastorales. Face à la dégradation avancée, les autorités et les médias soulignent que l'exploitation artisanale en est la principale source. Cet article tente de déconstruire ces

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[1] El Hadji Serigne Top (PhD student) and Gilles Arnaud-Fassetta (Professor) are in the Department of Geography, Université Paris Cité, France. Email: elhadjiserignetop@yahoo.fr. Mouhamadou Lamine Diallo is a lecturer and researcher in Geography at Université Cheikh Anta Diop, Senegal. Géraud Magrin is Professor of Geography at Université Paris 1 Panthéon-Sorbonne, France. Acknowledgements: The authors are all members of the UMR 8586 PRODIG research group. The authors are very grateful to the Editorial Board of the journal as well as to the two anonymous reviewers who contributed to the significant improvement of the first version of the manuscript.

arguments en montrant qu'en plus de l'exploitation artisanale de l'or, les activités minières industrielles et semi-mécaniques contribuent à la dégradation de cette rivière.

Mots-clés: Exploitation aurifère, menaces, analyse du discours, impact environnemental, Rivière Falémé, bassin versant du Sénégal, Mali, Sénégal

Resumen

En la fiebre del oro de la cuenca del río Faleme, entre Senegal y Malí, participan mineros artesanales de la subregión, multinacionales europeas y estadounidenses y empresas chinas de tamaño medio. Estos mineros practican tres tipos de extracción de oro (artesanal, industrial y semiindustrial). Las técnicas mineras que utilizan son actualmente una fuente importante de daños para el sistema fluvial. Hay contaminación del agua, destrucción de las riberas y desaparición de la fauna acuática y de las actividades agropecuarias humanas. Aún se desconoce el nivel de degradación, pero la mayoría de las veces se culpa a los mineros artesanales. Este artículo deconstruye estos argumentos demostrando que, además de la extracción de oro artesanal, la minería industrial y semimecánica también contribuyen a la degradación.

Palabras clave: Minería de oro, amenazas, análisis del discurso, impacto ambiental, río Faleme, cuenca del Senegal, Malí, Senegal

1. Introduction

In recent years, politicians and the media have tended to blame artisanal gold mining for the degradation of the Faleme River (Falémé, en français), a major tributary of the Senegal River in West Africa. This article shows that, contrary to this rhetoric, it is also the result of industrial and semi-mechanized mining operations. Discoveries of gold have led to huge diggings, moving volumes of earth and applying chemical treatments.

Mining has a negative impact on the living environment of local communities and in their quest for riches, the miners use polluting and environmentally devastating methods (Deshaies, 2016). Several studies illustrate this globally. Spitz & Trudinger (2009) showed that the use of mercury in mining has led to the spread of this toxic substance in the soil and rivers of the American West. Between 1991 and 1992, more than 320 m³ of cyanide solution leaked from the tailings ponds of the Summitville gold and silver mine in Colorado, located at an altitude of 3,500 m, contaminating the Alamosa river and destroyed 27 km of flora and fauna (Berger, 2002). There are also European examples, such as the cyanide pollution that occurred in 1998 in the Guadiama catchment area in Andalusia, following the rupture of a settling pond at the Aznalcollar copper mine, and in 2000 in the Tisza basin, a tributary of the Danube, from the Baia Mare gold mine in Romania (Deshaies, 2011). In the French Amazon, Lebeaupin-Salamon (2020) describes these mining methods as aggressive and damaging to the environment. In Africa, the revival of mining activities from the 2000s onwards led an initial wave of studies focusing on environmental issues (Gueye, 2001; Keita, 2001; Zonou, 2005).

Research has also exposed the responsibility of gold mining for the degradation of river catchments. Particularly in Mali and Senegal, gold mining is intensifying and involves various operators. These include mining companies whose activities also generate substantial income for governments and local authorities. In Mali, the contribution of mining to the state budget was estimated at more than US$605 million in 2019, or 10% of GDP. At the same time, artisanal miners, mainly working illegally, are attracted by rising mineral prices (Chevrillon-Guibert *et al*., 2019). This sector is described as informal and its profits largely escape the formal economy, to the benefit of the artisans. Artisanal mining is seen by governments and donors as a factor in environmental degradation (deforestation, water and soil pollution), as several studies have highlighted (Bamba *et al*., 2013; Bohbot, 2017; Le Tourneau, 2020). Artisanal miners along the Faleme River are no exception to this criticism from political authorities. Speeches and media report on the negative impacts of artisanal gold mining on the Faleme River and challenge their practices.

The article follows a logic of informed political ecology critique, going beyond the narratives that incriminate the artisanal miners. We attempt to deconstruct these discourses and show that the degradation of the Faleme is linked not only to artisanal gold mining, whose actors are trying to cope with socio-economic difficulties (agricultural problems, shortage of urban jobs, security crises in Mali), and trying to establish more resilient livelihoods in very vulnerable economies, but also to the activities of industrial and semi-mechanical gold mines.

The results are organized in three parts, which first characterize the types of gold mines (practices and relations with the river), then show the impact of the activities on the river, and finally discuss the results by attempting to situate the responsibility of each type of mine for the degradation of this river.

2. Blaming artisanal miners along the Faleme catchment

The Faleme River is the last major left bank tributary of the Senegal River. It is 625 km long and drains a catchment area of 28,900 km² located between latitudes 12°11' -14°27'N and longitudes 11°12'-12°15'W. Its catchment area (Figure 1) extends over the three republics of Mali (47.8%), Senegal (39.7%) and Guinea Conakry, where it rises (12.5%). The Faleme River forms the administrative border between Senegal and Mali, stretching for some 450 km. The geography of the region, with a geology conducive to gold mining and a river available to miners, is ideal for this industry. From south to north, the Faleme catchment crosses three geographical areas (Guinean, South Sudanese and North Sudanese), resulting in a decrease in average annual rainfall along this gradient (from 1,200 mm in the south to 600 mm in the north). The density of drainage (0.022 km/km²) and the hydrological regime (three months of high water) characterized by a period of low water, favour the gold mining activities of the various operators. The population of the catchment area, around 600,000 in 2013 (INSTAT, 2009; ANSD, 2013), lives mainly on the banks of the Faleme and relies heavily on the river for water supply (irrigation, domestic consumption, fishing where possible, then mining, gold panning). The downstream part of this river is dominated by agro-pastoral activities, while the upstream and middle parts are dominated by gold mining (Figure 1). It stretches across the Kédougou-Kéniéba buttonhole[2] (in Senegal and Mali respectively). Almost all the gold deposits in Senegal (Sabodala, Massawa, Boto) and Mali (Yatéla, Sadiola, Loulo and Tabakoto) are located in this cross-border zone between the Tambaoura hills and the Faleme River.

The area is home to three types of gold mine (industrial, semi-mechanized and artisanal), which depend on the river for their water supply and, in return, threaten it. These threats are perceived by the authorities, whose statements are also reported by the media, as the result of artisanal mining operations. They believe that gold panning is characterized by an informality that makes it difficult to control activities. This informality, which explains the proliferation of illegal sites, is at the root of practices that have a major impact on the environment, and on the Faleme River in particular. Local residents (farmers, stockbreeders, fishermen, etc.) whose livelihoods depend on the river Faleme denounce this degradation, and blame artisanal operators and administrators, whom they consider to be responsible for failing to regulate the environment. Indeed, the most disadvantaged players, in particular the artisanal miners, are blamed to the benefit of the most powerful (mining companies and miners of Chinese origin). However, critical discourse can sometimes clash with practices, since based on the interests of a more powerful minority (Benjaminsen & Svarstad, 2012). Several authors (Tschakert & Singha, 2007; Bashizi, 2020; Sawadogo, 2021) using a political ecology approach have addressed the issue of discourses that stigmatize smallholders as a strategy of struggle used by political actors, for example in the broader competition for access to resources. To this end, policies are often 'biased' in favour of large-scale extraction, as this is seen, despite mixed results, as a real source of rent for states (Hilson, 2019). Small-scale mining, on the other hand, whose rents largely escape governments, is often criminalized, accused of financing armed conflicts (Kaufmann & Côte 2021) or of damaging the environment (Sawadogo, 2021). This article is a contribution to the debate on the contradiction between rhetoric and practice in the extractive

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[2] This is a granite unit with affinities to the Birimian system of Ghana, in the shape of a triangle crossed by the Gambia and Faleme Rivers (Bassot, 1966).

sector, showing how the authorities are taking advantage of the degradation of the River Faleme to drive out artisanal miners as part of a drive to capture gold wealth.

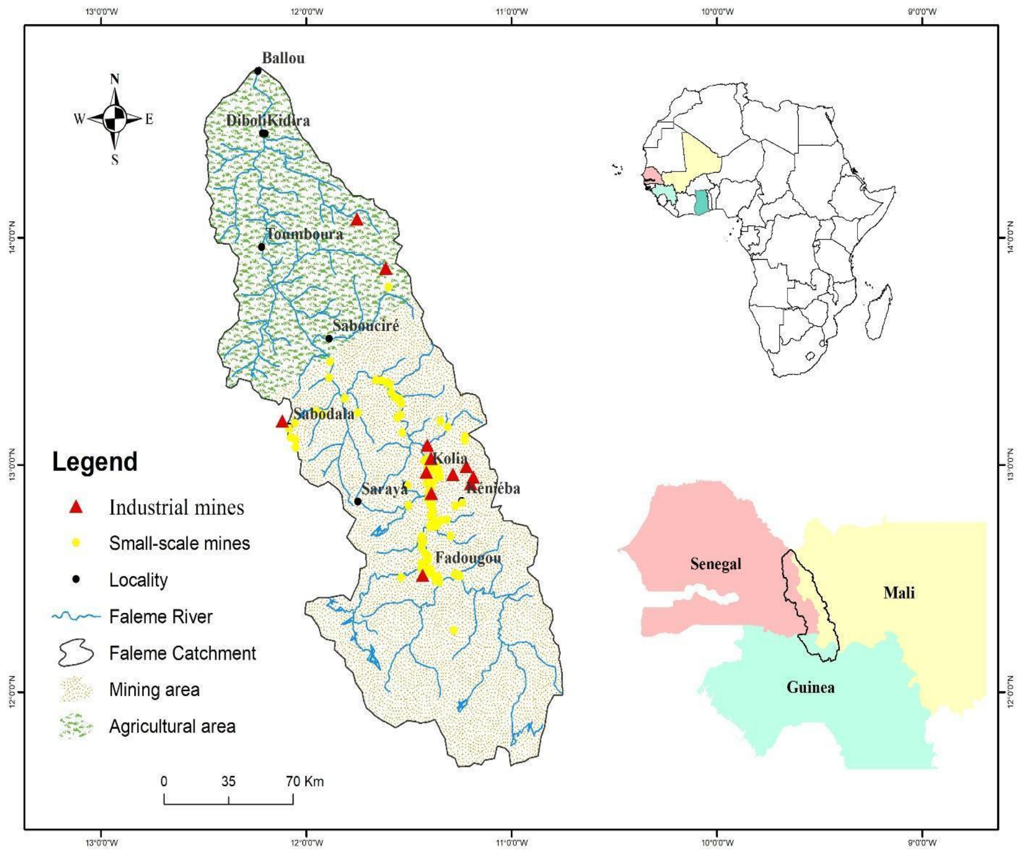

Figure 1: Location of the study area.

3. Methodology

Qualitative data were collected using interview guides administered to individuals on both banks of the Faleme River, in Mali (Saboucirè, Kenieba) and Senegal (Farading, Saensoutou, Kidira, Saraya). The following categories of stakeholders were interviewed: 10 members of associations fighting against the degradation of the Faleme (CVA/Faleme[3], Sauvons la Faleme[4], Wassaton[5], AJDVS[6]), three drivers employed by the Chinese (two Malians and one Ghanaian), administrative agents (mining services, and the director of ARD Kédougou),

[3] "CVA/Faleme" (Comité de veille et d'alerte/Faleme) is a collective created in 2018, made up of users of the Faleme waters (farmers, breeders, fishermen), emigrants and civil servants, who are campaigning to save the Faleme River by denouncing the practices that threaten the river.

[4] "Sauvons la Faleme" is a collective of young Senegalese and Malians fighting to protect the Faleme River and its banks from the threats posed by mining.

[5] "WASSATON" is a Malian association with its head office in Bamako. The aim of the association is to contribute to the improvement of the social and economic well-being of the populations of the mining regions, in general, and of the entire population of the Malian nation, in particular.

[6] AJDVS (Association de jeunes pour le développement du village de Saboucirè) is an association of young Malians fighting for the development of their village and trying to stop the destruction of their land and the Faleme River by Western and Chinese mining companies.

and local authorities, the traditional chiefs. In addition, focus groups were conducted with gold miners and villagers over the age of thirty-five. The interviews were combined with an analysis of press articles on the degradation of the Faleme and other bibliographical references on the two countries, Mali and Senegal. During the interviews, we were interested in the different types of gold mining, the different practices of the miners and the impacts on the Faleme. In addition to the qualitative data, quantitative data was collected using tests to compare the rhetoric of blame with scientifically proven realities. This quantitative data includes the results of the volumes of water used by the mining companies, mercury and cyanide tests[7], and the quantities of sludge discharged into the river each year. The volumes of water consumed by mining companies are estimated on the basis that 2,500 litres of water are needed to produce 1g of refined gold.[8] Based on the companies' gold production in 2019, we have estimated their water consumption. This estimate is difficult because of the diversity of the values put forward. While Leclerc-Olive (2017) considers that 250 to 300 m³ of water are needed to produce one kilogram of gold, B2Gold indicates that its production at Fékola in 2020 will require 305.5 m³/kg of gold and 600 m³ at Otjikoto (Leclerc-Olive, 2022). At the same time, Endeavour Mining's gold operations would use between 670 and 1,400 m³ of water to produce one kilogram of gold (Leclerc-Olive, 2022). The tests were carried out on the main course of the Faleme, two tributaries (Balin Ko, Koila Koba) and the Senegal River, to represent the spatial distribution of mercury and cyanide. The tests covered 15 stations named F1 to F15 (Figure 2) from upstream to downstream.

Finally, to estimate the amount of sludge[9] discharged into the river each year, in February we filled a 1.5 liter bottle with river water likely to contain sludge. We stored the bottle undisturbed for three weeks, just long enough for the mud to settle at the bottom of the bottle, before draining the more or less clear water and weighing the mud remaining.

These different methods make it possible to determine the impact of gold mining on the Faleme River and the responsibility of each type of mine for the degradation of the water course.

4. Results

Small-scale mines in full expansion

Between mechanization and the use of chemicals: Artisanal gold mining, which has a long history in the Faleme catchment between Senegal and Mali (Robyn, 2022), underwent a major revival in the early 2000s,

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[7] Tests for mercury in water are carried out using reagent strips. The presence of mercury is detected by immersing the strip in water for a few minutes. It is then removed and rinsed with drinking water to remove the mud contained in the river water, which can alter the color of the strip and falsify the result. The strip is then exposed to the sun for a few minutes to dry, in order to determine the concentration of mercury based on the color indicated by the strip. For river sediments, the same procedure was used, dissolving 25 grams of sediment in 1.5 liters of drinking water in a bottle before immersing the strip in it for a few minutes. To convert these results to mg/kg, we carried out a conversion. For example, during the first measurement we found 0.005 mg in the 25 g of sediment, so the mg of mercury in 1000 g of sediment, is: 1 kg: Mercury concentration (mg/kg) = (0,005 mg)/25g × 1000 g.

The cyanide tests were carried out exclusively on river water. We used reagent strips and a photometer to test cyanide levels in river water. The principle is simple: simply open the application already installed on a smartphone, switch on the photometer and connect the two devices via Bluetooth. The smartphone is used to set the parameters and choose the type of test to be carried out. Once the photometer and smartphone are connected, we add the water to be tested to the cell provided and a test strip, which we shake in the cell for one minute. Finally, we press the "READ" button on the photometer to obtain the result, which we can view directly on the photometer and smartphone. After each test, we clean the cell and carry out a new test.

[8] https://or-investissement.fr/blog/qu-est-ce-que-l-or-ethique--n551

[9] This exercise enabled us to find 3g of mud in 1.5 liters of water from the Faleme, which comes to 2g/l. This quantity is related to the volume of water flowing per year (V m³) at the various stations on the Faleme. V m³ = Q m³/s × t(s)

Qm³/s is the average flow, t(s): flow multiplier, equal to the number of seconds in the year, and for a long period t(s) is equal to 31,557,000 s. The Vm³/year is converted into liters before applying the multiplication and determining the quantity of sludge that would be in the river if the same conditions were maintained.

thanks to the use of chemicals, mechanization (Figure 3) and technology transfer linked to the arrival of gold miners from the sub-region.

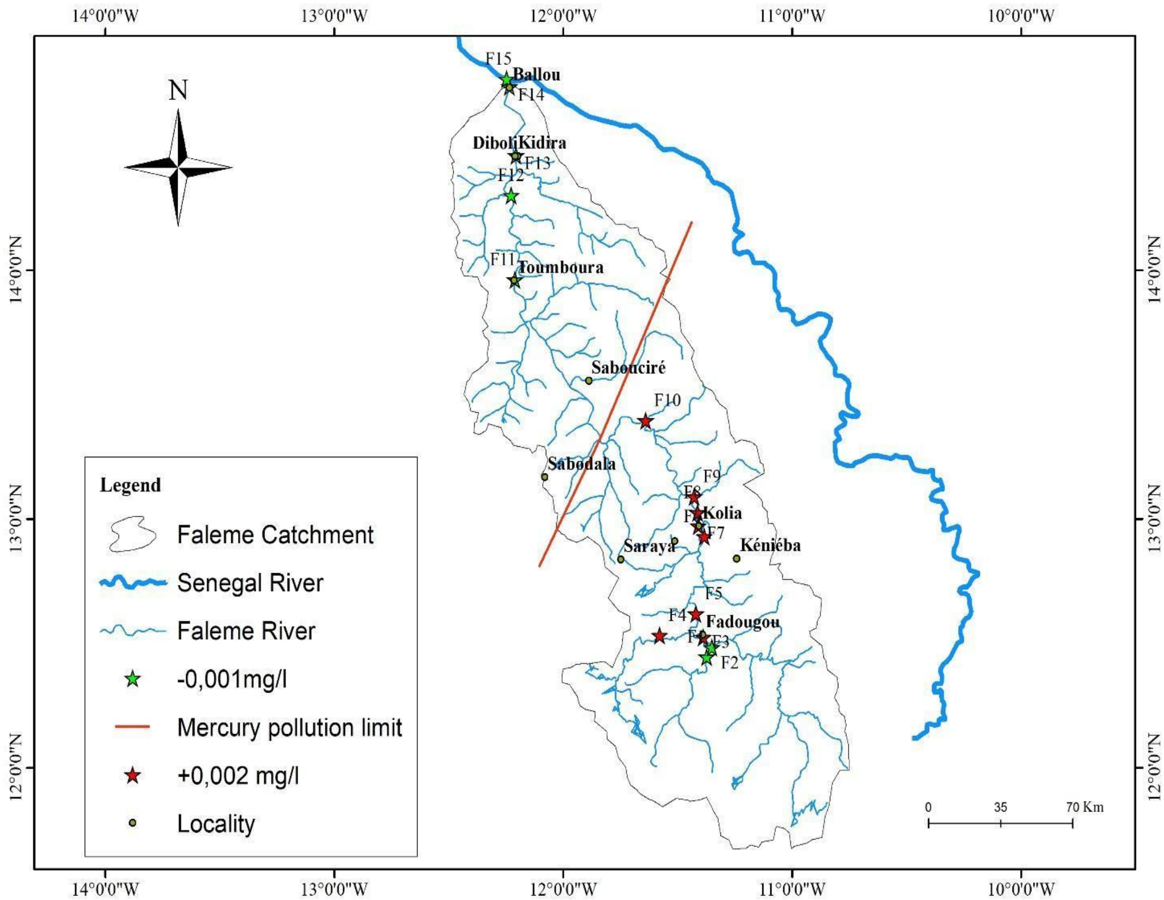

Figure 2: Classification of mercury test results in the Faleme River according to critical thresholds.

Mechanization (prospecting, extraction, mechanical processing) is increasing the hopes of artisanal miners of winning more gold, which is motivating them even more. The use of detectors (X-TERRA 705, GPX5000) capable of detecting metals at depths of between 1.5 and 8 metres is becoming increasingly widespread. The extraction and processing of minerals is also becoming easier with the use of new tools like jackhammers, dredgers, crushers, spitters, motor pumps, motorized tricycles and mills. Jackhammers can be used to dig holes up to several dozen metres deep in the hard basement rock, in order to find a vein that yields several grams of gold. Dredges (Figure 3B), unlike more traditional methods, are used to extract the gold contained in the sand, gravel and soil of watercourses. In addition, mills and spitters are used to crush the hard rock and separate it from the gold.

Two other important tools in the gold extraction chain are used to pump water and transport the ore. These are motorized tricycles (Figure 3D) for transporting the ore to the processing sites, and motor-driven pumps for supplying water. The artisanal miners interviewed consider the use of these various tools to be a factor that facilitates gold mining and enables them to generate more income. Access to these tools is facilitated by their availability in the markets of the major towns in Mali (Kayes, Kenieba) and Senegal (Saraya, Kedougou), and in the local markets of the major sites close to the river. These small local markets, found in the large gold panning sites on the banks of the Faleme, play an important role in supplying the sites with new tools and food products. In addition, a system of renting mining tools to gold miners facilitates the widespread use of different tools. Gold miners who do not yet have the capital to buy the necessary equipment can ask for the services of those who already own the machines in return for a fee. For example, "with the machine that consists of a crusher and a vibrating table, people pay US$13 to process twenty 40kg bags of raw ore" (Interview with a gold miner, 2022).

Figure 3: Some tools and processes used in artisanal gold mining (photos El. H. S. Top, 2022; G. Arnaud-Fassetta, 2023)/ **A**: Cyanidation catchments sluice; **B**: Spitter and washing workshop; **C**: Tricycle for transporting ores; **D:** A few objects used in artisanal gold mining on display at a market at a mining site on the banks of the Faleme; **E**: Artisanal dredgers in operation in the Faleme River.

In addition to mechanization, the use of chemicals (mercury and cyanide) has contributed to the development of artisanal gold mining in the Faleme basin. For example, the use of mercury to amalgamate gold makes it possible to recover 20% to 40% of the gold contained in the ore (Djibrilla, 2017), or even 60% (Gagnol *et al*., 2019). The use of mercury in artisanal mines in the Faleme catchment is linked to the arrival of foreign miners from the sub-region who mastered the technique, and the ease of smuggling the product in this cross-border area. The gold-mercury ratio is 1g of gold to 1.3g of mercury.[10] Using this ratio, 7,800 kg or 7.8 t of mercury have been used each year in Mali by artisanal mines since 2016, given that artisanal production is estimated at 6 tonnes per year. Using this reasoning, from 2016 to 2020, 39 tonnes of mercury will be used in the artisanal gold mining sector. According to the 2018 Artisanal Gold Council report, the amount of mercury used in Senegal in the context of gold mining is estimated at around 5.2 t/year (5,261.76 kg/year).

Cyanide, used more recently and more discreetly in the Faleme catchment area, is beginning to be incorporated into the gold ore treatment process. Its use, monopolized by Burkinabe gold miners who are experts in the technique, enables more gold to be obtained despite its toxicity. According to Djibrilla (2017), its use to isolate gold enables 60 to 80% of the gold contained in ores to be recovered.

The combination of all these factors (mechanization, use of chemicals, arrival of miners from the sub-region) has contributed to the development of artisanal gold mining, which is increasingly using the Faleme River to process the ore, posing a threat to the river.

Artisanal mines in contact with the Faleme: The presence of the Faleme River in this region, which provides the essential water supply for gold production, is an essential factor. This river plays a fundamental role in supplying water to the gold mines located in a basement rock area where the water table is low. Water supply difficulties have led to the establishment of processing sites close to the river. The main gold ore processing sites are located close to the main course of the Faleme or its tributaries, creating a connection between the mine and the river. Alluvial ores are processed in the riverbed, on the banks, or along tracks. In the river, the mining method involves digging up the riverbed using shovels and hoes to extract the sediment. At the same time, river water is used to wash the sediments using a belt placed in a washing device (sluice), to which water is added to separate the clay or sand fraction from the gold. The washing residue (clay or sand) is discharged into the river, while the gold is fixed by the conveyor belt. On tracks and roads, far from the river, the ore is transported by tricycle to the processing sites. A processing site often acts as a hub for several extraction sites, where the extracted ore is processed (Figure 4).

This principle also applies to lode ores. After extraction, lode gold ores in the form of stone blocks are reduced in size on site, and transported to processing sites near the Faleme for crushing using machinery. The crushed ore powder is washed to separate the clay fraction from the gold. The slurry from this solution is discharged into the river after the gold has been extracted. Crushed and powdered ore can also be used in cyanidation ponds, where cyanide is used to separate the gold (Figure 5). Dredging is another type of operation that involves contact with the river. As the dredger is a floating machine on the watercourse, the entire process (extraction, treatment, washing) takes place in the river, so all the waste also ends up in the river.

[10] From a 2019 Report on the National Action Plan to reduce and eliminate the use of mercury in artisanal and small-scale gold mining in Senegal.

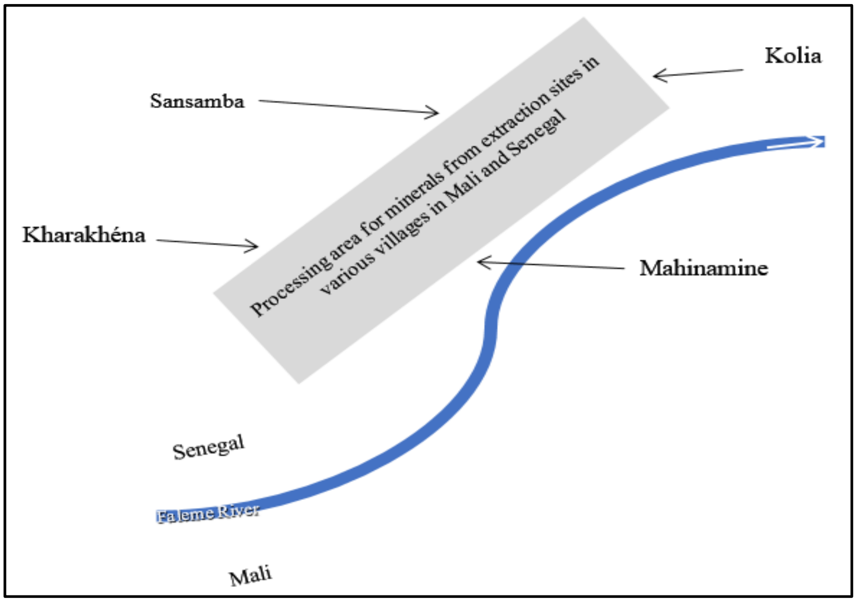

Figure 4: A processing site at Moussala North and its satellite extraction sites.

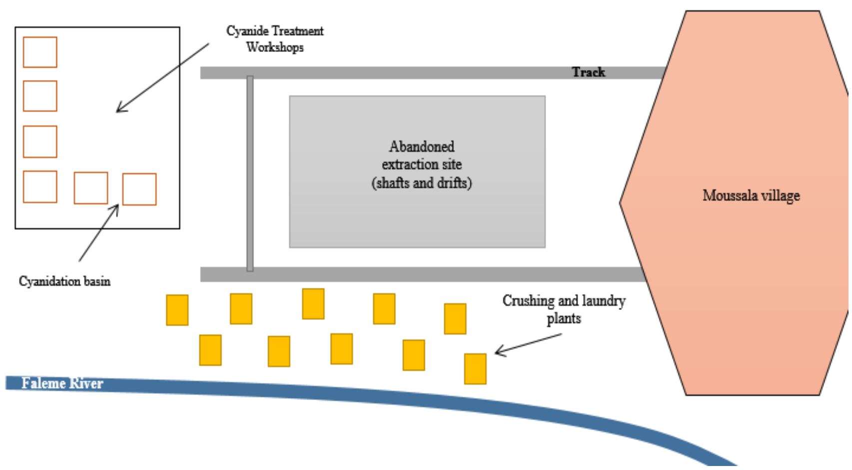

Figure 5: A gold processing site at Moussala Sud.

The essential use of water in gold mining is a source of connection between the artisanal mines and the Faleme River. This contact poses a threat to the Faleme, which is the receptacle for much of the waste from this type of mining, carried out by miners with modest material resources compared to other operators.

Semi-mechanical mining: A specialty of Chinese miners

The rush of Chinese miners to the gold zones of Senegal and Mali: The gold rush in this region is not limited to artisanal miners from the sub-region. It also involves Chinese miners who carry out semi-mechanical operations. The presence of Chinese miners in this region is the result of a long trajectory and numerous political factors. First established in Ghana in the early 2000s (Crawford & Botchwey, 2017), Chinese miners are gradually moving into other African countries such as Mali and Senegal. In 2013, the Chinese media estimated that around 50,000 miners from China were based in Ghana (Hilson *et al.*, 2014). Their sometimes-illegal operations result in tax losses that have prompted the Ghanaian state to conduct a vast campaign to hunt down Chinese *galamseys* (illegal small scale miners). The task force resulted in the expulsion of 4,592 Chinese nationals, as well as a small number of Nigerian, Togolese and Russian citizens (Tschakert, 2016). These operations have prompted the miners to turn to more favorable regions.

Mali, rich in gold resources and plagued by repeated crises since 2012, was a favorable destination. Given its political and economic situation involving internal conflict and turnover of political regimes in recent times, all the signs were green for corruption and illicit activities in the gold sector. The results of the interviews conducted show that Chinese miners first settled in the Malian part of the Faleme River in 2013. This first wave of Chinese miners, who had been expelled from Ghana, easily managed to find mining permits. Those who did not have any easy arrangements then made deals with the local authorities or landowners to obtain an agreement. Since 2013, fourteen small-scale mining and dredging permits have been issued to Chinese operators by the relevant Malian authorities. These companies, which are legally established after receiving authorization from the relevant authorities, work with other Chinese companies with subsidiary arrangements.

These include DPSTE Huayi, which operates in the commune of Sadiola after being expelled from Ghana. DPSTE Huayi has been dredging in the Faleme River since 2021, but it works with a subsidiary called Feng Yi SARL, which was granted permission to mine gold by dredging in 2014. Chinese operators are taking advantage of the absence of the state and opportunities for corruption to enter the illegal mining circuit. Although there are no official figures, interviews indicate that there are hundreds of Chinese sites along the Faleme River. This situation is said to have been facilitated by nebulous practices between the Chinese and local authorities such as the mayors and their municipal teams.

On the Senegalese side, Chinese incursions have gone from being repressed, to making working arrangements. After years of operating on the Malian side, since 2018 Chinese miners have been taking advantage of the porous border to set up illegal sites on the Senegalese side of the Faleme River. The government, which is mobilizing the forces of law and order to attempt combat illegal Chinese mining, is now granting semi-mechanized mining permits to Senegalese economic operators. Through a system of nominees, Chinese miners have been able to set up in this sector thanks to the permits issued to these national companies.

Small-scale mining techniques with greater resources: The arrival of Chinese gold miners in 2013 brought with it new gold mining practices using superior equipment. Chinese operators use mechanical shovels, tractors, mini-trucks, and industrial dredgers (Figure 6).

Unlike artisanal miners, they use more advanced mechanization and mainly carry out two types of mining: mining by dredging the riverbed and semi-mechanized small-scale mining. Mining by dredging, described above, is an operation that consists of removing material from the bottom of watercourses and recovering the marketable products using a combination of semi mechanized and mechanized methods and processes.[11]

The Chinese method consists of extracting the gold contained in the sand, gravel and soil of watercourses. The technique is based on the fact that the gold contained in the sand, gravel or soil settles to the bottom of the riverbeds and can be recovered in the form of grains or flakes simply by mechanical washing. Dredging is mainly carried out during periods when water levels are low. Lower water levels allow dredgers to cut through the main course of the river by forming gravel banks with mechanical shovels, in order to carry out their activity properly. Today, the dredging of the Faleme riverbed in search of gold is well known among the players, as the Chinese who use industrial dredgers are followed by Malian operators who use artisanal dredgers made by local craftsmen. Almost in competition with the artisanal miners, Chinese firms have a

[11] Republic of Mali (2019) Ordonnance N°2019-22/P-RM portant code minier du Mali, 33 p.

greater capacity for environmental destruction. Their large-scale mining practices pose a serious threat to the Faleme River, particularly through the huge quantities of sludge that are dumped into it.

Figure 6: Equipment used in semi-mechanical mining by Chinese miners (photos G. Arnaud-Fassetta, 2023; El. H. S. Top, 2023) / **A**: Mechanical shovels in operation on a Chinese semi-mechanical trail; **B**: A Chinese operator takes delivery of a machine intended for gold mining; **C**: Lubricant tank and a sludge evacuator; **D**: Generator used to supply water to the gold processing site; **E**: A bene truck in operation on a semi-mechanical site.

In addition to dredge mining, Chinese miners carry out small-scale mining, also known as semi mechanized mining. The latter is any operation whose daily processing capacity does not exceed five hundred tonnes of ore, and it consists of extracting and concentrating mineral substances and recovering the marketable products for disposal using some mechanical means in the chain of operations.[12] Semi-mechanized mining authorization grants the beneficiary, within the limits of the perimeter allocated and to a maximum depth of 15 m, the exclusive right to exploit, using semi mechanized methods and processes, the minerals for which it is issued.[13] Chinese semi-mechanical mining sites have proliferated along the Faleme River, especially in the Malian part. Their practices involve the use of mechanical shovels, trucks and generators, which make it possible to dig to great depths and transport the ore to the banks of the Faleme for washing. Chinese gold mining practices are often criticized by local people for destroying the environment in general, leading to tense moments that can threaten the safety of the Chinese miners. However, Chinese miners holding mining permits enjoy protection on both sides of the river. On the Senegalese side of the Faleme, their protection is provided by the DSF (Defense and Security Forces), in this case the national *gendarmerie*, while on the Malian side, their protection is provided by the private security company 711.[14]

Industrial mines on the rise since 2000

Industrial mining booming since 2000: Since the early 2000s, West African gold has been coveted by foreign mining companies. Their investments have increased gold exploration and mining in the West African region (Thune, 2011), including Mali and Senegal, particularly in the parts covering the Faleme basin. Currently, around eleven industrial mines have been set up in this region. This number can be explained by the rise in gold prices and mining policies favorable to investment by major companies (Diallo, 2021), such as the introduction of new mining codes and mining cadasters. As noted above for the smaller operations, gold mining companies do not hesitate to resort to environmentally harmful practices, such as digging deep pits, large-scale cyanidation, and using large volumes of water to make their investments profitable (Deshaies, 2016).

Industrial mining techniques: Industrial mines have the reputation of working based on exploration or exploitation permits issued after an environmental impact study (EIA). Unlike artisanal and semi-mechanical mines, there are no clandestine or illegal industrial mines. Despite this attractive image, industrial mining practices that sometimes fail to comply with regulations are an environmental threat. Their mining methods require the use of explosives, heavy and technologically sophisticated machinery and toxic substances such as arsenic and cyanide (UNCTAD, 2007). Along the Faleme River, industrial mines use large areas, large volumes of water and products that are dangerous for biodiversity, in particular cyanide. So, like other types of mine, they can contribute to environmental pollution, destruction of biodiversity and premature drying up of water courses.

Huge volumes of water: As water is an essential element for gold mining, the dynamics of the sector along the Faleme catchment are partly linked to the availability of water, particularly from the river itself. Although the water table is low because of the Precambrian basement rocks, with weak fissures (Sow, 2007), many mining companies rely on the river to meet their water needs. The number of companies and their location in relation to the Faleme River and its tributaries an be explained by the availability of water for their operations. The water needed to run many of the processing plants and mining operations is drawn from the river and stored behind dams. This is the case for Sabodala gold, which has built two surface water storage

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[12] Law 2016-32 of 8 November 2016 on the mining code of Senegal, 53 p.

[13] *Ibid*

[14] Sécurité 711 is a private security company approved by Mali's Ministry of Security and Civil Protection. It provides protection for people and their property, especially for companies and banks. The name 711 referred to the 703 communes and 8 regions of Mali in 2010 when the company was founded.

dams and a 41.8 km water pipeline connected to the Faleme River to meet its water needs (Tropica, 2006). The Loulo Gounkoto company's 2018 technical report clearly notes that:

> …the Faleme River, the natural border between Mali and Senegal, supplies the majority of the company's water needs. A main pumping station with two transfer pumps is located in the river catchment upstream of a weir, which maintains a 1m elevation to ensure water availability during the dry season. Water is pumped to the Loulo raw water dam, from where it is taken to the treatment plant. There are no restrictions on the amount of water that can be taken from the river. [15]

The same report also notes that a treatment plant, fed by the river water supply, provides all the operation's drinking water needs. A borehole pump is located near the offices to provide emergency drinking water. It is also noted that the "Fékola mine will need to draw make-up water from the Faleme River during the dry months of the year".[16] This is true for all the Malian mines that are located on the main course of the river, which means that the volume of water drawn is significant, and much of it for industrial mines. Our estimate shows that 4.05% of the volume of water available per year is consumed by mining companies. This value is meaningful during periods of low flow, which poses a threat to the water needs of the population.

In sum, industrial mines threaten a river subject to a deficit of more than 50%. Other practices like obstructing the riverbed, storing cyanide in proximate basins likely to have a connection with the river, and accumulating waste, threaten to the Faleme River.

Threats to the Faleme hydrosystem

Between excavation, destruction of banks and obstruction of the riverbed: The river hydrosystem is defined as a complex, hierarchical system whose functioning depends directly or indirectly on the active course of the river (Amoros & Petts, 1993). Thus, anything that affects the river in its catchment, including the variability of water and sediment flows (in quantity and quality), for physical or human reasons, can threaten the proper functioning and balance of the hydrosystem. Gold mining in all its forms threatens the Faleme hydrosystem. The most visible threats today are the excavations several meters deep in the riverbed and on its slopes. The banks and bed of the river are largely destroyed (Figures 7F/7C/7E). As a result, a large volume of water, which is supposed to feed the river, is trapped by these excavations several dozen meters deep, which affects the flow. In addition, the materials (sand, gravel) taken from these holes often end up in the river, causing siltation or obstructions. Riverbanks are affected by dredging and alluvial gold extraction, destroying all the vegetation responsible for fixing the soil and causing landslides that contribute to silting up the river and dumping large quantities of mud. In addition, dredging extracts gravel and sand from the riverbed and creates obstructions.

The most audacious practices threatening the functioning of the river are the construction of concrete dams (Figure 7A) on the main course, completely preventing the flow of water, especially during low-water periods (December to June). In addition, some of the river's tributaries are completely disconnected from the main river and are crossed by an open-cast mine (Figure 7G). These developments threaten the river's geomorphology and contribute to a flow deficit.

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[15] Technical Report on the Loulo Gounkoto Gold Mine Complex, Mali, 2023.

[16] Feasibility study report on Fékola, 2013.

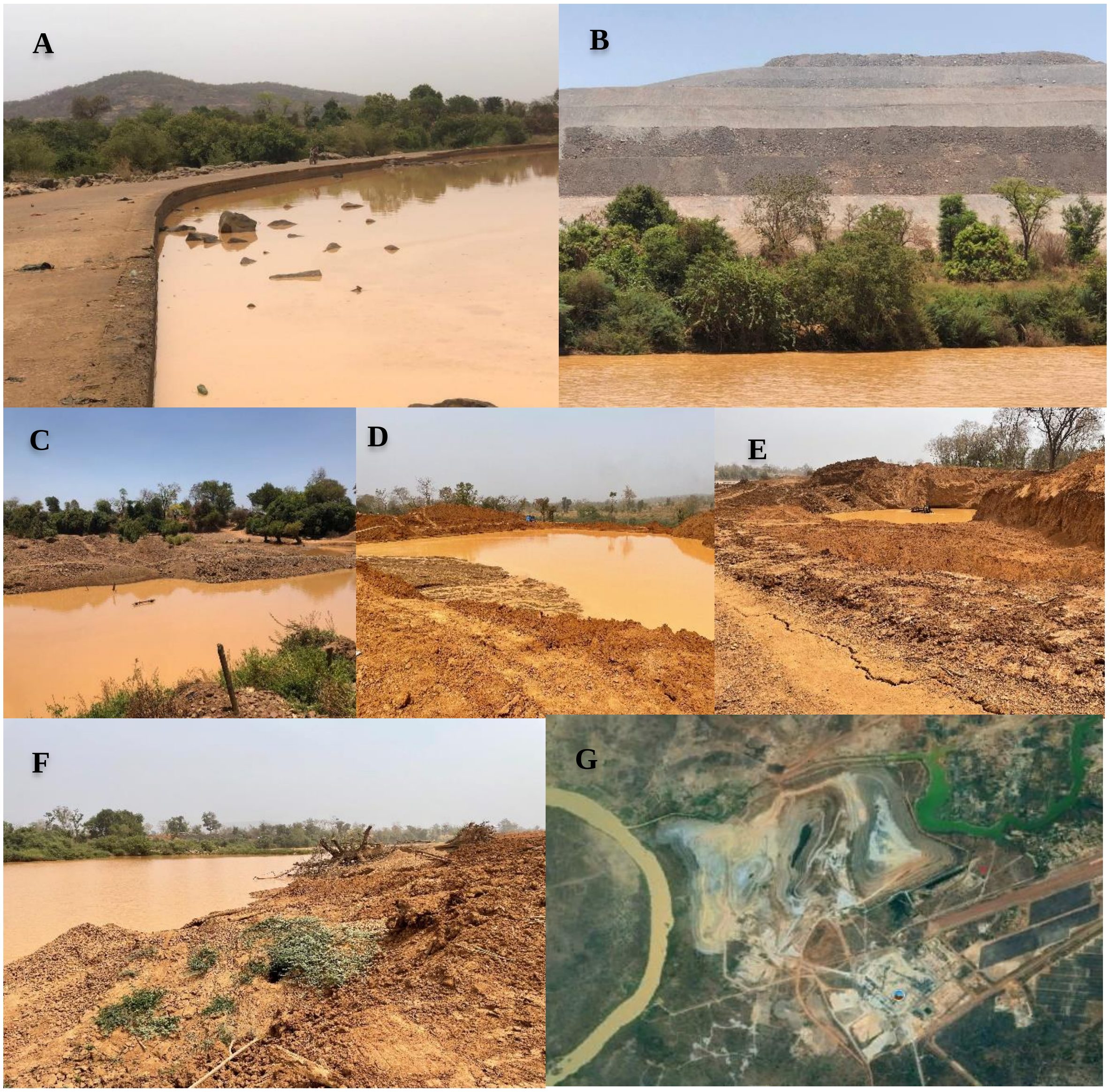

Figure 7: Some of the impacts of gold mining on the Faleme River (photos G. Arnaud-Fassetta, 2023; El. H. S. Top, 2023) / **A**: Concrete dam across the Faleme River Main course of the Faleme, built by the Loulo mining company; **B**: Mining waste (gravel and sand) from ore extraction, a few metres from the Faleme; **C**: Gravel mounds blocking the flow during low-water periods; **D**: Mud pond from a semi-mechanical mine, a few metres from the Faleme; **E-F**: Excavations on the banks of the Faleme; **G**: Google Earth image showing the obstruction of a tributary of the Faleme by a mining pit from an industrial mine at Gounkoto.

Pollution of water and sediments by mercury and cyanide: The surface waters and sediments of the Faleme River are polluted by chemicals used in ore processing. The spatial distribution of these results shows high mercury concentrations (greater than 0.002 mg/l) in the middle section of the Faleme. Concentrations exceed the WHO standard of 0.001 mg/l in this area. The highest concentrations of mercury in water are recorded in the middle part of the Faleme. These concentrations extend over a distance of around 150 km in the central part of the Faleme. In the lower part of the Faleme, on the other hand, mercury concentrations are zero, i.e. below the critical threshold. This spatial distribution of mercury concentrations in the waters of the Faleme shows that the further away from the mining sites, the lower the concentrations. This poor drainage is linked to the nature of mercury, a heavy metal that is easily deposited in the soil, and to the lack of continuity in the flow due to the obstructions in the bed put in place by the operators. The results of our mercury tests on river sediments show low concentrations in the middle Faleme and zero concentrations upstream and downstream of this area. In the mining zone (the middle Faleme), concentrations vary from 0.2 mg/kg to 0.8 mg/kg. This shows that the mercury is deposited in the sediments, and does not flow out of the mining area.

Cyanide test results ranged from 0 to 18 mg/l. The highest cyanide concentrations were found in the cyanidation basins located in the gold-bearing zone. Upstream and downstream of the gold zone, cyanide concentrations were zero. All the mercury and cyanide tests show that the pollution is real, but it is localized in the Faleme mining area.

Muddy water and threats to agro-pastoral activities: Gold mining in rivers results in a significant transfer of suspended matter during the dry season, due to ore processing. The connection between the river and the ore processing sites results in large quantities of sludge being discharged into the Faleme. Figure 8 shows the quantities of sludge in tonnes that would have been discharged into the Faleme River between 2018 and 2020.

Years	Flow m^3/s	$Vm^3/year$	Quantities of sludge (t)
2018	90	2,840,130,000	5,680,260
2019	186	5,884,957,920	11,739,204
2020	143	4,518,746,565	9,025,302
Total			**26,444,766**

Figure 8: Estimated quantities of sludge discharged into the Faleme River.

These huge quantities of sludge can have many consequences for a river's ecosystem (Tudesque *et al.*, 2012). By limiting the penetration of sunlight, muddy water can reduce plant photosynthesis, adversely affect the biological productivity of the aquatic environment and lead to a reduction in oxygen in the water and food for aquatic fauna. According to Yoboue (2017), suspended particles can also clog fish gills and affect the development of eggs and larvae.

Local people believe that solid loads have slowed plant growth and reduced yields. Generally speaking, the people interviewed highlighted various threats (chemical pollution, muddy water, etc.) that have ended up having an impact on agro-pastoral activities. Interviews with market gardeners, fishermen and livestock farmers revealed problems such as the scarcity of fish in the Faleme River, and the impossibility of using the water for agriculture or domestic consumption. There is also the loss of livestock and the degradation of biodiversity. One fisherman reports "a very drastic reduction in the number of fish, which explains the drop in catches to around 10 kg, whereas they could exceed 50 kg before 2018".[17] Residents noted that "two years ago, fish were dying of asphyxiation on the banks of the Faleme, and in February 2022, it was the turn of the birds to suffer the consequences, with an unprecedented mortality rate along the Faleme".[18] While it is difficult to establish a direct link, those interviewed are convinced that these losses are linked to the consumption of

[17] Interview with a fisherman in Kidira, July 2022.
[18] Field survey, July 2022.

water from the Faleme and the deterioration in its quality over the last five years (2018). One market gardener said that "mud-laden water makes it very difficult to water plants, as the accumulated mud clogs the soil and makes it difficult for water to infiltrate, which has a negative impact on plant growth".[19]

Damage to the Faleme River: Which type of mine is responsible for what?

We have attempted in Figure 9 to show the degree of involvement of each type of operation on the degradation of the Faleme River, considering the techniques and tools used. We assign + signs according to the degree of involvement. This classification is based on the characteristics of the three types of gold mines in operation in the basin as outlined above, including the type of mining, the equipment and chemicals used and the mining practices we observed in the field.

Threats	Artisanal mines	Semi-mechanical mines	Industrial mines
Mercury pollution	++++	++	+
Cyanide pollution	+++	+	+++
Noise pollution	++++	++	+++
Mud spill	+++	++++	++
Destruction of riverbanks	++	++++	+
Bed obstruction	+++	++++	++++
Drying up of the river	+++	+++	++++
Threats to downstream activities	+++	++++	++++

+ None ++ Not important +++ Important ++++ Very important

Figure 9: Summary of threats to gold mining by mine type.

In this sense, mercury pollution is attributable to artisanal mining. It uses gravimetric techniques that involve the use of mercury to isolate the gold. The study showed above that significant quantities of mercury are used each year by artisanal miners. Chinese miners who use quite similar processes could contribute to this type of pollution. Given the proximity of the processing sites to the river, the mercury reaches the river or is deposited on the sediments along it.

Cyanide pollution can come from two sources: gold miners and industrial mining companies. Gold miners are increasingly using cyanide in the processing of ores, as it enables them to obtain more gold. They use it in small cyanidation ponds very close to the river, which means that the cyanide ends up in the water. Mining companies also use cyanide, the waste from which is stored in cyanidation ponds. However, these settling ponds can collapse, causing some of the waste to spill into rivers.

The investigations carried out by Deshaies (2011) into this type of accident highlight the negligence that led to the failure of settling tanks built with materials that were too fragile. In the case of the Faleme, the proximity of the mines to the Faleme in Mali suggests that some of the waste produced by the mining companies could easily end up in the river and contribute to cyanide pollution.

In addition to proven mercury and cyanide pollution, huge quantities of sludge are dumped into the river every year, to the extent that it is now considered a mudflow. As we have shown, extensive rock-crushing comes mainly from Chinese semi-industrial mining operations. At semi-mechanical mining sites, poorly

[19] Interview with a market gardener in Kidira, July 2022.

protected sludge ponds result in sludge being discharged into the river. To a lesser extent, these quantities of sludge are linked to artisanal miners who use small crushers installed on slopes, which means that the sludge flows directly back into the river. In addition, Chinese miners, like the gold panners, use industrial dredgers that suck up the sediment from the bottom of the river, producing and dumping tonnes of sludge into the water.

The destruction of the banks and alluvial terraces is mainly due to the practices of Chinese miners, who work on the banks, digging huge holes using mechanical shovels and large equipment. Small scale gold miners also use rudimentary equipment to dig holes in the banks and terraces in their quest for gold. Their practices, which are banned in many other Africa countries[20], destroy the banks in places, facilitating erosion and silting. The obstructions to the riverbed are mainly due to the dredging of the riverbed by industrial dredgers operated by Chinese miners. As part of the dredging for gold carried out by the Chinese and the operations of some artisanal miners, large quantities of gravel are dumped on the riverbed, creating mounds of stones which, in places, act as veritable dams, slowing the flow during periods of low water. These blocks of stone are also sometimes used by Chinese miners, using mechanical shovels, to stop the flow completely in order to carry out dredging activities when the river is dry. Mining companies also build concrete dams on the riverbed to store water and ensure their supply during dry periods.

The early drying up of the river is linked to the heavy use of water by all types of operators. However, it is a fact that industrial and mechanical mining use much more water than artisanal mining. The threats to livestock farming, market gardening, fishing and irrigation activities downstream from mining areas are mainly linked to the huge quantities of sludge dumped into the river every year by semi-mechanical mines in particular. Analyses we undertook have revealed that mercury and cyanide pollution is localized to the mining areas, so that problems such as reduced yields, the disappearance of fish and the impossibility of using the river water for domestic purposes, as reported by local people, are attributable to the turbidity of the water caused by the sludge.

Since the resurgence of gold mining in the Faleme catchment in Mali and Senegal in the early 2000s, the number of mining companies involved in industrial and semi-mechanical mining has grown steadily. As for artisanal mining, the number of legal and illegal sites is increasing despite attempts at formalization. The illegality that characterizes the artisanal mining sub-sector and its low contribution to the formal economy mean that its negative consequences are highlighted, leading to hostile rhetoric from governments (Sawadogo, 2021) in favor of industrial and semi-mechanical mines which, thanks to their financial power and their contribution to state revenue, enjoy a good image with politicians and the media. This race for gold revenues explains the rhetoric of politicians who try to stigmatize artisanal miners by accusing them of being responsible for the degradation of the Faleme River.

The evidence presented in this article, based on observation and study of the practices of the various mines, runs counter to these arguments. Indeed, beyond the practices of artisanal miners, the degradation of this river is the result of the activities of industrial and semi-mechanical mines. These results largely corroborate those of Sawadogo (2021), who demonstrates, using the example of the commune of Kampti (south-west Burkina Faso), that in addition to artisanal gold mining, other political and social factors play a role in environmental dynamics. Industrial gold mining is often considered to be the most environmentally friendly. As we have explored, it begins with a permit issued by the government, followed by an environmental impact assessment carried out by the company rather than an independent body. However, in developing countries like Mali, where governments are relatively less influential, the application of environmental impact assessments can leave much to be desired. This leads to environmentally damaging practices, as we have seen in the case of the Faleme River.

The involvement of Chinese miners in semi-mechanical gold mining, corruption and environmental degradation have been highlighted by authors in Ghana (Hilson *et al.*, 2014; Crawford *et al.*, 2015; Boafo *et al.*, 2019) and DR Congo (Mwetaminwa & Vircoulon, 2022). In this case study, Chinese involvement in gold mining along the Faleme River is explained firstly by the political instability in Mali from 2012, and secondly in Senegal by the porous nature of the borders and the nominee system negotiated between Chinese miners and

[20] For Zimbabwe, a ban on alluvial and riverbed mining was instituted in 2024. https://www.chronicle.co.zw/government-bans-riverbed-alluvial-mining/

Senegalese economic operators. In Ghana, on the other hand, Boafo *et al*. (2019) argue that this involvement is linked to uncoordinated interactions between key state institutions and customary bodies. Chinese mining practices are known across Africa (Ghana[21], DRC[22], Mali, Côte d'Ivoire) for their capacity to destroy the environment. Somewhere between legal and illegal, Chinese miners use dredging and semi-industrial mining methods along the Faleme, the main impact of which is the destruction of riverbanks, the discharge of sludge and chemical pollution of the water, all of which contribute to the degradation of the river.

5. Conclusion

The aim of this article has been to show that the degradation of the Faleme River is not exclusively linked to artisanal gold mining. This is a classic political ecology problem, where the operations of industrial and semi-industrial mines, through their mining techniques, the chemicals and large volumes of water used, and the huge quantities of sludge dumped into the river, are also responsible. An analysis of the practices of the various gold mines and their impact on the Faleme River shows that multinationals and Chinese companies are as much involved in the degradation of the river as the artisanal miners.

At present, the impact of gold mining is resulting in mercury and cyanide water pollution, mud-laden water, and destroyed riverbeds and banks. These impacts, particularly physico-chemical pollution, compromise the use of water for agriculture, livestock farming, fishing and tourism, particularly in the downstream part of the river, which is an agricultural area. The rhetoric that blames artisanal miners for the degradation of this river can be explained by government's pursuit of revenues from gold. Indeed, governments support industrial mines like those we have surveyed because they provide them with rents, whereas the resources generated by artisanal mining escape them. It is in this race for gold revenues that the governments of Mali and Senegal, and the media, are trying to stigmatize artisanal miners by accusing them of being the main cause of the degradation of the Faleme River, in order to exclude them from the capture of revenues by the industrial and semi-mechanical mines that benefit the economies of the state, as well as corporate interests. In contradiction to this rhetoric, practices observed in the field, the results of mercury and cyanide tests and data processing deconstruct this rhetoric, and prove the involvement of all gold mines in the degradation of the river. We have observed this for almost a decade. This situation also highlights the responsibilities of the governments of Mali and Senegal, which are supposed to ensure the environmental regulation of gold mining activities.

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