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Determination of Total Mercury (THg) and Methylmercury (MeHg) in Samples of Crabs (*Callinecte amnicola*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This work was initiated with the aim of evaluating the mercury content in crabs *Callinectes amnicola* at three sites in the Ebrié lagoon. The crabs were taken from the landing sites in the different areas. A total of ninety (90) crabs were graded to obtain a representative sample of all landings. The analyzes focused on the levels of total mercury and methyl mercury in the *Callinectes amnicola* crabs. The analysis of variance showed that the site with the highest mercury content is the most

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urban site, namely the Boulay Island site in Abobodoumé. The results obtained showed that the total mercury content varies according to the mass and size of the crab. Furthermore, mercury, at all the sites of our study presents concentrations well below the threshold values set by the WHO and the EU. The determination of mercury levels in crabs from different landing sites in the Ebrié lagoon makes it possible to assess the risks of contamination of the food chain, incurred by the top predator at the end of the chain, which is human beings, the main consumer of seafood products.

Keywords: Total mercury (THg); methyl mercury (MeHg); bioacumulation; ebrie lagoon; Callinectes amnicola.

1. INTRODUCTION

In the countries of the tropical regions of West Africa, more than 90% of the effluents resulting from the processes of production and use of chemical products flow into the receiving environment without treatment. Rivers, lakes, lagoons and seas are subject to pollution of various kinds from these effluents [1]. In recent years, in Côte d'Ivoire as everywhere in Africa, gold panning activities have intensified. Political authorities and the scientific community are increasingly interested in water pollution in the context of climate change.

The lagoons which contain important aquatic resources and which play a buffer role between marine waters are subject to heavy chemical pollution. The water becomes cloudy, dark and gives off a foul odor. This pollution comes mainly from mining effluents, chemicals discharged by factories, mechanical garages, sewers and septic tanks, fertilizer residues from agricultural areas, domestic water and household waste.

Recent studies have shown the presence of mercury (Hg) in sediments [2] and fish in the Ebrié lagoon [3]. This lagoon contamination by mercury could affect local populations, feeding on lagoon aquatic resources.

The United Nations Environment Program took resolutions under the Minamata Convention in October 2013 on mercury to protect human health and the environment against the harmful effects of mercury [4].

Mercury and alkyl derivatives have a cumulative and persistent character in aquatic organisms. This article focuses on crab, the staple diet of many local populations, whose contamination can lead to serious public health problems [5,6]. The majority of crab species are predatory and/or scavengers. In general, crabs play an essential biological role in the ecosystem of the Ebrié lagoon and are found at the level of the muddy bottoms in the mangrove areas and the mouths of rivers [7].

This work aims to determine the level of mercury and methyl mercury in crabs from the waters of the Ebrié lagoon using the direct mercury analysis technique of DMA-80.

2. MATERIALS AND METHODS

2.1 Study Zone

The study is located in part of the Ebrié lagoon system of Côte d'Ivoire with an area of 566 km^2 and stretches over 140 km along the Gulf of Guinea between 3°40' and 4°50' at latitude 5°20 N. It has many bays and shallow channels (between 4 and 6 m approximately) sometimes leading to "pits" 20 m deep [8] With a volume of approximately 2.5 x 10^9 m^3, the lagoon plays an important economic role in West Africa, with many functions for port traffic, tourism, sanitation and fishing. The parts of the Ebrié lagoon concerned by this study are:

- N'Djem, this sampling site located in a maritime area west of the Ebrié lagoon (Fig. 1) where the importance of agricultural activities and the degree of fish mortality are recorded in May 2013 [9].
- Ile Boulay this sampling site is located opposite the port of Abidjan and the lagoon station of abobodoumé (central west basin) (Fig. 1) where lagoon transport is practiced with transport boats which release all day long motor oils as well as the fumes they give off, on this site there are also agricultural and tourist activities [3].
- Ile Désirée, a site located between the municipality of Cocody M'badon and Koumassi (Fig. 1) influenced by runoff and domestic water from these places, the pressure of industrial, urban and agricultural activities play a major role in the water pollution of this site location, landing stage.

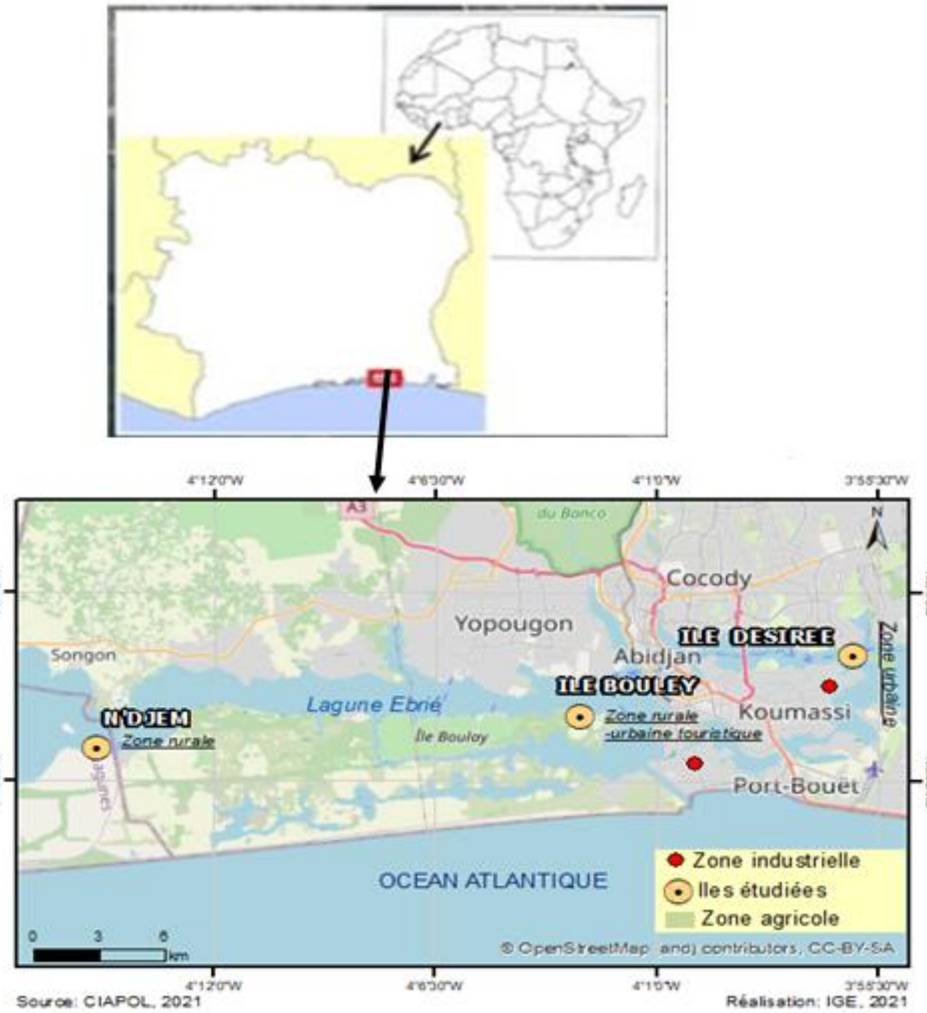

Fig. 1. Location of study sites (Source: Ciapol 2021)

2.2 Materials

2.2.1 DMA-80 direct mercury analyzer

The mercury analyzer (DMA-80) is an electrothermal Atomic Absorption Spectrophotometer. It is based on the absorption of a specific wavelength (λmax = 253.7 nm) of mercury.

2.2.2 Equipment and chemicals

The water used for the preparation of all solutions is ultra-pure water. Hydrochloric acid (HCl) (30%, Suprapur) from Merck, Darmstadt, Germany was used for the hydrolysis of the studied samples. A solution of 0.002 M sodium thiosulfate (Suprapur, Merck) prepared in 12% (w/v) anhydrous sodium sulfate and 0.8% (w/v) sodium acetate (Suprapur, Merck) was used for back-extraction.

A stock solution of inorganic mercury standard 1000 mg/kg in 12% (v/v) nitric acid (Trace Cert, Fluka, Steinheim, Germany) is used for the preparation of the daughter solutions. Working solutions were prepared by diluting standard solutions of 1% (v/v) nitric acid (40%, SuprapurMerck), 0.1% (v/v) HCl (Suprapur, Merck) and 0.2 % potassium dichromate (analytical grade, 10% (w/v), Merck). Calibration solutions in the range of 5 to 200 g/L were prepared daily by dilution as working solution in 0.002 M thiosulfate solution.

2.2.3 Certified reference material

The reference material used in the verification of this method is IAEA-436 whose certified value in methylmercury is 3.62 mg/Kg. The results are recorded in Table 1. Three extraction and analysis tests with DMA 80 were carried out. The respective results are 3.69 mg/Kg, 3.68 mg/Kg and 3.59 mg/Kg. The calculated average concentration is 3.65 mg/Kg with a standard deviation of 1.68 and a coefficient of variation of 0.46.

2.3 Methods

2.3.1 Sampling

The crab samples (Fig. 2) were collected directly from the sites of N'Djem in Jacqueville, Ile Boulay in Abobodoumé and Ile Désirée in Koumassi (Fig. 1) during the period from January to April. At the same time, water salinity, temperature and conductivity were measured using a WTW multi 3430 brand multiparameter and a HANNA Instruments type HI 2211 Ph/ORP Meter brand pH meter.

Thirty (30) batches of crabs were sampled per site. Each batch consists of 3 individuals of the same size, divided into males and females. A total of 90 batches were counted (Table 2). The crabs are cleaned with distilled water, ground fresh, stored in plastic bottles and kept on ice in the refrigerator.

2.3.2 Crushing crabs

In the laboratory, the crab samples were thawed, cleaned while trying to handle as little as possible to avoid possible contamination. The crabs were measured and weighed before being crushed. The grinding was done using a mortar and pestle porcelain. Thus, the pulp is collected for chemical analysis. With the DMA-80 method, samples do not require any pretreatment (digestion) prior to analysis for total mercury. On the other hand, for the quantification of methyl mercury, a specific extraction must first be carried out in order to stabilize the methyl mercury.

Table 1. Concentration of mercury and methylmercury in the reference material IAEA – 436

Sample	Extract 1 (mg/Kg)	Extract 2 (mg/Kg)	Extract 3 (mg/Kg)	Mean (mg/Kg)	Standard deviation	Coefficient of variation	Certified value (mg/Kg)
IAEA - 436	3 ,69	3,68	3,59	3,65	1,68	0,46	**3,62**

Fig. 2. Crab *Callinectes amnicola*

Table 2. Summary tables of crab samples taken

Site	GPS coordinates	Batches / of males	batches / females	Total (batches)	Total Crabs (3individuals /lot)
Ndjem	5°16'26'' N 4°14'38'' W	15	15	30	90
Iles boulay	5°17'52'' N 4°02'33'' W	15	15	30	90
Iles désirée	5°19'09'' N 3°56'07'' W	15	15	30	90

2.4 Analysis of Total Mercury (HgT)

A mass of the fresh sample between 0.03 and 0.04 g is weighed and analyzed directly DMA-80.

2.5 Extraction and Analysis of Methyl Mercury

A quantity between 0.6g and 0.8g of each sample is weighed using a balance precision ± 0.1 mg then introduced into a 100 mL beaker. With a pipette, 5 mg of 25% hydrochloric acid is added to the contents of the beaker. The mixture is shaken vigorously for at least 30 s. Then, 15 mL of toluene are added. The 15 ml of the content is transferred into a centrifuge tube. After centrifugation for 15 min, part of the phase above, which contains total mercury, is recovered and then transferred to another 15 mL centrifuge tube previously containing 6 mL of sodium thiosulfate solution. The solution obtained is brought again to centrifugation for 15 minutes. The organic phase below forming a MeHg + sodium thiosulfate complex (6 mL) is collected in a 10 mL tube (final extract) and stored at 4°C [10].

Two hundred (200µL) of the final organic extract is taken, weighed and analyzed directly with DMA-80.

2.5.1 Calculation methods

The volume of toluene used (V0) is different from the volume of toluene (V1) used to extract the methylmercury therefore a correction factor (K) was necessary.

$$\boldsymbol{K} = \frac{\boldsymbol{V1}}{\boldsymbol{V0}} \quad (1)$$

V_0: initial volume of toluene
V_1: final volume of toluene

The concentration of methylmercury is then calculated by the following relationship:

$$\mathbf{C} = \frac{V*C1}{m*K} \quad (2)$$

C: concentration of methylmercury in the sample (µg/kg)
m: mass of sample taken (g)
C_1: concentration read on the DMA-80 (µg/L)
V: total volume of sodium thiosulfate solution (ml)
K: correction factor

2.5.2 Determination of Organic Matter (OM)

The organic matter (OM) was obtained following a combustion reaction of the matter, by bringing a defined mass (m1) of the sample to a temperature of 700°C then the sample is recovered and weighed again to obtain a new mass (m^2). The organic matter rate is obtained by taking the following difference :

$$\boldsymbol{MO} = \frac{m1-m2}{m1} * \mathbf{100} \quad (3)$$

m1: mass of the matrix before combustion
m2: mass of the matrix after combustion
MO: organic matter

3. RESULTS

For a better exploitation of the results, we used Excel and Statistica software for the processing of raw data.

3.1 Physicochemical Characteristics of the Environment

The results of the physico-chemical analyzes of the waters studied are shown in Table 3 and show a fluctuation of the parameters from one site to another (pH, EC, T, salinity). The measurement of these physicochemical properties allows an initial estimation of the quality of the environment.

Table 3. Some physico-chemical parameters of lagoon water

Parametres / Station	pH	CE (mS/Cm)	Temperature (°C)	Salinity (‰)
Jacques-ville (N'Djem)	7.43 ± 0.3	123.80 ± 2	28.30 ± 0.5	9.70 ± 1
Ile Boulay	8.00 ± 0.3	21.00 ± 2	29.00 ± 0.5	12.60 ± 1
Koumassi (Désired island)	7.42 ± 0.3	30.30 ± 2	28.00 ± 0.5	18.80 ± 1

3.1.1 Hydrogen potential (pH)

According to the pH determination values, it can be seen that the pH of the water at the three sites is weakly basic (7.42 < pH < 8.00). The pH varies slightly from one site to another. Value of pH is closely related to salinity, but this relationship is influenced by major ions [11], so at sites with high electrical conductivity (EC) this relationship is disturbed.

3.1.2 Electrical Conductivity (EC)

The conductivity is a function of the concentration of soluble salts, that is to say the concentration of chlorides, sulphates, carbonates and alkali and alkaline earth bicarbonates, nitrates and phosphates [12]. It is a numerical expression of the ability of a solution to conduct electric current. According to the table, the lagoon in N'Djem conducts electricity better and that of Abobodoumé (Ile Boulay) conducts relatively little.

3.1.3 Temperature

The extreme temperatures of the waters of the Ebrié lagoon are 25.5°C and 34°C [12], our different temperatures measured during this study fall within this range (28°C and 29°C).

3.1.4 Salinity

The salinity varies according to the study sites on the site of Ile Jacques Ville N'djem, we note the lowest salinity of 9.7 ± 1 and the maximum values are observed on the site of Koumassi Ile Désirée nous 12, 6 ± 1 and on the site of Koumassi on the desired island.4.3. Concentration of total mercury, methyl mercury and physical characteristics of crabs.

Tables 4a, 4b and 4c clearly show the concentrations of methylmercury (MeHg) and total mercury (HgT) as well as the rate of organic matter (OM), these tables also indicate the physical characteristics of the crabs such as the width, the length and mass.

Statistical processing was applied using Excel software on the raw data to allow better exploitation.

3.2 Weight-Height Relationship

The relationship was established from the 45 pairs (g, cm) of calculated values. Figs. 3 and 4 were made from the mass and length of each individual. The mass varies between 20 and 120 g with a length between 3 and 6 cm It is observed that the mass increases with the length both in males and in females. Which is natural given that it is the same species and that there is no morphological anomaly.

The equation of the trend line obtained seems to reflect the fact that the animal is growing faster than it is growing in size. This reality growth is explained by the growth of the claws (secondary sexual character) which accelerates after sexual maturity.

3.3 Variation of OM According to the Mass of Male Crabs

The rate of organic matter fluctuates and does not exceed 2%. Figs. 5 and 6 showed randomly distributed dots. This means that organic matter is not related to the weight of the species although it is made up of part of the biomass.

3.4 Distribution of HgT and MeHg in crab *Callinectes amnicola* Samples

The distribution of mercury (Hg) and methylmercury (MeHg), was also studied according to the sex and the mass of the crabs (Figs. 6; 7 and 8).

3.5 Comparison of Data to International Standards

The distribution of total mercury and methylmercury (Fig. 10) in female and male crabs was compared to international standards. In our case, we used the WHO standards, namely 2000 µg/Kg for total mercury and 1320 µg/Kg for methyl mercury and the European standards, 500 µg/Kg for total mercury and 330 µg/Kg for methyl mercury, to show that the mercury concentration values found in the crabs were below the tolerated threshold values.

Table 4a. Results of measurements taken on crabs (*Callinectes amnicola*) from the Jacques Ville site (N'Djem)

No.	Males						Female					
	Mass (g)	**Width (cm)**	**Length (cm)**	**MO (%)**	**HgT (µg/Kg)**	**MeHg (µg/Kg)**	**Masse (g)**	**Width (cm)**	**Length (cm)**	**MO (%)**	**THg (µg/Kg)**	**MeHg (µg/Kg)**
1	38.93±0.1	8.2±0.1	4.2±0.1	0.79	19.23±0.21	6.75±0.04	18.57±0.1	6.6±0.1	3.4±0.1	1.29	21.56±0.22	2.45±0.3
2	39.89±0.1	8±0.1	4.3±0.1	0.86	39.43±0.15	6.26±0.06	21.95±0.1	6.8±0.1	3.7±0.1	0.52	25.37±0.32	8.38±0.04
3	46.41±0.1	9.7±0.1	4.6±0.1	0.52	24.65±0.13	6.50±0.02	24.40±0.1	7.3±0.1	4±0.1	0.65	32.43±0.24	4.08±0.05
4	56.69±0.1	8.9±0.1	5±0.1	0.97	17.88±0.14	8.03±0.01	37.32±0.1	7.9±0.1	4.1±0.1	0.51	35.79±0.42	7.88±0.05
5	66.54±0.1	10.9±0.1	5.4±0.1	1.35	46.35±0.21	7.41±0.07	39.71±0.1	8.5±0.1	4.4±0.1	0.29	17.49±0.21	3.42±0.11
6	68.24±0.1	10.6±0.1	5.8±0.1	1.15	37.01±0.23	6.67±0.03	43.72±0.1	9.3±0.1	4.4±0.1	0.56	26.69±0.41	11.48±0.12
7	75.08±0.1	10.8±0.1	5.5±0.1	1.27	27.65±0.41	11.18±0.11	44.62±0.1	8.6±0.1	4.2±0.1	0.57	46.33±0.31	10.26±0.11
8	105.31±0.1	12.3±0.1	5.9±0.1	0.27	57.56±0.45	7.76±0.21	47.84±0.1	8.9±0.1	4.9±0.1	0.675	43.60±0.33	16.50±0.14
9	111.80±0.1	12.4±0.1	6.3±0.1	0.59	38.86±0.61	10.95±0.18	50.89±0.1	9±0.1	4.7±0.1	0.61	63.89±0.19	32.29±0.13
10	124.74±0.1	12.5±0.1	6.7±0.1	0.31	49.02±0.31	8.77±0.21	54.54±0.1	9.6±0.1	5.1±0.1	0.64	31.47±0.17	7.70±0.20
11	130.10±0.1	12.3±0.1	5.9±0.1	1.00	101.72±0.09	10.21±0.31	56.31±0.1	9.7±0.1	4.9±0.1	0.76	24.46±0.13	14.20±0.15
12	132.76±0.1	13.5±0.01	7.5±0.01	0.73	51.36±0.04	7.38±0.22	59.69±0.1	12±0.1	5.3±0.1	1.63	98.71±0.31	11.63±0.09
13	139.86±0.1	13.2±0.1	7±0.1	1.42	58.86±0.07	6.57±0.11	60.97±0.1	9.5±0.1	4.9±0.1	0.72	44.21±0.15	14.35±0.14
14	141.08±0.1	14.2±0.1	7.2±0.1	0.68	55.37±0.11	12.44±0.21	102.00±0.1	12.3±0.1	5.5±0.1	0.46	31.89±0.31	20.15±0.18
15	167.42±0.1	13.7±0.1	6.8±0.1	1.29	61.04±0.31	11.98±0.22	105.53±0.1	11.8±0.1	5.1±0.1	0.93	33.77±0.11	22.85±0.21
Min	38.93±0.1	8±0.1	4.2±0.1	0.27	17.88±0.14	6.26±0.06	18.57±0.1	6.6±0.1	3.4±0.1	0.29	17.49±0.21	2.45±0.13
Max	167.42±0.1	14.2±0.1	7.5±0.1	1.42	101.72±0.09	12.44±0.21	105.53±0.1	12.3±0.1	5.5±0.1	1.63	98.71±0.31	32.29±0.13
Mean	96.32±0.1	11.41±0.1	5.87±0.1	0.88	45.73±0.26	8.59±0.13	51.20±0.1	9.19±0.1	4.57±0.1	0.72	38.51±0.11	12.51±0.18
S D	42.44	2.01	1.05	0.37	21.09	2.17	25.09	1.76	0.61	0.34	20.33	8.03
C V	44.06	17.65	17.87	41.85	46.12	25.28	48.99	19.19	13.29	46.93	52.79	64.17

Table 4b. Results of measurements taken on crabs (*Callinectes amnicola*) from the Koumassi site (desired island)

No.	Males						Female					
	Mass (g)	Width (cm)	Length (cm)	MO (%)	Total mercury (μg/Kg)	Methyl mercury (μg/Kg)	Masse(g)	Length (cm)	Length (cm)	MO (%)	Total mercury (μg/Kg)	Methyl mercury (μg/Kg)
1	25.75±0.1	6.5±0.1	3±0.1	1.04	81.27±0.11	6.29±0.12	22.34±0.1	6.4±0.1	3.2±0.1	1.17	28.49±0.33	4.64±0.01
2	26.83±0.1	6.6±0.1	3.1±0.1	0.82	57.89±0.31	8.89±0.34	25.17±0.1	6.7±0.1	3.4±0.1	1.40	34.42±0.22	8.35±0.04
3	28.17±0.1	6.8±0.1	3.1±0.1	0.63	62.73±0.41	8.96±0.21	26.74±0.1	7.3±0.1	3.5±0.1	0.96	17.90±0.01	6.18±0.12
4	30.25±0.1	7.2±0.1	3.2±0.1	1.07	17.58±0.21	5.15±0.31	27.18±0.1	6.9±0.1	3.5±0.1	1.25	36.96±0.31	5.34±0.11
5	30.48±0.1	7.3±0.1	3.3±0.1	0.93	28.97±0.23	1.32±0.41	28.35±0.1	7±0.1	3.6±0.1	0.54	25.81±0.08	5.94±0.31
6	34.95±0.1	7.3±0.1	3.4±0.1	0.61	28.46±0.31	5.05±0.31	29.33±0.1	7.5±0.1	3.6±0.1	0.79	18.70±0.25	5.89±0.14
7	40.15±0.1	8±0.1	4.1±0.1	0.50	59.09±0.24	9.87±0.01	49.83±0.1	8.9±0.1	4.5±0.1	0.42	51.91±0.03	13.90±0.26
8	45.88±0.1	8.7±0.1	4.2±0.1	1.23	20.90±0.41	4.56±0.41	53.09±0.1	9.3±0.1	4.7±0.1	0.29	43.60±0.04	6.51±0.01
9	48.31±0.1	8.9±0.1	4.4±0.1	1.10	87.84±0.61	12.50±0.12	60.24±0.1	9.7±0.1	4.9±0.1	1.07	49.46±0.36	10.42±0.41
10	59.15±0.1	10.2±0.1	4.4±0.1	0.46	117.01±0.32	10.38±0.13	61.54±0.1	9.7±0.1	5±0.1	1.22	27.68±0.42	12.34±0.31
11	71.49±0.1	11.5±0.1	5.3±0.1	0.69	49.01±0.41	8.91±0.21	62.61±0.1	10.1±0.1	5.2±0.1	0.36	43.22±0.06	5.86±0.01
12	73.33±0.1	11.1±0.1	5.2±0.1	1.71	48.73±0.61	11.46±0.31	64.64±0.1	9.6±0.1	5.5±0.1	0.74	52.80±0.01	16.53±0.05
13	88.52±0.1	11.9±0.1	6.1±0.01	1.32	46.89±0.41	13.46±0.33	75.52±0.1	9.9±0.1	5.4±0.1	0.32	112.61±0.6	12.19±0.24
14	93.13±0.1	12±0.01	6.2±0.1	1.31	72.11±0.31	14.70±0.17	83.19±0.1	10.6±0.1	5.1±0.1	0.51	71.14±0.04	19.61±0.21
15	108.89±0.1	13±0.1	6.3±0.1	1.00	28.99±0.51	7.19±0.32	83.59±0.1	10.4±0.1	5.7±0.1	1.76	31.31±0.23	6.64±0.04
Min	25.75±0.1	6.5±0.1	3±0.1	0.46	17.58±0.21	1.32±0.41	22.34±0.1	6.4±0.1	3.2±0.1	0.29	17.90±0.01	4.64±0.01
Max	108.88±0.1	13.0±0.1	6.3±0.1	1.71	117.01±0.32	14.70±0.17	83.59±0.1	10.6±0.1	5.7±0.1	1.76	112.61±0.6	19.61±0.21
Mean	53.68±0.1	9.13±0.1	4.35±0.1	0.96	53.83±0.15	8.58±0.21	50.22±0.1	8.67±0.1	4.45±0.1	0.85	43.07±0.21	9.35±0.03
S D	27.27	2.27	1.20	0.35	27.69	3.69	22.10	1.51	0.89	0.45	23.99	4.60
C V	50.80	24.87	27.64	36.40	51.43	42.99	44.01	17.42	19.94	52.53	55.72	49.15

Table 4c. Results of measurements taken on crabs (*Callinectes amnicola*) from the Iles Boulay site

No.	Males						Female					
	Mass (g)	Width (cm)	Length (cm)	MO (%)	THg (µg/Kg)	MeHg (µg/Kg)	Masse (g)	Width (cm)	Length (cm)	MO (%)	THg (µg/Kg)	MeHg (µg/Kg)
1	40.45±0.1	9.5±0.1	4.8±0.1	0.79	77.27±0.31	10.15±0.05	20.68±0.1	7.6±0.1	3.5±0.1	1.29	40.26±0.23	11.69±0.05
2	48.09±0.1	9.8±0.1	5.1±0.1	0.86	46.39±0.21	10.64±0.03	22.98±0.1	7.4±0.1	3.4±0.1	0.52	70.49±0.34	13.07±0.04
3	53.98±0.1	11±0.1	5.6±0.1	0.52	33.67±0.11	11.41±0.04	30.02±0.1	8.4±0.1	3.9±0.1	0.65	73.32±0.21	7.27±0.02
4	55.87±0.1	10.4±0.1	5.5±0.1	0.97	39.47±0.11	11.95±0.02	30.55±0.1	9.9±0.1	4.2±0.1	0.51	36.60±0.11	4.86±0.06
5	56.01±0.1	10.5±0.1	5.5±0.1	1.35	106.50±0.51	14.06±0.06	33.64±0.1	8.1±0.1	3.9±0.1	0.29	94.43±0.36	17.47±0.08
6	58.94±0.1	10.6±0.1	5.7±0.1	1.15	55.08±0.21	15.11±0.04	40.33±0.1	9.8±0.1	4.2±0.1	0.56	116.41±0.72	11.67±0.02
7	61.45±0.1	11.2±0.1	5.5±0.1	1.27	62.23±0.31	18.54±0.08	41.64±0.1	10.1±0.1	4.9±0.1	0.57	65.62±0.41	11.68±0.04
8	61.65±0.1	11.1±0.1	5.8±0.1	0.27	86.18±0.41	16.12±0.05	43.70±0.1	10.9±0.1	5.1±0.1	0.67	153.53±0.81	25.40±0.06
9	69.53±0.1	11.4±0.1	5.6±0.1	0.59	111.01±0.5	15.75±0.03	44.96±0.1	9.2±0.1	4.1±0.1	0.61	42.11±0.61	16.57±0.05
10	71.07±0.1	11.6±0.1	6.2±0.1	0.31	75.91±0.18	15.59±0.04	47.11±0.1	10±0.1	4.3±0.1	0.64	161.74±0.84	14.15±0.07
11	71.90±0.1	11±0.1	4.9±0.1	1.0	51.47±0.19	20.72±0.08	49.06±0.1	10.7±0.1	5.2±0.1	0.76	137.09±0.36	24.52±0.08
12	73.84±0.1	12.1±0.1	5.9±0.1	0.72	66.30±0.21	14.65±0.03	58.26±0.1	10.4±0.1	4.4±0.1	1.63	115.71±0.45	9.66±0.06
13	82.44±0.1	14.5±0.1	7.6±0.1	1.42	91.44±0.48	12.97±0.07	61.11±0.1	10±0.1	4.5±0.1	0.72	96.55±0.26	21.15±0.14
14	89.55±0.1	12.9±0.1	6±0.1	0.68	61.23±0.33	8.20±0.02	61.61±0.1	10.5±0.1	5.1±0.1	0.46	102.32±0.41	20.64±0.1
15	110.25±0.1	13±0.1	6.5±0.1	1.29	59.17±0.24	18.83±0.05	61.77±0.1	10.2±0.1	4.9±0.1	0.93	91.49±0.15	16.04±0.05
Min	40.45±0.1	9.5±0.1	4.8±0.1	0.27	33.67±0.11	8.20±0.02	20.68±0.1	7.4±0.1	3.4±0.1	0.29	36.60±0.11	4.86±0.06
Max	110.25±0.1	14.5±0.1	7.6±0.1	1.42	106.01±0.51	20.72±0.08	61.77±0.1	10.9±0.1	5.2±0.1	1.63	161.74±0.84	25.40±0.06
Mean	67.0±0.1	11.37±0.1	5.75±0.1	0.88	68.22±0.29	14.31±0.07	43.16±0.1	9.55±0.1	4.37±0.1	0.72	93.18±0.76	15.06±0.07
S D	17.55	1.31	0.68	0.37	23.02	3.49	13.72	1.136	0.57	0.34	39.36	6.01
C V	26.19	11.51	11.91	41.85	33.74	24.42	31.79	11.90	13.12	46.93	42.25	39.94

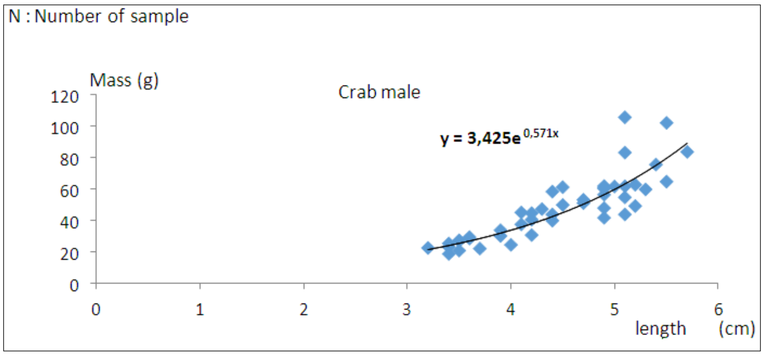

Fig. 3. Evolution of the mass according to the length of the male crabs

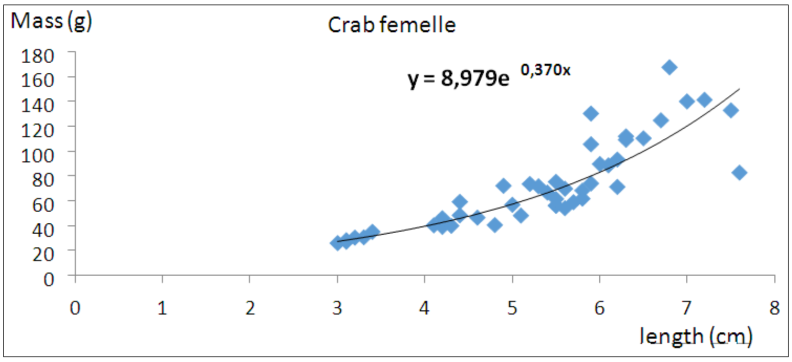

Fig. 4. Evolution of the mass according to the length of the female crabs

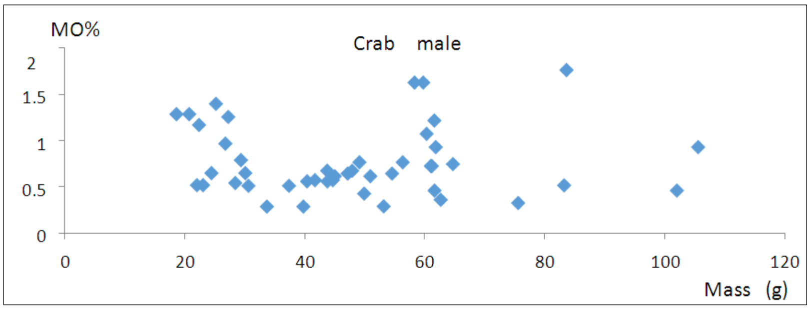

Fig. 5. Variation of organic matter according to the mass of male crabs (*Callinectes amnicola*)

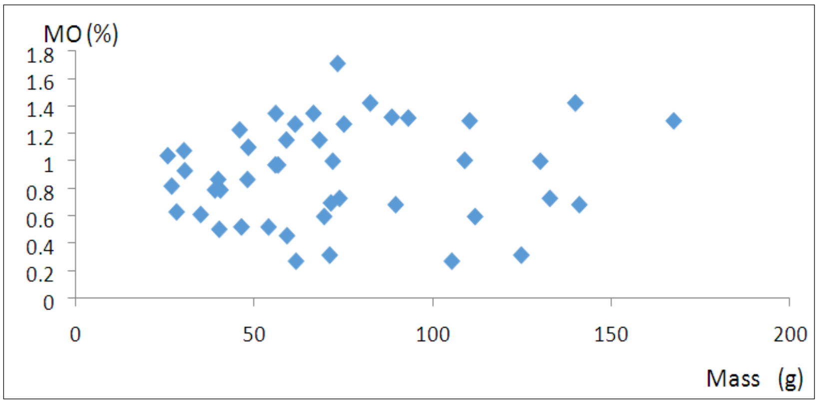

Fig. 6. Evolution of organic matter according to the mass of female crabs

Fig. 7. Evolution curves of mercury as a function of mass in male and female crab (*Callinectes amnicola*) from N'Djem

Fig. 8. Evolution curves of mercury as a function of mass in female crab (*Callinectes amnicola*) from Boulay Island

Fig. 9. Evolution curves of mercury as a function of mass in female crab (*Callinectes amnicola*) from Désirée Island

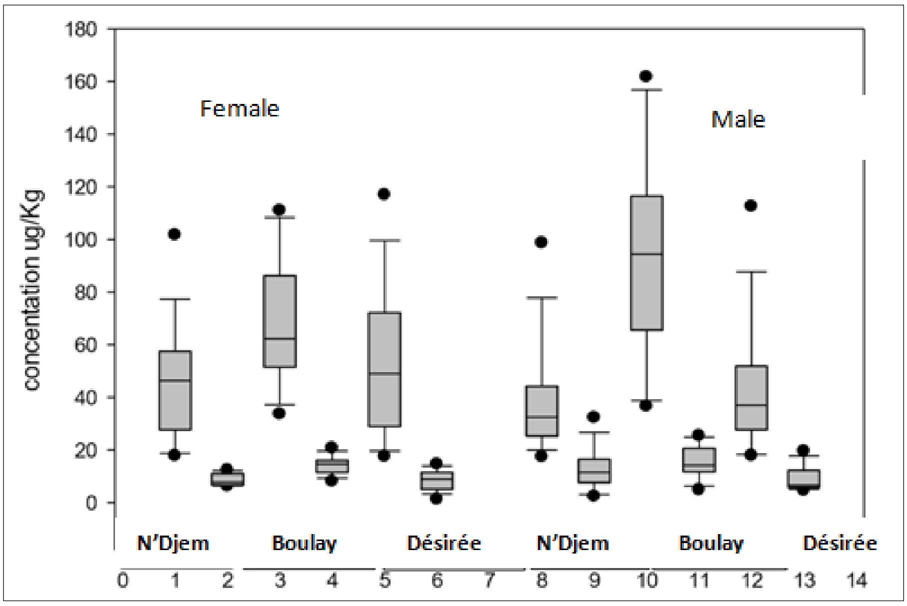

Fig. 10. Distribution of total mercury and methyl mercury in the samples 5

4. DISCUSSION

The lagoon system is a transfer zone for pollutants in aquatic organisms [13]. Through the curves of evolution of total mercury and methyl mercury, it generally appears on different sites, the concentrations of HgT and MeHg fluctuate according to the mass. A trend with a slight increase is observed with total mercury. The MeHg remains low despite the increase in masses. Indeed, mercury having a cumulative behavior during life through food [14-16], it is certain that large or old organisms contain relatively more mercury than small or old species. youth.

The concentrations obtained with the IAEA - 436 reference material confirmed that the extraction method gives good yields (Table 2). This method was used by Sabine et al., during her work and she also obtained good performance [10].

It is noted that the concentrations of total mercury are higher than those of methyl mercury. These results show that HgT incorporates all forms of mercury including methylmercury itself. It appears that the salinity is significant and being between 12.6% and 18.8%) can influence the rate of methylation.

Salts, mainly chloride ions in aqueous media, play an important role in the direction of the methylation-demethylation balance that takes place within organisms. The rate of methylation in salt water is relatively low compared to water with almost zero salinity [17]. In addition, increasing the pH induces the formation of precipitated species that can limit the solubility and bioavailability of ionic forms [18].

The results show that the areas under pressure from industrial and urban activities are the most contaminated areas. It can be seen that the mercury level in the Boulay Island area is higher with an average total mercury of 68.22 µg/Kg for female crabs and 93.18 µg/Kg for male crabs and an average in methylmercury of 14.31 µg/Kg for female crabs and 15.06 µg/Kg for male crabs.

The organic matter found during the analyzes is relatively low, on the other hand, it could favor the phenomena of mercury adsorption in the crab tissues [19]. Organic matter also participates in the complexation of metals [19] in living organisms. Organic matter therefore contributes to the bioavailability of mercury in organisms. Indeed, it is the area closest to the city of Abidjan, the most urban with great human activity. There are reports in this area of intense attiéké-producing activities that generate quantities of sludge and puddles of cassava waste water that could contain mercury.

The N'Djem area is the least contaminated with an average total mercury of 45.73 µg/Kg for female crabs and 38.51 µg/Kg for male crabs and an average methylmercury of 8.59 µg/Kg for female crabs and 12.51 µg/Kg for male crabs. This is explained by the distance from industrial and port activities.

In the Ile Désirée area, the maximum averages are 54.23 µg/Kg total mercury and 9.36 µg/Kg methylmercury. The desired island is an area influenced by the urban activities of Koumassi and Cocody M'badon without forgetting the agricultural activities which could participate in the anthropogenic contamination of this area.

The spatial distribution shows on each site, the maximum concentrations measured are lower than the international threshold values (WHO and EU). Given the bio-accumulative nature of mercury in organs, these low values should not exclude permanent monitoring given that regular consumption of crabs by a population.

5. CONCLUSION

In conclusion, we can retain that this study made it possible to show that the crabs which constitute an important food in households of the town of Abidjan do not escape the character accumulator of mercury and methyl mercury. this study found low concentrations of mercury and methylmercury and higher concentrations in urban areas than in rural areas.

The analysis of mercury and methylmercury according to the mass of the crabs showed that the accumulation is significant in the largest masses.

Admittedly, the study reveals relatively low levels of concentrations in crabs below international standards in the study areas. The severity of the impact must be interpreted with regard to the reference toxicity values by assessing the health risks on the basis of mathematical models on the local populations. Due to the bioaccumulation of mercury, it is still necessary to continue health control programs and surveillance of the various aquatic environments.

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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