








Research Article

Preliminary Assessment of Mercury and Methyl Mercury Contamination of Sediments, Water and Fish from the Bétaré-oya Gold Extraction Site (Cameroon)

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Abstract

The gold extraction process by mercury amalgamation is recognized worldwide as a process presenting an environmental and health risk linked to mercury contamination of the geo and biosphere close to the gold panning site. The aim of this work is to assess the risk of contamination by mercury of populations living in the locality of Bétaré-oya, which is subject to the phenomenon of small-scale artisanal mining. In order to achieve this, a small social survey was carried out on two gold extraction sites in the locality of Bétaré-oya. Samples of sediment, water and fish were also taken from these sites. After characterization, these samples underwent the total mercury was determined by an automatic mercury analyzer. Moreover, the methyl mercury was extracted from the samples and analyzed by inductively coupled plasma mass spectrometer coupled to gas chromatography and by gas chromatography coupled to an electron capture detector. The results obtained showed total mercury concentrations varying from 386 to 5072 µg/kg in sediments and from 24.6 to 8451 ng/L in water. Methyl mercury was measured at concentrations ranging from 7.62 to 165 µg/kg in sediments, from 2.54 to 15 µg/L and from 45.4 to 90.8 µg/kg in fish. Well water (15.0 ± 2.4 µg/L of methyl mercury) which is consumed by the populations of the study site, and fish contaminated with an average concentration of 68 µg/kg of Methyl mercury, represent the main vectors of the risk of direct contamination of the populations of the locality of Bétaré-oya by this pollutant.

Keywords

Gold Panning, Methyl Mercury, Sediment, Water, Fish, Health Risk, Bétaré-Oya

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1. Introduction

Mercury (Hg) is a metal found in the environment in the form of elemental mercury (Hg^0), divalent inorganic mercury (Hg^{2+}), methylmercury (MeHg) and dimethylmercury (Me_2Hg) [1]. It is a metal of concern due to its toxicity for living beings [2]. Tragic events such as Minamata in Japan in 1956, highlighted the lethal effects of mercury [3]. But for several years, certain activities including the exploitation of gold in mines have been responsible for the contamination of the environment by Hg. The most incriminated and internationally recognized is called "artisanal and small-scale mining (ASGM)" [4, 5].

ASGM uses a mercury amalgamation process to extract gold from the ore. This process involves the operations of crushing, grinding, amalgamation (with Hg), evaporation of Hg and melting [6]. When the miner does not use a mercury recovery device during amalgamation, evaporation and smelting operations, this metal is deliberately emitted into the water and surrounding air. The mercury vapors released are highly toxic, invisible and odorless. They poison miners, gold dealers and buyers, their families and communities. As permanent contamination by Hg of environmental compartments (soil, water, air) through the process used in ASGM is no longer in doubt [7], it is important to clarify the aspect of quantification and speciation of this contaminate (with Hg) in these environments. Especially since studies have shown that, the quantity (in grams) of Hg, necessary for the extraction of one gram of gold (Au) varies depending on the type of amalgamation. In fact, the miner who will carry out an amalgamation of the raw ore will use 5g of Hg for 1g of Au. On the other hand, it would need 1.3g of Hg to extract 1g of Au in the case of an amalgamation of ore concentrated into gold [6]. A special and temporal projection of the study of environmental contamination by Hg is imperative to assess the real level of contamination of different environmental entities and the health risks associated therewith, in the localities of the Eastern region of Cameroon, plagued by risky ASGM activity. This first work is part of the preliminary phase of a vast health risk study project linked to contamination of the environment by Hg in localities in eastern Cameroon which are subject to gold mining.

Several studies have been carried out on Hg contamination of the environment of gold mining sites in different African countries such as Senegal [7, 8], Ghana [9, 10], Nigeria [11], South Africa [12-14] and Cameroon [15]. However, there is no data in Cameroon showing the level of contamination of environmental entities by MeHg, which represents the most

toxic form of Hg [16]. Especially since it has been demonstrated that Hg^{2+} and MeHg which are found in the three components of the biospheric environment (soil, water and air), end up being found in foods (drinking water, plants, fish) and finally in the body of food consumers including humans [17, 18]. Indeed, these two chemical forms of Hg are bioavailable in soil and water [18]. Therefore, once these environments are contaminated by Hg, its transfer into crops and fish which serve as food for humans is only a matter of time [7, 18]. This is an opportunity to point out that the inhabitants of Eastern Cameroon subsist on fishing, agriculture and gathering. This is what justifies the interest in studying the potential risk of exposure of the population of B éare-oya to contamination by MeHg.

2. Material and Methods

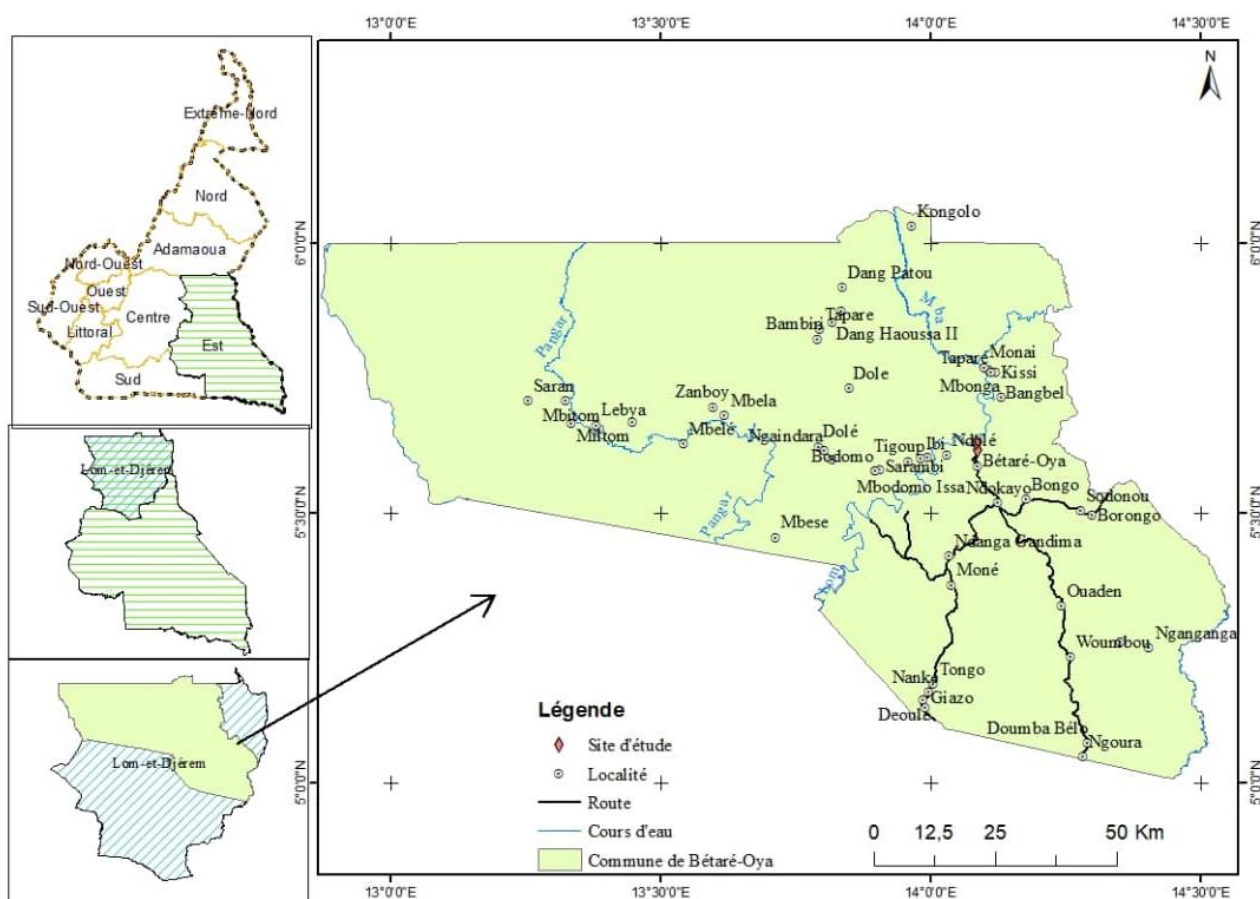
2.1. Area of Study

2.1.1. Location of Area of Study

The study was carried out in the Eastern region of Cameroon, precisely in the Lom and Djerem Division, B éare-oya sub-division (figure 1a). Two gold mining sites were chosen for the study. Site 1 (figure 1c) with coordinates 5°37'56"N 14°05'11"E, is located approximately 20 km from the town of B éare-oya and 500 m from the Lom river. Site 2 (figure 1d), with coordinates 5°37'00"N 14°05'14"E, is located approximately 10 km downstream from site 1 and 15 km from the town of B éare-oya.

2.1.2. Sociological Representation of the Active Population of the Area of Study

The sociological data presented in this work constitute the summary of a small survey carried out in the field during the sampling phase. Indeed, the gold miners recorded in the study area are made up of men and women of all age groups (children, adolescents and adults) (figure 2). The presence of children on the site is justified by the establishment of small families in makeshift accommodation serving as a family home. These gold miners are of several nationalities including Cameroonians who represent more than 80% of the gold miners workforce. The other nationalities identified in the two sites consist of Chinese, Central Africans, Burkinabes, Nigeriens and Chadians.



(a)

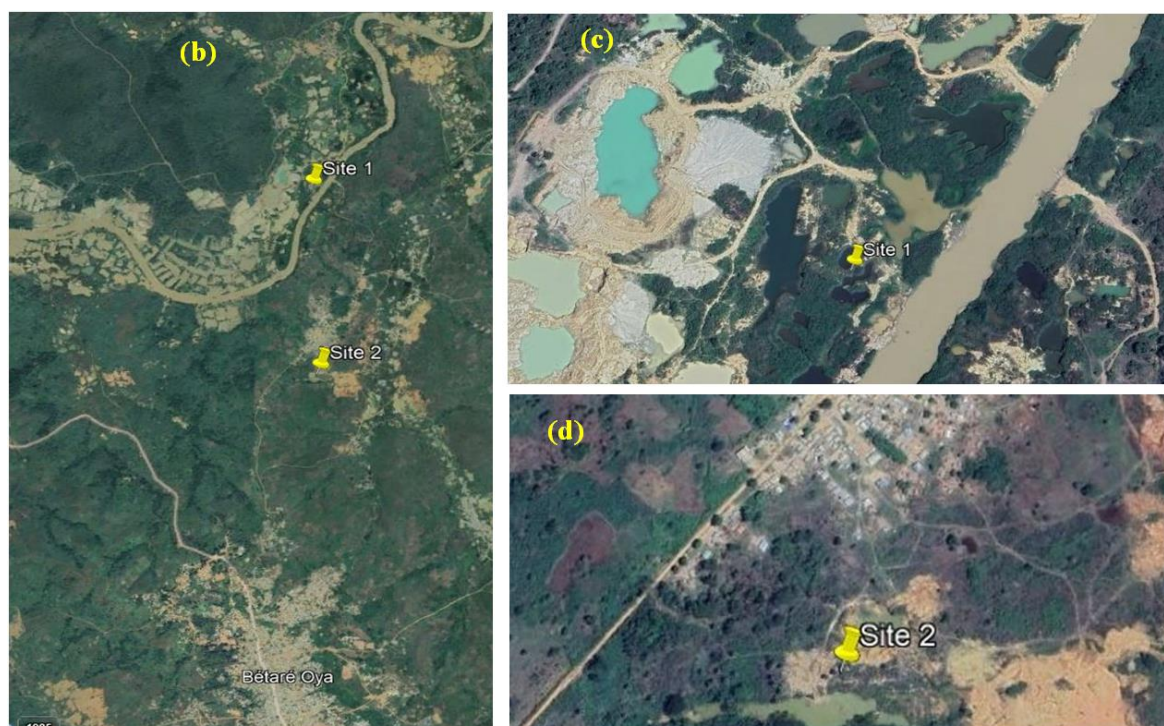
**Figure 1.** Location of Bétaré-Oya (a) and study sites 1(c) and 2(d).



Figure 2. Illustration in image of ages represented on the two gold panning sites in the study.

2.2. Sampling

2.2.1. Sediment Sampling

Five sediment samples were taken. The 1st sediment sample consists of the bottom of the pan (S_{pan}). The bottom of the pan is a residue from washing amalgam. It was taken after the amalgam washing operation. The 2nd sediment sample consists of mud taken from a river which flows into the Lom River (S_{river}). This river is an outlet for water from a few amalgamation basins on site 1. The mud was taken from the middle and edges of the bed and then mixed to form a representative sample of the sampling point.

The 3rd sample consists of sediment (S_{basin}) taken from the bottom of the amalgamation basin. Five sampling points were taken for this 3rd sample. The five samples were mixed into one sample, to express the representativeness of the sample in the amalgamation basin. The 4th sample consists of soil from an agricultural field on site 1 (S_{agri}). The soil was taken from five points at a depth of 10 cm over an area of 15m² of the cultivated field. The five samples were then mixed to make a representative sample of the field plot.

The 5th sample consists of sludge taken from the edge of an amalgamation basin (S_{edge}). It was also a question of taking several samples to make a representative sample at the edge of the amalgamation basin. Once in the laboratory, the soil samples were dried in an oven at 40 °C. The dry samples were crushed, sieved ($\phi < 2$ mm) and packaged in hermetically sealed plastic bags and stored at 4 °C.

2.2.2. Water Sampling

Three types of water samples were collected in sterile

plastic bottles. The 1st water sample (W_{well}) is well water. This water was taken from water retention containers from wells. This water is treated with bleach and made available for consumption by the populations present in the study sites. The 2nd water sample (W_{basin}) was taken from the 12 m² amalgamation basin on site 2 which has been in operation for 4 months. The 3rd water sample (W_{river}) was taken from the river constituting one of the tributaries of the Lom river. Each water sample was acidified with analytical grade of hydrochloric acid representing 1% of the liquid sample, then stored at 4 °C.

2.2.3. Fish Sampling

The fish were purchased directly from fishermen returning from fishing in the Lom River. Two species of fish widely distributed in Lom and marketed in the locality of B éare-oya were selected. It is firstly about *Arius africanus* (458 g) of the Ariidae family, locally called “*machoiron*”. It is next about *Cyprinus carpio* (280 g) of the cyprinidae family, which is a teleost fish locally called “*Carp*”. In addition to being very available and widely consumed in the locality of B éaré Oya, these two species of fish are those, which adapt best to the harsh physicochemical modifications of surface waters (lakes, rivers) in Cameroon. The sampled fish were immediately kept cool and transported to the laboratory.

2.3. Physicochemical Characterization of Samples

The residual soil moisture and the water content of the fish were determined according to the NF ISO 11465 standard [19]. The pH was determined in the soil and water samples

following the NF ISO 10390 method [20]. Suspended matter in water was determined following the method used by Djonga *et al.*, [21].

Organic matter (OM) was determined in the soil samples following the method used by Noubissié *et al.*, [18]. It was determined in the water samples following the method used by Djonga *et al.*, [21]. The principle of each of the methods used is based on the hot oxidation of organic matter, by an excess of potassium dichromate [18] or potassium permanganate (Djonga *et al.*, [21] in a medium acid.

2.4. Total Mercury Extraction

Total mercury (HgT) was determined in sediment and water samples. THg concentration in sediment samples were determined by atomic absorption spectrophotometry after dry mineralization and gold amalgamation with an automatic mercury analyzer (Altec, Model AMA 254). Briefly, an aliquote of homogenized sample was weighted in a Ni boat using an analytical balance (Mettler Toledo XP26), prior to pyrolysis and subsequent amalgamation in the instrument. All analyses were duplicated. The relative error was routinely " $\pm 13\%$ ". Detection limit (defined as three times the standard deviation (SD) of the blank) is 4.3 ng/g. Concentrations obtained for repeated analyses of the certified reference material IAEA-456 (marine sediment) were in agreement with the published range of concentration (76 ± 1 ng/g measured vs 77 ± 5 ng/g certified).

HgT extraction was carried out in water following the method used by Monperrus *et al.*, [22]. The synthetic seawater and real water samples were applied to test the accuracy of the analytical procedure. Synthetic seawater samples were obtained by dissolving NaCl in Milli-Q water at concentration of 13 and 35 g/L. Samples were then spiked with natural monomethylmercury (MeHg) and inorganic mercury (iHg). It was specifically question to weigh 100 mL sample in a flask and spiked with known amounts of the enriched MeHg and iHg solutions. The mixture is then directly submitted to derivatization. This step consisted to add 5 mL of acetic acid buffer (0.1 mol/L) to 100 mL of water sample. The pH was adjusted to 5, using concentrated ammonium hydroxide. Isooctane (0.2 mL) and 1 mL of NaBPr₄ (0.5 %) were added. The flask was immediately capped and vigorously shaken for 5 min. The organic phase was transferred to an injection vial and analyzed by GC-ICP-MS. The operating condition for coupled GC-ICP-MS is displayed in table 1 of the supplementary material. Concentrations of total mercury (THg) were obtained in this method by adding concentrations of MeHg and iHg.

2.5. Dosage of Methyl Mercury (MeHg) in Samples

2.5.1. Extraction of MeHg in the Soil

The extraction of MeHg from the soil was carried out following the (modified) method used by Caricchia *et al.* [23]. Concretely, it was a question of mixing 0.2 g of soil with 10 mL of HCl (6N). The mixture was stirred in an ultrasonic bath (power, temperature) for 45 min. After cooling, 10 mL of benzene was added. The mixture was shaken for 5 min then centrifuged at 2500 rpm for 5 min. The organic phase was recovered and counter-extracted twice with 1 mL of a cysteine solution (1%). The two cysteine solutions (1/1 mL) were collected in the same bottle. A mixture consisting of 0.5 mL of benzene, 0.5 mL of saturated CuSO₄ solution and 1 mL of 4 M KBr was added to the previous cysteine solution. The mixture was stirred for 2 minutes and the organic phase was collected and stored at 4 °C until analysis.

2.5.2. Extraction of MeHg in Fish

It was made using the modified Korean Food Code (KFC) method. Concretely, it was a question of introducing 0.2 g of the fish into a centrifuge tube containing 10 mL of 25% NaCl solution. After homogenization, 4 mL of HCl (37%) and 15 mL of toluene were added and the mixture was stirred for 2 min. After centrifugation at 3000 rpm for 20 min, the recovered organic phase was washed with 10 mL of 25% NaCl solution (extraction), then with 5 mL of L-cysteine solution (back extraction). The aqueous fraction (L-cysteine) was recovered then mixed with 4 mL of an HCl solution (37%) and 5 mL of benzene. After 5 min of stirring, the mixture was centrifuged at 2500 rpm for 5 min. The organic phase was collected and stored at 4 °C until analysis.

2.5.3. MeHg Analysis

The analysis of MeHg extracted in soils and fish were carried out by gas chromatography coupled with electron capture detector (GC-ECD). The acquisition parameters of the analysis are presented in Table 1. But before the injections of the sample extracts, a range of standard solutions of MeHg with concentrations varying from 0.24 µg/mL to 4.8 µg/mL was prepared from Methylmercury Chloride (MeHgCl) in toluene for a total volume of 10 mL. The blank of the standard solution consisted solely of toluene. After injection of the range of standard solutions, a calibration line was obtained with an $R^2 = 0.9993$. The detection limits (LD) of MeHg and iHg were 0.0021 mg/L and 0.0018 mg/L, respectively, with respective retention times of 6.25 min and 8.38 min.

Table 1. Acquisition parameter for the analysis of MeHg by GC-ECD.

Parameters	Carrier gas flow (N ₂)	Make-up gas flow (N ₂)	Volume of Injection	T °C of injection	T °C of detector	T °C of oven
Values	7 mL/min	60 mL/min	1 µL	160 °C	240 °C	100 °C -160 °C / 12 min and 5 °C/min

3. Results and Discussion

3.1. Characteristics of Samples

Table 2 presents the physicochemical characteristics of the different samples.

Table 2. Physicochemical characteristics of the samples.

Sediments	pH	OM (%)	RH (%)
Bottom of pan	3.81 ± 0.05	0.11 ± 0.03	11.8 ± 0.41
Mud of river	4.62 ± 0.02	1.94 ± 0.09	22.14 ± 2.45
Amalgamation basin	3.5 ± 0.07	0.68 ± 0.04	12.52 ± 0.91
Agricultural soil	5.2 ± 0.06	2.45 ± 0.06	9.67 ± 0.32
Edge of amalgamation basin	3.5 ± 0.02	0.98 ± 0.07	15.6 ± 0.56

Water	pH	OM (mg O ₂ /L)	WSM (mg/L)
Well	5.9 ± 0.02	400 ± 12	21.1 ± 0.54
Amalgamation basin	3.82 ± 0.01	1060 ± 98	69.12 ± 1.25
River	4.83 ± 0.03	2190 ± 58	45.61 ± 0.70

OM: organic matter; RH: residual humidity; WSM: Water suspended matters

It appears overall from Table 2 that the waters and soils are all acidic with pH varying from 3.5 in the soil to 4.83 in the water. River water is 2 times more loaded with OM than water from the amalgamation basin and 5 times more loaded with OM than well water.

3.2. Total Mercury Content in Samples

The concentrations of total mercury (THg) in the different samples are presented in Table 3. It appears that THg was identified in water samples as much as in sediment. This is

logical insofar as the operation of amalgamation of gold with mercury is the main source of generation of this metal in both environments. Indeed, whether the amalgamation was carried out on the raw ore (5g Hg/g Au) or on the concentrated ore (1.3 Hg/g Au) as is the case at B éar éOya, the bottom of the pan rejected will retain a significant amount of mercury, which corresponds to Hg not bound to gold (Hg-Au). This is also what justifies the high concentration of Hg in the bottom sediment of the pan (5072 µg/kg), which represents almost double those of the sediments from the amalgamation basin (2549 and 3641 µg/kg).

Table 3. Concentrations of THg and MeHg in samples.

Samples	Description	HgT	MeHg
Sediment (µg/kg)	Bottom of pan	5072 ± 848	165 ± 15

Samples	Description	HgT	MeHg
	Mud of river	386 ± 44	45.6 ± 1.5
	Amalgamation basin	3641 ± 735	165 ± 11
	Agricultural soil	635 ± 3	7.6 ± 0.4
	Edge of amalgamation basin	2549 ± 337	30.6 ± 8.7
	Well	24.6 ± 0.5	15.0 ± 2.4
Water (ng/L)	Amalgamation basin	8451 ± 215	6.1 ± 0.8
	River	28.3 ± 0.7	2.5 ± 0.5
Fish (µg/kg)	<i>Cyprinus carpio</i>	/	45.4 ± 3.9
	<i>Arius africanus</i>	/	90.8 ± 4.6

The Table 3 shows that the river sludge and agricultural field soil are the samples least concentrated in THg. This is justified by the mode of contamination by which they can be affected. Indeed, mercury has the particularity of changing form (liquid or gas) depending on the temperature of the environment. Indeed, a significant quantity of Hg is transferred into the air in its gaseous form by evaporation, during the heating operation of the amalgam (Hg-Au) to recover the sponge gold. The atmospheric transport of Hg in space and over a significant distance depending on the wind current is one of the modes of contamination of agricultural soils by this metal. Table 3 also shows that HgT was identified in the soil of an agricultural field (S_{agri}), located upstream of the amalgamation basin at a concentration of 635 µg/kg, which is 5 times lower than that of amalgamation basin sediment. In the rainy season, the soils are washed by runoff water which carries the Hg to surface waters, including the *Lom* River. Table 3 also shows that the sediments (S_{river}) collected from this river contain 385 µg of THg/kg. This concentration is in the range of THg concentrations (from 90 to 9930 µg/kg) obtained by Niane *et al.*, [7] in sediments collected from gold mining sites in the Kedougou Region in Senegal. This concentration is, however, higher than that of natural soils which are generally around 30 to 150 µg/kg [24, 25].

The results of table 3 show that the concentration of THg recorded in the water of the amalgamation basin is more than 330 times higher than each of the concentrations recorded in river and well water. This is explained to the extent that, after recovering the gold, the miner pours the bottom of the pan either onto the ground or into the amalgamation basin. The water contained in the amalgamation basin, which is already contaminated with Hg, flows at low flow rates to the *Lom* river. The low concentration of THg in river water (28.1 ng/L), which is 300 times lower than the concentration of THg contained in the water of the amalgamation basin, is justified by a dilution phenomenon. Indeed, the water from the amalgamation basin, which is heavily loaded with Hg, will be highly diluted when discharged at low flow rates into the river

downstream. The concentration of THg found in the water of the *Lom* River, is in the range of THg concentrations (from 0.01 to 223 ng/L) similar to those found by Lusilao-Makiese *et al.*, [26] in surface waters at Randfontein in South Africa. On the other hand, it is lower than the range of values (from 300 to 40,700 ng Hg/L) found by Rindi *et al.*, [27] in the waters of the Kuantan Singingi regency river, Riau (Indonesia). The contamination of well water by Hg finds its origin in the mobility of this metal in the soil. Indeed, the Hg present in agricultural soil or in the sludge from amalgamation basins will be present, among other things, in its ionic form (Hg^{2+}). This will therefore make it mobile depending on certain physicochemical parameters of the sediment such as porosity, residual humidity, pH and richness in organic matter (OM). A soil which is, for example, poor in OM, humid, porous and acidic, will promote strong vertical mobility of Hg in its depths with the consequence of strong contamination of its groundwater. This is not the case in this work where the concentration of THg recorded in the well water, which is consumed by the populations of the study site, is lower than the normal value (200 ng/L). The concentration of THg found in the water of the *Lom* River (28.26 ± 0.70 ng/L) is close to that obtained by Oladipo *et al.*, [28] who found 21 ± 4 ng/L in the Manyera River in Nigeria. This concentration is on the other hand lower than that found by Ayiwouo *et al.*, [29] and by Atangana *et al.*, [30] who obtained on the same *Lom* river 4 to 5 µg/L and 0.7 to 10 µg/L, respectively. The difference may be due to the analysis method used, to the sampling point on the site or to the difference in the sampling year.

3.3. Methyl Mercury in Samples

The contamination levels of the different samples by MeHg are also presented in Table 3. These results show higher MeHg concentrations in sediments than in water and fish. The bottom sediments of the pan and the amalgamation basin are also the samples most heavily loaded with this pollutant. MeHg concentrations are not automatically proportional to

HgT concentrations in samples. Indeed, Figure 3a shows for example that agricultural soil contains twice as much THg as mud from the river, which on the contrary contains 5 times more MeHg than agricultural soil. The same observation is made in water samples. Figure 3b shows, for example, that the water from the amalgamation basin contains 330 times more THg than the water from the well. But it contains half as much

MeHg as well water. It is important to note that MeHg was identified in fish at concentrations almost equal to, if not greater than, those in some sediment samples. The concentration of MeHg in *Arius africanus* ($90.8 \pm 4.6 \mu\text{g/kg}$) is for example twice that of river mud ($45.6 \pm 1.5 \mu\text{g/kg}$) and 11 times higher than that of agricultural soil ($7.62 \pm 0.41 \mu\text{g/kg}$).

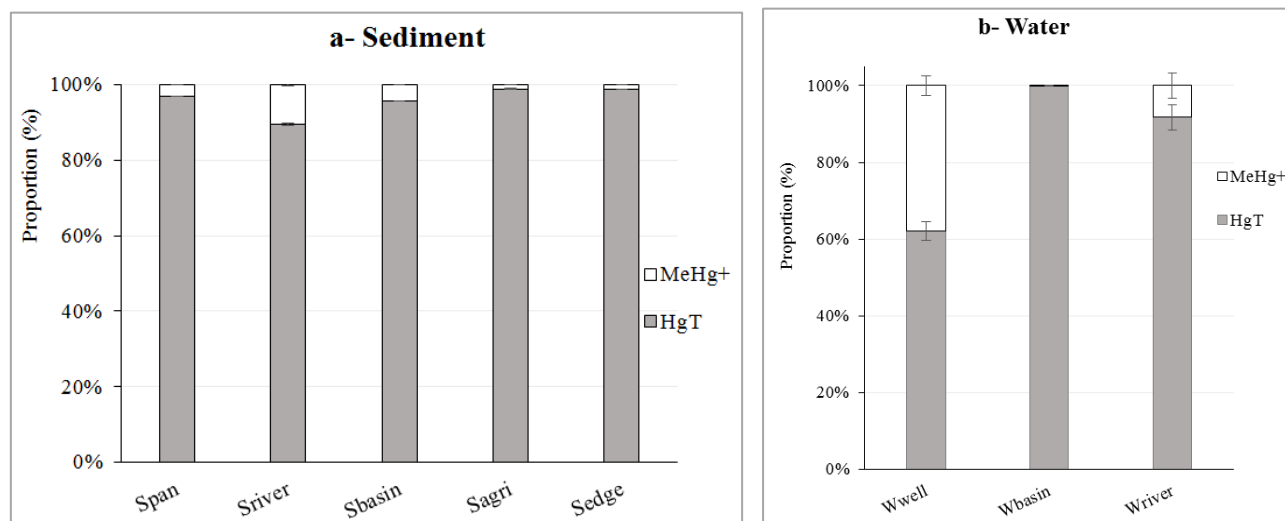


Figure 3. Comparative representation of the presence of HgT and MeHg in sediments (a) and water samples (b).

S_{pan}: bottom of pan; S_{river}: mud of river; S_{basin}: amalgamation basin; S_{agri}: agricultural soil; S_{edge}: Edge of amalgamation basin; W_{well}: water of well; W_{basin}: water of amalgamation basin; W_{river}: water of river

3.3.1. Origin of Methylmercury in Samples

The results in Figure 3 showed that the MeHg concentrations are not automatically proportional to the THg concentrations in the samples. Indeed, the presence of MeHg identified in the different samples is firstly the consequence of a methylation phenomenon before being that of the mobility of MeHg already present in one of the environments. The methylation phenomenon is obviously favored by the presence of Hg in the medium. But it is also dependent on precursors of the microbial activity responsible for methylation such as organic matter, humidity and more or less significant sunlight [31, 32]. The sampling having been carried out in the dry season with daytime sunshine imposing a temperature between 25 and 27 °C, the main limiting factor for the methylation phenomenon becomes the presence of OM [33, 34]. Thus, an environment poor in OM will not promote methylation, despite the presence of a significant quantity of Hg. This justifies why an environment like the water of the amalgamation basin which is heavily loaded with THg (8451 ng/L), contains a concentration of MeHg representing less than 1% of that of THg. On the other hand, the large quantity of OM present in river water favored the production of MeHg, the concentration of which represents 9% of that of THg. The

same observation is made in the sediment samples. Indeed, the bottom of the pan, which is heavily loaded with THg (5072 $\mu\text{g/kg}$) but poor in OM, contains MeHg representing only 3.25% of THg. While river mud, which is less loaded with THg (386 $\mu\text{g/kg}$), but rich in OM, contains MeHg representing 12% of its THg.

The presence of MeHg in the different samples is also due to its mobility in the environment. Indeed, as much as the THg identified in river water comes from the water of the amalgamation basin which is heavily loaded with it, this amalgamation basin water would also be responsible for the contamination of the river water by MeHg. Leaching, runoff and infiltration of rainwater into soil contaminated by MeHg are also phenomena leading to the transfer of MeHg from the soil to river and well water.

3.3.2. Risk of Exposure of the Population of Béjar to MeHg contamination

The main danger of environmental contamination by Hg is the health risk for humans. Human exposure to Hg contamination can be direct or indirect. It can be directly exposed to contamination by Hg through the consumption of so-called drinking water, but contaminated by this metal. In this context, Hg can be found both in its inorganic form and in its methyl-

ated form (MeHg). This is the case for example in the present work where the sample of water from the well which is consumed by the populations of the gold panning site contains MeHg (15 ng/L (table 3)). These populations are therefore exposed to direct contamination by MeHg on a daily basis.

Humans can also be indirectly exposed to contamination by Hg. This route of contamination manifests itself through the phenomena of bioaccumulation, biomagnification and finally bioconcentration of MeHg in the body [35, 17]. In the present work, the most perceptible chain of biological contamination would begin with the accumulation of MeHg in fish caught in the *Lom* River. Indeed, MeHg was identified in fish at concentrations (45 and 90 µg/kg) higher than that identified in river water (table 3) which explains the bioconcentration phenomenon mentioned above. Indeed, Boudou *et al.*, [36] showed that the mass of the fish is strongly correlated to its size, which itself is strongly correlated to the concentration of Hg accumulated in its muscles. This indicates that the mass of the fish sampled (280 and 458 g) is an indicator of the duration of their exposure to MeHg contained in the *Lom* River. MeHg, which has an affinity for fat, accumulates in the biological tissues of the fish during its growth. Once caught, this MeHg contaminated fish will be sold for consumption to the populations of the locality of B éar éoya or to other populations in markets in the Eastern Region of Cameroon. In all cases, this MeHg will ultimately end up in the human body, which can cause diseases. Moreover, the maximum concentration of MeHg ingested through fish consumption recommended by FAO-WHO is 1.6 µg/kg of body weight per week [37]. Chronic exposure to weekly concentrations of MeHg greater than 1.6 µg/kg of body weight results in individual exposure to Minamata disease, destabilization of the nervous system characterized by delayed body development, vision disorders, hearing and brain functions, ataxia, paresthesias (abnormal sensations on the skin) and reduced IQ [38, 39]. It also sets the predicted tolerable concentration of inorganic Hg (iHg) ingested per week at 4 µg/kg of body weight [37]. The concentrations of MeHg recorded in fish caught in the *Lom* River in Cameroon are also indicative of signs of exposure of the populations of the locality of B éar éoya to the worrying Minamata disease. To confirm all these assertions, it would be imperative to evaluate the real level of contamination of the populations of the locality of B éar éoya by Hg in general and MeHg in particular.

4. Conclusion

The aim of this work was to make a preliminary assessment of the risk of contamination of bio-geo-environmental entities of two gold panning sites in the locality of B éar éoya in Cameroon. Overall, it appears that the ASGM developed in B éar éoya favors the contamination of soil and water by Hg in both its inorganic and organic form (MeHg). The environmental entities impacted and identified as sensitive are mainly agricultural soils, well water (consumed by the population) and river water used for fishing. The concentrations of MeHg rec-

ordred both in fish caught in the *Lom* River and in well water, which are foodstuffs inevitably consumed by the populations of the locality of B éar éoya, are risk indicators of their certain exposure to the Minamata disease. To confirm this assertion, it would be imperative to evaluate the real level of contamination of the populations of this locality of B éar éoya by Hg in general and MeHg in particular.

Abbreviations

Hg	Mercury
MeHg	Methylmercury
THg	Total Mercury
iHg	Inorganic Mercury
ASGM	Artisanal and Small-Scale Mining
S _{pan}	Bottom of Pan
S _{river}	Mud of River
S _{basin}	Amalgamation Basin
S _{agri}	Agricultural Soil
S _{edge}	Edge of Amalgamation Basin
W _{well}	Water of Well
W _{basin}	Water of Amalgamation Basin
W _{river}	Water of River
AIEA	International Atomic Energy Agency
KFC	Korean Food Code
GC-ECD	Gas Chromatography Coupled with Electron Capture Detector
LD	Detection Limits
OM	Organic Matter
RH	Residual Humidity
WSM	Water Suspended Matters

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Author Contributions

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Ousmanou Bia: Methodology

In è Estelle Nkenmogne Kamdem: Formal Analysis, Methodology

Eric Noubissie: Conceptualization, Data curation, Investigation, Validation, Visualization, Writing – original draft, Writing – review & editing

Emmanuel Tessier: Formal Analysis, Methodology, Software, Visualization

David Amouroux: Supervision, Validation

Martin Benoit Ngassoum: Conceptualization, Supervision, Validation

Conflicts of Interest

The authors declare conflicts of interest.

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