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Study of heavy metals in hospital effluents in the city of Abidjan (Côte d'Ivoire) in 2020 during the COVID-19 pandemic

CISSE Souleymane[1], ASSOHOIUN Egomli Stanislas[2, 3], AMON Lydie[4], COULIBALY-KALPY Julien[4], Kouamé KINTOSSOU Ambroise[1], GUEDE Cataud Marius[5], AKA Ayebe Kouadio Edwige[1], NGUESSAN Felix Kouassi[1], COULIBALY Litio Sinali[1], and DOSSO Mireille[6]

1 Department of the Biological Resource Center, Pasteur Institute of Côte d'Ivoire
2 Laboratory of Microbial Genomics and Metagenomics, Pasteur Institute of Côte d'Ivoire
3 Laboratory of Environmental Sciences and Technology, Jean Lorougnon Guédé University of Daloa, Côte d'Ivoire
4 Department of Environment and Health, Pasteur Institute of Côte d'Ivoire
5 Department of Epidemiology and Clinical Research, Pasteur Institute of Côte d'Ivoire
6 Direction, Pasteur Institute of Côte d'Ivoire

Abstract:
Background: *The COVID-19 pandemic was marked by an overproduction of biomedical waste with a 15%-18% increase in wastewater generation including hospital effluent. Untreated hospital wastewater discharged into the environment results in high concentrations of organic matter, pathogens and emerging contaminants such as heavy metals. The problem of liquid discharges from hospitals is a growing international concern because of the potential risks associated with the substances contained and the large volumes of wastewater discharged. In Côte d'Ivoire, the level of involvement of hospitals in heavy metal pollution of the environment is poorly documented. Very few articles are devoted to it, especially in situations of large-scale epidemics.*
Materials and methods: *In order to evaluate the concentrations of silver, copper and mercury in hospital effluents of the city of Abidjan in relation to the standards of wastewater discharge in the city and to assess the evolution of the levels of these heavy metals with the health crisis, we took 112 samples of hospital wastewater collected as part of a program to study pathogens in wastewater underway at the Pasteur Institute of Cote d'Ivoire were analyzed by inductively coupled plasma spectroscopy and the data obtained were compared using statistical tests*
Results: *This study indicates variable levels of silver, copper and mercury in the effluents with respective average concentrations of 0.108 mg/l (±0.145); 0.016 mg/l (±0.018) 0.056 mg/l (±0.025) which remain within the limits authorized by the standards. However, we note a variable impact of the COVID-19 health crisis on the concentrations of these TMEs in the effluents with an increase in silver and a decrease in mercury. In contrast, the pandemic appears to have no effect on copper levels.*
Conclusion: *Further studies of discharged hospital wastewater and receiving ecosystems in Abidjan are needed to establish more comprehensively the contamination levels of the main toxic metals.*
Keywords: *Hospitals; Wastewater; MTE; Heavy metals; Silver; Copper; Mercury; COVID-19*

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I. Introduction

The COVID 19 pandemic has caused many acute and chronic health problems around the world. It has also caused serious economic and environmental problems. The unexpected increase in the number of patients was accompanied by an overproduction of biomedical waste. The implementation of regular hand washing measures and repeated disinfection resulted in a 15%-18% increase in wastewater production with a significant increase in hospital effluents[1].

The characteristics of hospital discharges are variable. They depend on the size of the hospital, the number of beds and patients, the types of services offered, the geographical location and the season of the year during which the hospital is assessed[2]. Hospital wastewater discharged untreated into the environment results in high concentrations of organic matter, pathogens and emerging contaminants such as heavy metals in aquatic ecosystems[3]. Heavy metals, also known as trace metals (TMEs), are naturally found in soils, water and air but in very low quantities. On the other hand, certain human activities such as medical services and factories unfortunately release them in larger quantities into the environment[4]. Among the main heavy metals produced by human activities, mercury, lead and cadmium are the object of particular attention, because they are very toxic for humans with a very long life span. Heavy metals are micro-pollutants that can cause nuisance even when they are released in very low quantities (their toxicity develops by bioaccumulation).

Hospitals use large quantities of water for their needs, resulting in large volumes of wastewater produced. It is estimated that hospitals in industrialized countries use between 400 and 1,200 liters of water per bed per day, compared to 200 and 400 liters per bed per day in developing countries[5][6]. Hospital wastewater can contain various multi-resistant pathogens and carcinogenic substances.

The problem of hospital wastewater is now a growing international concern because of the potential risks associated with the substances contained in the effluents, and the large volumes of wastewater discharged by hospitals. The situation is more worrying in resource limited countries where the vast majority of wastewater (more than 80%) is discharged directly into the environment without adequate treatment[7]. According to recent previous studies[6], hospital effluents have particular characteristics and their assimilation to simple domestic wastewater deserves further investigation by the scientific community as well as by political and health authorities.

In a large majority of developing countries, wastewater sanitation is still a poor relation of urban policies, despite many efforts observed in recent years. The less efficient management of wastewater in general and hospital wastewater in particular is a common problem in all African countries. Some hospital activities such as radiology services, the use of certain antiseptics derived from heavy metals, as well as the breaking of thermometers and barometers continuously discharge trace metal elements into hospital effluents[8].

In the city of Abidjan, hospital wastewater is mainly discharged into large collector systems without prior treatment[9]. Heavy metals such as mercury and copper that cannot be biodegraded could thus persist in the environment for long periods. The accumulation of heavy metals in the environment can affect the health of humans and animals[10].

Our work on this subject is focused on the megacity of Abidjan, because very few articles are devoted to it in Côte d'Ivoire, particularly in a large-scale epidemics. At the Pasteur Institute of Côte d'Ivoire (IPCI), a research program focuses on the monitoring of pathogens in wastewater. This article reports the results of the study of silver, copper and mercury concentrations in hospital liquid discharges before and during the COVOD-19 pandemic. It also compares these different concentrations in order to assess their evolution with the health crisis.

II. Material And Methods

Study site:

We chose three types of public sector hospitals (Figure 1):

- A University Hospital Center, that of Cocody (CHU Cocody). The second largest UHC in Côte d'Ivoire with a capacity of 377 beds;
- Two General Hospitals: the one of Port Bouet (HG Port Bouet) and Abobo (HG Abobo), respectively to the south and north of the city of Abidjan. These two hospitals are located in two densely populated communes and have about 300-350 beds each;
- A specialized hospital: the oldest anti-tuberculosis center in the city of Abidjan (CAT Treichville) (day hospital for ambulatory care)

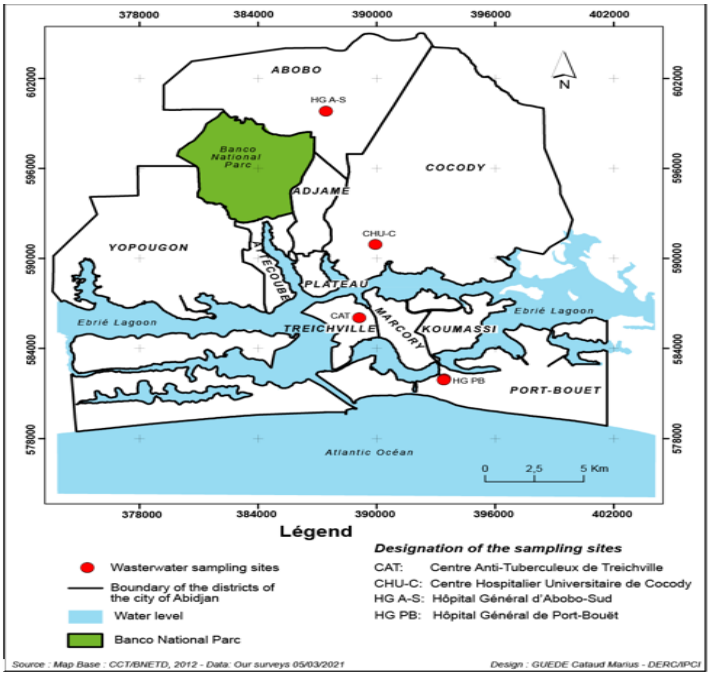

Figure 1: Map of sampling sites in the city of Abidjan

Sample collection material

The sampling material was composed of :

- 1.5 L sterile screw-top bottles of clear color for the study of microbiological parameters
- 1.5 L sterile borosilicate glass opaque screw-top bottles for the study of physicochemical parameters
- Clean bucket, equipped with a rope in order to collect samples from manholes which are often very deep
- A transport container with frozen ice accumulators

Sampling campaigns

The sampling campaigns took place during 7 months divided into 2 main periods:

- January to March 19, 2020: period before the COVID-19 pandemic
- March 19, 2020 to December 2020: period of the COVID-19 pandemic**

***Due to containment measures and travel restrictions, sampling was interrupted from mid-April to the end of September*

Sampling method

Samples were collected at the main manholes at each sampling site. These main manholes collect all secondary manholes at each site. The four sampling sites were visited once a week between 8:00 am and 11:00 am, a time of intense activity at the hospitals.

Transport to the laboratory

After collection, the samples were stored in the container and sent to the laboratory within 4 hours after the test was taken. In the laboratory, the samples were immediately analyzed for physicochemical and microbiological studies. A portion of the microbiological samples was divided into aliquots and stored at the biological resource center of the Pasteur Institute of Côte d'Ivoire (-20°C, -80°C and -196°C) for further studies.

Heavy metalanalysis (ISO 11885: 2006)

The sample was first digested on a carbon oven at a rate of 40 ml in 20ml of 7 mol/litre nitric acid at 120°C for 2 hours. The mixture was then filtered through pleated filter paper on to a 100ml volumetric flask, topped up with distilled water to the mark of the flask, The final mixture was well shaken before being submitted to the ICP-OES (optical emission spectroscopy/inductively coupled plasma) reading after setting up the apparatus, by introducing the suction ramp into the flask.

Data management and analysis

The collected data were recorded on a Microsoft Excel spreadsheet suite office 365 and then analyzed using R software version 4.0.5. Quantitative data were described as mean plus or minus standard deviation and median associated with interquartile range. Qualitative data were described in terms of frequency.

For the comparison of the means of the heavy metals with the respective accepted threshold values, we performed the Student's test or the Wilcoxon test for comparison of means when the samples were not distributed according to a normal distribution. The same principle was followed for the comparison of heavy metal averages obtained before and during COVID-19. For the threshold value of copper, the Ivorian standard for wastewater discharged into the natural environment was used. For silver and mercury, a European community wastewater standard was used.

III. Result

Distribution of samples by site and sampling period

112 (100%) samples were analyzed during this study.

From each of the four hospitals included in the study, 7 samples were collected before the pandemic while 21 samples were collected during the pandemic, for a total of 28 (25%) and 84 (75%) hospital effluent samples collected before and during the COVID-19 period respectively (Table 1).

Table no 1: Distribution of samples by site and collection period

	Number of samples before COVID-19	Number of samples during COVID-19	Total (N=112)
Site of Prelevement			
HG Abobo	7	21	28 (25.0%)
CHU Cocody	7	21	28 (25.0%)
HG Port Bouet	7	21	28 (25.0%)
CAT Treichville	7	21	28 (25.0%)
Total	28 (25.0%)	84 (75.0%)	112 (100%)

Heavy metal concentrations for all periods and sites combined

The average concentrations of heavy metals for all periods, compared to the standards, are presented in Table 2. The concentrations of silver vary between 0.01 and 1.08 mg/l. Copper concentrations vary between 0.00 and 0.099 mg/l, while mercury concentrations vary between 0.005 and 0.097 mg/l.

For all periods, the average concentrations of the heavy metals analyzed were found to be lower than the reference values of the standards for wastewater discharge into the environment for P value <0.05 (Table 2).

Table no 2: Comparison of the average concentration of TME in the effluents, all sites and periods combined, to standards

	Min*(mg/l) Max*(mg/l)	Mean (SD*) Médian [Q1*, Q3*]	Standards (mg/l)	P value (Wilcoxon. Test)
Silver				
	0,01	0.108 (±0.145)		
	1.08	0.06 [0.03, 0.12]	O.1	<0.05
Copper				
	0	0.016 (±0.018)		
	0.099	0.012[0.006, 0.017]	0.5	<0.05
Mercury				
	0.005	0.056 (±0.025)		
	0.097	0.054[0.038, 0.078]	0.1	<0.05

Min*: Minimum concentration; Max*: Maximum concentration ; SD*:Standard deviation ; Q1*:First cartyl Q2*: Lastcartyl

Average concentrations of heavy metals according to the periods

The different averages of heavymetal concentrations according to periods for all sites combined, compared to the standards are presented in Table 3.

According to the periods before and during COVID-19, the concentration averages of heavy metals also show values lower than the norms (p<0.05) except for the average of silver TME during COVID-19 which seems to beat the limit of the norm for a P value>0.05 (Table 3)

Table no 3: Comparison to standards of average TME concentrations in hospital effluents according to samplingperiods for all sites combined

	Before COVID-19 (N=28)	P value (Wilcoxon. Test)	During COVID-19 (N=84)	P value (Wilcoxon Test)
Silver				
Mean (±SD)	0.033 (±0.02)		0.133 (±0.16)	
Médian [Q1, Q3]	0.03 [0.02, 0.05]	<0.05	0.085 [0.049, 0.16]	0.8584
Copper				
Mean (±SD)	0.011 (±0.012)		0.018 (±0.02)	
Médian [Q1, Q3]	0.011[0.003, 0.015]	<0.05	0.013[0.006, 0.018]	< 0.05
Mercury				
Mean (±SD)	0.064 (±0.021)		0.054 (±0.026)	
Médian [Q1, Q3]	0.058[0.048, 0.082]	<0.05	0.05 [0.033, 0.078]	<0.05

Evolution of the average concentrations of heavy metals in hospital effluents during COVID-19

The results of the pairwise comparison of the mean concentrations of silver, copper and mercury TMEs are shown in the figures below, respectively.

The average concentration of silver TME during the COVID 19 period is found to be higher than it saverage concentration before the pandemic with a value of P <0.05 (Figure 2).

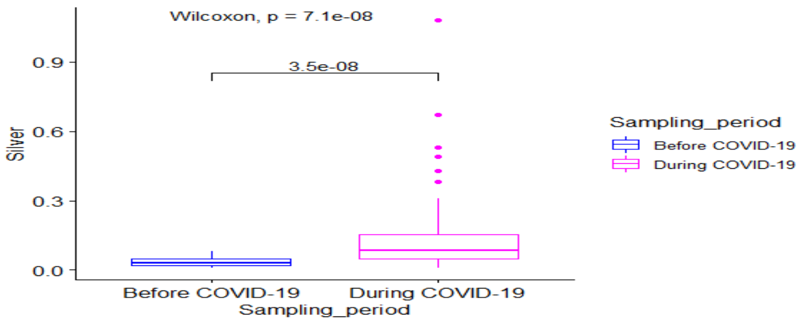

Figure 2: Comparison of average silver TME concentrations in effluent before and duringCOVID-19.

However, there was no significant difference between the mean copper concentrations over the two periods with a P value >0.05(Figure 3).

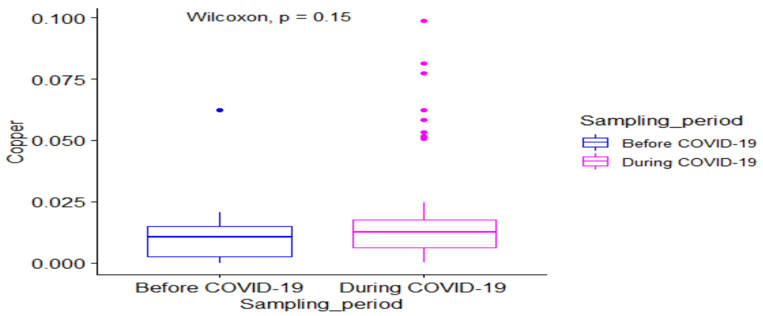

Figure 3: Comparison of average copper TME concentrations in effluent before and duringCOVID-19.

In contrast to silver and copper TME, the mean concentration of mercury TME during the pandemic is significantly lower than its mean concentration before COVID-19 with a value of P <0.05 (Figure 4)

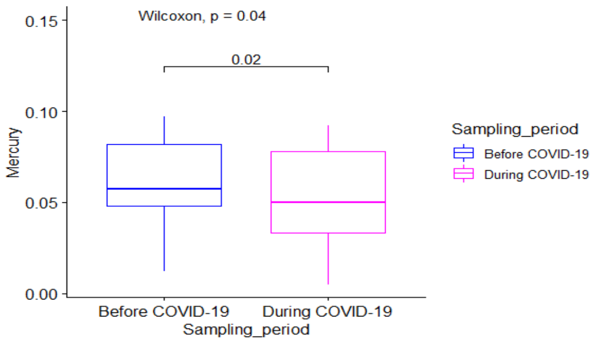

Figure 4 : Comparison of average effluent mercury TME concentrations before and during COVID-19

IV. Discussion

According to the WHO, the response to the COVID-19 pandemic has led to the generation of tens of thousands of tons of additional medical waste, which has challenged health care waste management systems worldwide[11]. Hospital wastewater contains a wide range of toxic and/or persistent compounds, some of which belong to the group of emerging contaminants. The release of these substances into the aquatic ecosystem threatens human and environmental health and demonstrates the urgent need for improved waste management practices.

The concentrations of three heavy metals during the periods before and during COVID-19 were measured in the liquid effluents of four hospitals in the city of Abidjan in order to investigate the impact of the COVID-19 pandemic on the content of these substances in the discharge.

Analysis of silver TME in effluents

Like many metals, silver can cause intoxication of varying severity. The best known clinical picture remains argyria, a dermatosis characterized by a grey/grey-blue coloration of the mucous membranes and the skin. The almost zero toxicity of the metallic form of silver contrasts with the sometimes important toxicity of its salts. In hospitals, silver salts are used therapeutically as antiseptic solutions (e.g. silver nitrate solution for cleaning wounds) or as antibiotic compounds (silver sulfadiazine or silver sulfadiazine[12]. However, radiology services can represent a more important source of pollution with radiological films with mainly wet development called silver. The toxic liquid discharges generated during the development of silver films include the overflows of processing tanks, including used fixer baths rich in silver salts (9/10ths of the dissolved silver compounds) and plate rinsing water[13].

The hospital effluents analyzed in this study show that silver TME discharges from hospitals in the city of Abidjan remained within the norm even during the COVID-19 pandemic. This result could be explained by the rise of digital imaging with the appearance of dry films using laser reprography techniques that contain little or no silver. Analysis of the study data also indicates that the average silver TME concentration during the pandemic at Covid-19 was significantly higher than that of the pre-pandemic period. Indeed, in the fight against SARSCOV2 disease, radiology systems are essential, while Covid-19 can affect not only the lungs but also other vital organs[14]. In Côte d'Ivoire, the city of Abidjan is known to be the epicenter of COVID-19 disease. Therefore, the demands for radiological examinations that accompanied the management of the many symptomatic COVID-19 patients could explain the increase in the mean concentration of silver TME in hospital discharges.

Analysis of copper TME in effluents

Copper in very low doses is an essential trace element for the proper functioning of the body. It serves as a cofactor for many enzymes, the daily needs being around 2mg in adults.

However, this metal can be toxic by increasing the formation of reactive oxygen species, responsible for oxidative stress. High doses of copper can cause irreversible kidney and liver damage and death.

In medicine, copper is used in the manufacture of antimicrobial compounds, radioactive markers ...and certain intrauterine devices. In the environment, copper contained in hospital waste can be ecotoxic even at low doses, particularly for certain aquatic organisms. It can accumulate in the soil and then in plants[15].

The average concentrations of copper found in this study indicate that the content of this metal in hospital effluents in Abidjan remains below the norm even for the period of study considered. In their work, Perez-Alvarez et al. also found a relatively normal level of copper in hospital wastewater from Toluca, Mexico[10].

Comparison of the mean copper concentrations for the periods before and during COVID-19 showed no significant difference. It appears that the COVID-19 health crisis did not influence the level of copper in hospital wastewater in Abidjan. By persisting in outdoor environments such as waterways, copper in certain proportions can present health risks to populations. According to the European Chemicals Agency (ECHA), copper can affect fertility, cause damage to the fetus or to the organs of adults following long-term exposure[16].

Analysis of mercury TME in effluents

Hospital effluents can be a significant source of mercury releases to the environment. In medicine, mercury is found in a variety of products such as thermometers, sphygmomanometers, some analytical and research chemicals, dental amalgams and some lamps. According to one study, hospital wastewater is the second largest point source of mercury in a Canadian city's wastewater treatment plant[17]. In the U.S., hospitals were previously estimated to contribute 4-5% of the mercury load in wastewater[18]. More recently in Mexico, hospital effluents have been found to contain considerable concentrations of mercury[10].

Some of the mercury released by the hospital could come from dental care services given their high potential for release in case of inadequate maintenance of amalgam separators. In Côte d'Ivoire, mercury dental amalgams are one of the most important sources of mercury emissions, with nearly 4,161 kg Hg/year[19]. It is also estimated that more than 10% of the mercury thermometers distributed per year in all of the country's health facilities would break, releasing approximately 600 kg Hg/year. In addition, mercury emissions from the category of chemicals and laboratory equipment are estimated to be around 1040 kg Hg/year. Some of the mercury discharged by hospitals is found in the wastewater produced.

In the present study, no exceedance of the standard was observed for mercury over the two periods considered, including the period of the COVID-19 pandemic. Peshin S. et al. found similar results in the analysis of discharges from some hospitals in India[18]. Since 2013, Côte d'Ivoire, a signatory to the Minamata Convention on mercury, has committed to a policy for the management of this toxic metal and the implementation of this policy is underway. The reduction in the rate of dental amalgam-based restorative care from 80% in 2000 to 15% in 2018 is a relative indication of awareness of the dangers associated with mercury. The results of this study show that the COVID-19 pandemic was accompanied by a significant decrease in the level of mercury in hospital effluents in the city of Abidjan. This situation is probably related to a focus on the fight against the SARSCOV2 virus and a tendency to prioritize certain types of consultations such as dental care. Containment measures and movement restrictions were obstacles to the continuity of this type of care, which was cited as a significant source of mercury in hospital wastewater[20][21].

V. Conclusion

The present study indicates low concentrations of silver, copper and mercury TMEs in wastewater discharged from four hospitals in the city of Abidjan. In addition, despite the overproduction of biomedical waste caused by the COVID-19 health crisis, the levels of these three toxic metals also remained within wastewater standards. These results, however, suggest that the impact of the pandemic on the discharge of these heavy metals in effluents varies from one metal to another. For example, the average concentration of silver TME increased significantly while that of mercury TME decreased significantly. As for copper TME, its concentration did not change with the health crisis. This work focused on a specific number of metals. In fact, it does not provide information on the situation of other equally dangerous metals such as cadmium and lead, which are subject to special monitoring. The concern about hospital liquid discharges lies in the fact that the downstream water bodies that receive them behave as reservoirs of contained contaminants, from which they are reintroduced into the food chain by biomagnification or seep into aquifers, causing damage by various routes.

In Abidjan, liquid hospital effluents are discharged untreated into the municipal sewer system before reaching the Ebrie Lagoon in the south of the city. Further studies and experimental investigations in the receiving ecosystems of hospital liquid discharges in the city of Abidjan are necessary to establish more exhaustively the levels of contamination of toxic metals. The results of this work could eventually contribute to the advocacy with the authorities for appropriate actions.

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