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## Physico-chemical characterization of liquid waste from sugar production unit labs in Zuenoula, Côte d'Ivoire

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### ABSTRACT

Managing liquid waste from the laboratories of Integrated Agricultural Unit (IAU) of Zuénoula (Côte d'Ivoire) is a major concern for the decision-makers of the company, who are working to solve this problem in their sustainable development policy. This work aims at quantifying liquid waste from the agronomic laboratories and factory of IAU of Zuénoula and to assess their level of pollution. The quantities of waste produced daily are estimated at 28.5 L, 52.6 L and 2600 L respectively for waste from the agronomy laboratory, the factory laboratory and from the rinsing water from latter's glassware. The following parameters were analyzed, temperature, pH, conductivity, turbidity, total suspended solids, COD, BOD5, total nitrogen, total phosphorus, zinc, copper, lead and mercury. The results of these analyzes generally showed that waste produced did not comply with national standards. In particular, the level of lead was very high in these liquid wastes and reached 160 times the standard value. These results require a waste treatment system, which would reduce all the parameters, in particular those of the most noxious metals (lead and mercury).

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**Keywords:** Heavy metals, Pollution, Industrial unit, Ivorian standards, Wastewater.

### INTRODUCTION

The impact of industrial effluents on the environment is today a pressing reality and a seriously threatens the quality of surface and ground waters in the long run (Gnagne et al., 2015; Ouedraogo et al., 2018). Almost all industrial activities using energy and raw materials in their processes produce waste and/or effluents, which are then found in natural environment. The fate of this waste and effluents varies according to the phases of product life cycle, depending on the raw materials used, product design and technology applied during its manufacture (Weidenhaupt and Meier, 2000). Such impacts, which may occur at local, regional or global levels, exert

harmful or even dangerous effects on human health and environment. Thus, industrial development has led to worrying environmental situation for all those involved in economic, social and legal matters. It has been marked in recent years by the establishment of large factories, which discharge their liquid wastes into environment (Dhimni et al., 2015). These liquid wastes, if not treated before being discharged into nature, can seriously damage the ecosystem. In order to provide a best answer to the issue regarding the amount of waste generated by businesses and their specificities, the legislator has established comprehensive regulations in this area. Various international

meetings on the environment have accelerated adoption of environmental legislation targeting sustainable development. Côte d'Ivoire, having ratified several treaties and conventions, has therefore passed laws in order to protect the environment, which industries are to abide by. The decree regulating discharges and emissions from amenities classified for protection of environment (MEF, 2008) was adopted on November 04, 2008 and henceforth published (Ivorian standard). These new provisions require the company to manage its waste. An environmental assessment, both quantitative and qualitative, is imperative and requires permanent monitoring to predict the trend in the receiving environment and thus recommend appropriate remedies (Zegaoula and Khellaf, 2014). Concerned with protection of environment, the IAU (Industrial Agricultural Unit) of Zuénoula (Côte d'Ivoire) considered that it is essential to quantify and to characterize its liquid discharges produced by their two laboratories (factory and agronomic activities) so as to set up a waste management system.

This paper aims at assessing the level of pollution of liquid waste from IAU laboratories on the environment. It specifically includes quantifying liquid waste produced and determining their physico-chemical characteristics.

## **MATERIALS AND METHODS**

### **Study zone**

The Integrated Agricultural Unit of Zuénoula is located 25 km from Zuénoula in Center-West of Côte d'Ivoire (Figure 1). It is geographically located between 7°30 and 7°40 north latitude, and between 6°5 and 6°15 west longitude, and located at 209 m altitude above the sea (Péné and Assa, 2003). The factory's sugar production campaign lasts about seven months in a year (from September to March).

### **Liquid laboratory waste**

The liquid waste, constituting our working material, comes from the activities of two laboratories of the IAU of Zuénoula during the sugar production campaign (2018-

2019). The agronomic laboratory and the factory laboratory. Liquid waste from the agronomic laboratory is made up of rejections from analyses on sugar cane, leaves and soils. As for factory laboratory, the liquid waste comes from analyses of the cane juice produced and rinsing water from the lab's glassware after analysis.

The samples of these liquid wastes are named in this work by letters (A, B and C). Thus, the samples from all discharge from the agronomic laboratory are designated by the letter A, samples from the reading discharge from the factory lab are designated by the letter B and samples from the rinsing water from the of factory lab's sinks are designated by the letter C.

### **Quantification of liquid waste**

The quantities of liquid waste produced each day for forty-five days (45) during the production campaign were measured using a cylindrical container of known diameter. Measuring the level of liquid in container makes it possible to determinate the volume of liquid waste. Measurements have been made for the three sources of liquid waste production.

### **Sampling methods**

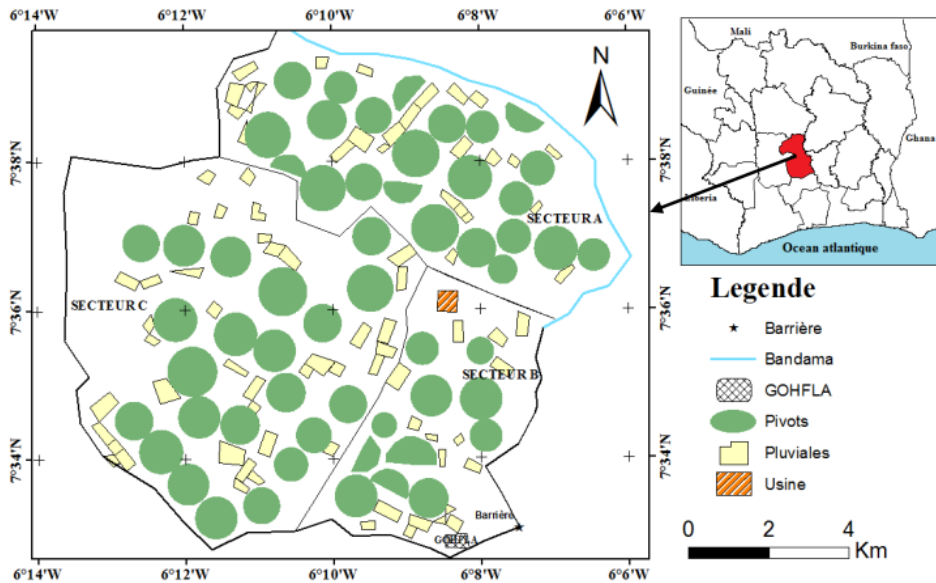
The sampling was carried out for four weeks, during the production campaign, in a proportion of one liter per week for each of the three sources of liquid waste. The samples collected this way from each of the three sources (A, B and C) during the four weeks were mixed. Each mixture was the sampled in polyethylene bottles and stored in the freezer at 2 to 5 °C. Great care has been taken to maintain clean conditions during the collection and handling of the samples, in order to minimize any possible contamination (Degrémont, 2005). In addition, all the samples were collected using pre-cleaned polyethylene bottles and acidified to pH 2 with concentrated HCl.

### **Laboratory analysis**

Temperature, pH, conductivity, total suspended solids (TSS) and turbidity were

measured in the factory lab after sampling and before the samples were stored in the freezer. Determination of inorganic and organic parameters such as chemical oxygen demand (COD), biochemical oxygen demand (BOD5), total nitrogen, total phosphorus, mercury (Hg), lead (Pb), zinc (Zn) and copper (Cu)

was carried out at the National Laboratory for tests, Quality, Metrologies and Analyses (LANEMA) in Abidjan. Determination of the different metals was carried out using Atomic Absorption Spectroscopy (AAS). The analysis methods used are mostly according to the ISO standard and are listed in Table 1.



**Figure 1:** Map of the Integrated Agricultural Unit (IAU) of Zuénoula.

**Table 1:** Materials or methods of analyzing different parameters.

Parameters	Unit	Materials or methods used
Temperature	°C	Knick-765 Laboratory pH Meter
pH	-	Knick-765 Laboratory pH Meter
Conductivity	(µS/cm)	multimeter Consort C933
TSS	(mg/L)	multimeter Nalco DR/ 890 Colorimeter
Turbidity	(NTU)	multimeter Nalco DR/ 890 Colorimeter
Total Phosphorus	(mg/L)	ISO 6878 v 2004
Total nitrogen	(mg/L)	ISO 5663 v 1984
COD	(mg/L)	ISO 6060 v 1989
BOD5	(mg/L)	Rodier 9 <sup>th</sup> edition
Copper	(mg/L)	Rodier 9 <sup>th</sup> edition
Zinc	(mg/L)	ISO 15586 v 2003
Lead	(mg/L)	ISO 15586 v 2003
Mercury	(mg/L)	Rodier 9 <sup>th</sup> edition

## RESULTS

### Quantification of liquid waste

The results of the daily quantity measurement of the liquid waste produced by agronomy and factory laboratories of IAU of Zuenoula over a period of forty-five days are shown in Figure 2.

The daily curve presenting quantities of waste from agronomic laboratory (Figure 2.1) shows that daily quantities vary greatly over the entire measurement period, from 0.005 to 0.061 m<sup>3</sup>, ie from 5 to 61 liters. The daily average over the 45 sampling period is 0.0285 ± 0.015 m<sup>3</sup>, which is approximately 28.5 liters (Table 2). Figure 2.2 also shows how varied are daily quantities of liquid analytical waste produced by factory laboratory. These quantities vary from 0.007 m<sup>3</sup> to 0.081 m<sup>3</sup> over the measurement period with daily average of 0.0526 ± 0.018 m<sup>3</sup> (Table 2), i.e. approximately 52.6 liters. The quantity of rinsing water from utensils used for analyses in the factory laboratory was captured once a week for four weeks and the results are shown in Figure 2.3. These results present quantities varying from week to week, from 2.24 to 3.04 m<sup>3</sup> and an estimated daily average of 2.6 ± 0.36 m<sup>3</sup> (approximately 2,600 liters).

### Physico-chemical parameters of liquid waste

To assess the environmental impact of the liquid waste produced by IAU laboratories, the main parameters indicating pollution have been measured and the results have been compared to the standard established by the State of Côte d'Ivoire. Results of temperature measurement, pH, conductivity, turbidity, total suspended solids (TSS), COD, BOD5 and the COD / BOD5 ratio are captured in Table 3.

#### Temperature

The average temperature values of each of the three samples of liquid waste

produced (A, B and C) are all below 30 °C. These values do not exceed the maximum 40 °C recommended by Ivorian standards (MEF, 2008).

#### Potential hydrogen (pH)

The pH values of the three liquid wastes are between 4.37 and 4.54. They are not within the range of values recommended by Ivorian standard (between 5.5 and 8.5). These pH values show that all the liquid waste produced is acidic and does not comply with the standards.

#### Conductivity

Although the conductivity of sample B is high (3300 µS/Cm), the one of sample A (11820 µS/Cm) is much higher with a more than 3.5 factor. Unlike the other two, sample C has a lower conductivity. These values show that the first two samples (A and B) are loaded with dissolved salts while sample C is less loaded (540 µS/Cm).

#### Turbidity

Turbidity measures the more or less cloudy appearance of the water. The results show that the liquid waste studied are very turbid with highest value for sample A equal to 5745 NTU, followed by 2160 NTU for sample B. The sample C has a value of 262 NTU, lower than the other two.

#### Total suspended solids (TSS)

TSS values of the three samples are higher than the Ivorian standards (150 mg/L). However, the values of samples A (4035 mg/L) and B (2150 mg/L) are highest with factors of 27 and 14 respectively. As for sample C, the TSS value is 187 mg/L and slightly exceeds that of the standard. These values show that the samples are loaded with suspended solids.

### Chemical oxygen demand (COD) and Biological oxygen demand (BOD5)

The COD of sample C (150 mg/L) complies with to the standards as the value does not exceed the authorized 500 mg/L. On the other hand, the COD of sample A (3000 mg/L) and B (1700 mg/L) greatly exceed the maximum value authorized and are respectively 6 and 3 times higher than the standard. The BOD5 of samples A and B, respectively 2400 mg/L and 1500 mg/L are much higher than 150 g/L, which is the value set by the Ivorian standards. These values are respectively 16 and 10 times higher than standard. The BOD5 of sample C equal to 120 mg/L and therefore meets the standards.

All the three samples have COD/BOD5 ratios less than 1.3, which indicates that the organic matter in this wastewater are biodegradable. The biodegradability of organic matter in wastewater is effective when the COD/BOD5 ratio is estimated to be less than 2.5 (Dongo et al., 2013).

### Total phosphorus and Total nitrogen

Figure 3 shows the total phosphorus values for the three samples. Apart from sample C which has a total phosphorus value

lower than 15 mg/L (Ivorian standards), the values of the other samples A and B are higher than the maximum value authorized in Côte d'Ivoire. The same is true for measurement of total nitrogen. Only sample C meets the standard (50 mg/L) with a value of 2.10 mg/L. The other two samples greatly exceed (more than 3 times) the value allowed.

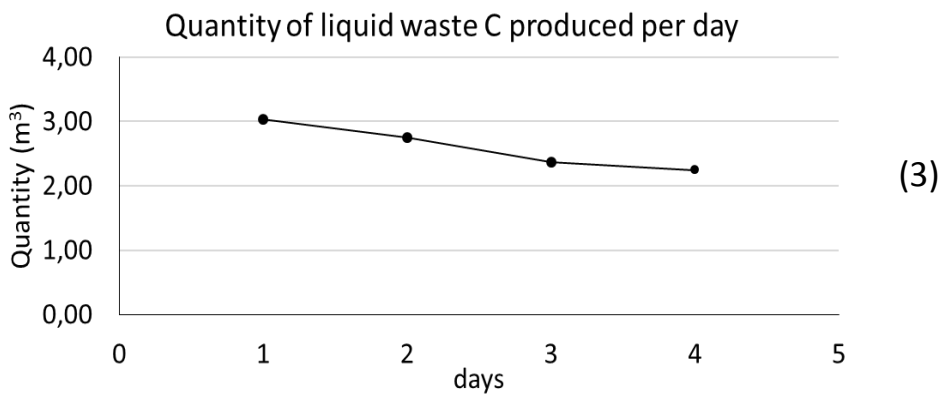
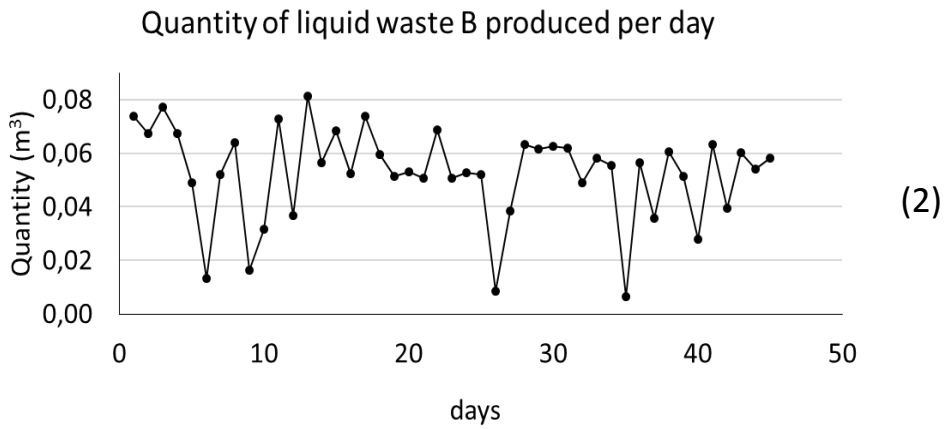
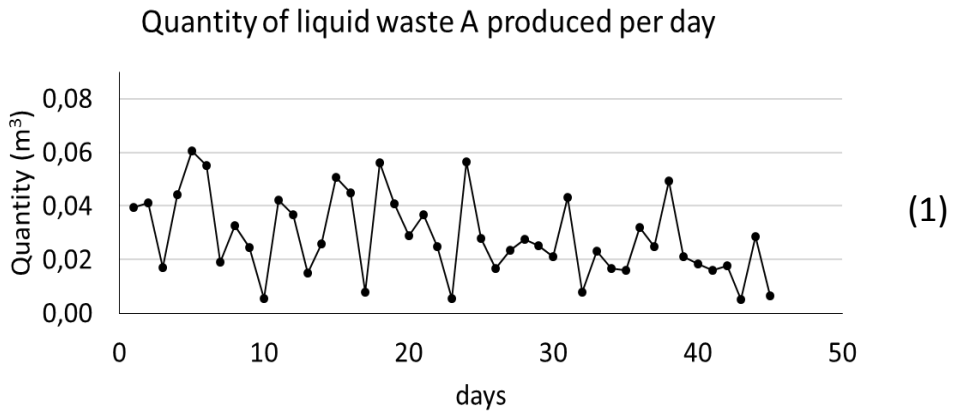
### Metallic elements

The analysis of the three samples of liquid waste revealed the presence of heavy metals including copper, zinc, lead, mercury. Copper and zinc concentrations, as illustrated in Figure 4, show that the values obtained for each of these parameters are significantly lower than the maximum limits recommended by the Ivorian standards namely 0.5 mg/L for copper, and 2 mg/L for zinc. However, lead and mercury concentrations widely exceed the maximum limit values (0.5 mg/L for lead and 0.2 mg/L for mercury) before being released into the receiving environment.

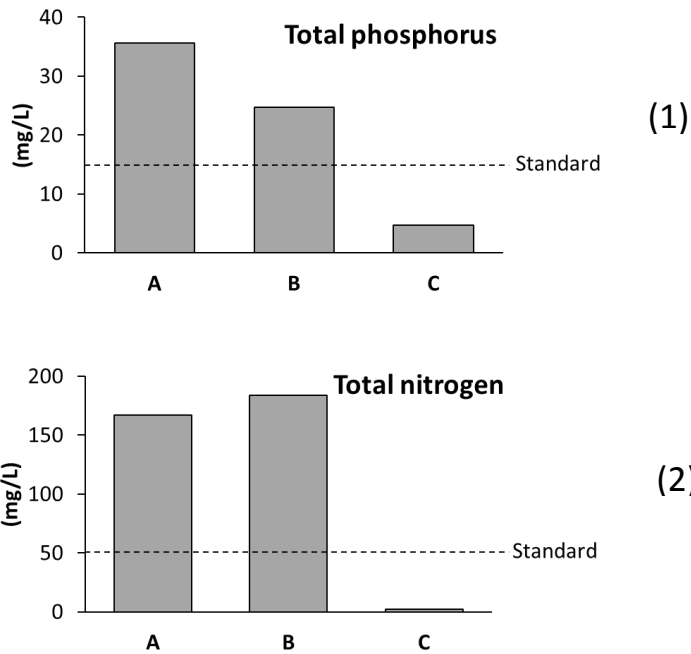
**Table 2:** Mean daily quantity of liquid waste produced at the IAU of Zuenoula during the annual production campaign (September 2018 to March 2019).

Code	Mean daily quantity (m <sup>3</sup> )	Nature of waste	Waste origin
A	0,028 ± 0,015 <sup>a</sup>	liquid waste of analysis	agronomy laboratory
B	0,053 ± 0,018 <sup>a</sup>	liquid waste of analysis	factory laboratory
C	2,598 ± 0,364 <sup>a</sup>	Glassware rinsing water	factory laboratory

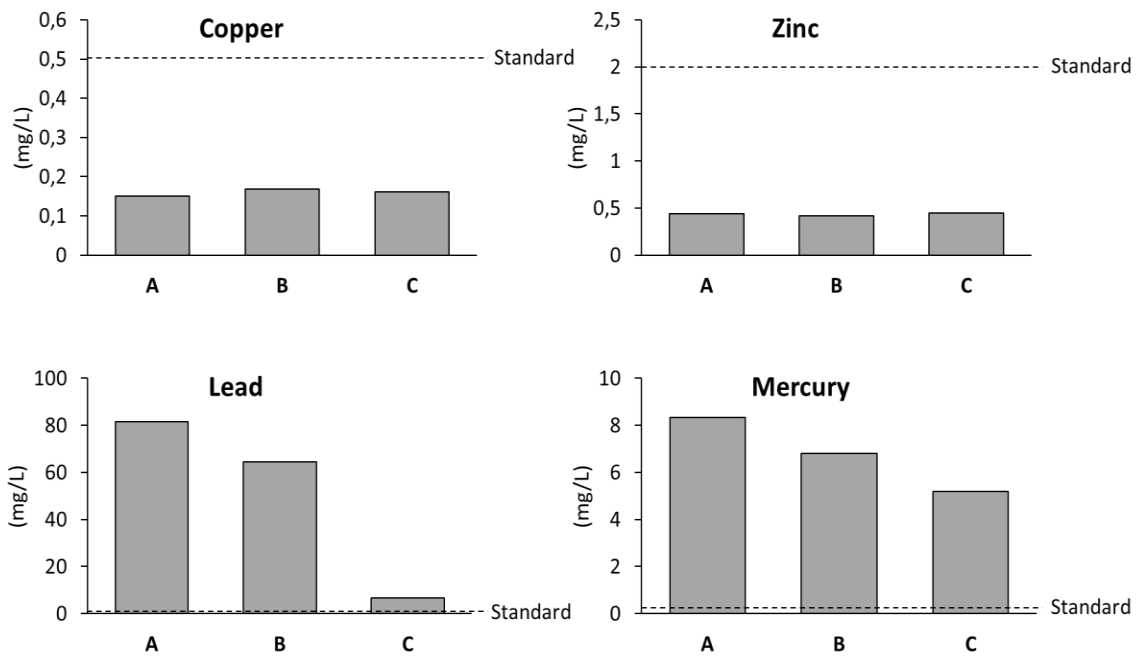
<sup>a</sup> standard deviation was calculated with microsoft excel 2016.



**Figure 2:** Quantity of liquid waste production per day in 1. agronomy laboratory (A), 2. factory laboratory (B) and 3. rinsing water of factory laboratory (C).



**Figure 3:** Concentration of 1. total phosphorus and 2. total nitrogen of liquid waste from agronomy laboratory (A), factory laboratory (B), rinsing water from factory laboratory (C) and Ivorian standard.



**Figure 4:** Concentration of heavy metals in liquid waste from agronomy laboratory (A), factory laboratory (B), rinsing water from factory laboratory (C) and Ivorian standard.

**Table 2:** Physico-chemical parameters of liquid waste from agronomy laboratory (A), factory laboratory (B), rinsing water from factory laboratory (C) and Ivorian standard.

Samples	A	B	C	Ivorian standard
Temperature (°C)	24	23,1	28	40
pH	4,48	4,37	4,54	5,5-8,5
Conductivity (µS/cm)	11820	3300	540	-
Turbidity (NTU)	5745	2160	262	-
TSS (mg/L)	4035	2150	187	150
COD (mg/L)	3000	1700	150	500
BOD5 (mg/L)	2400	1500	120	150
COD/BOD5	1,25	1,13	1,25	3,33

## DISCUSSION

Liquid waste from the agronomic laboratory comes mainly from analyses on sugar cane, cane leaves and soils. Analysis of cane leaves and soils makes determination of mineral elements they contain possible before proceeding to fertilization. In the same manners, sugar cane analysis allows us to follow the level of maturation and to determine sugar level before harvesting. The Liquid waste produced by the factory lab results from the different analyses at each stage of transformation of cane into finished product. These analyses are carried out daily throughout the sugar production campaign, which lasts approximately seven months a year (from September to March). The daily quantities of liquid waste generated by these laboratories during the production campaign are 28.5 liters, 52.6 liters and 2600 liters respectively for the agronomy laboratory (sample A), the factory laboratory (sample B) and for the rinsing water from the factory laboratory (sample C). the factory laboratory produces more liquid waste, compared to the agronomic laboratory. The quantity of liquid waste from the factory laboratory analyses is approximately 2 times higher than that from the agronomic laboratory. There are two reasons to this: either far more analyses are effected in this laboratory, which follows each stage of processing from cane to final sugar or this laboratory operates 24 hours a day all along a week during the production period, unlike agronomy laboratory, which does not work 24 hours a day, even as it works every

day. The amount of rinsing water from utensils used for analyses in the factory laboratory is about 50 times higher than the liquid waste from these analyses.

The results of the analyses of two waste samples A and B from agronomy and factory laboratories show that the parameters studied do not comply with the Ivorian standards except temperature, copper and zinc concentration. However, concerning sample C, less than half of the parameters studied does not meet the standards, namely pH, TSS, lead and mercury. Thus, this liquid waste discharged into nature will be a source of pollution for the environment.

Measurement of the samples pH shows that they all have an acidic character (pH between 4.37 and 4.54). Such a value is below the biological range which is between 5.6 and 8.5 and which would enable the bacterial development necessary for the biological degradation of organic pollutants (Maïga et al., 2006). This acidic character is related to the presence in these releases of acidic chemicals such as sulfuric acid (H<sub>2</sub>SO<sub>4</sub>), nitric acid (HNO<sub>3</sub>), hydrochloric acid (HCl), perchloric acid (HClO<sub>4</sub>) which are strongest acids used in IAU laboratories.

In addition, the conductivity of liquid waste from the analysis activities of the agronomic (sample A) and factory (sample B) laboratories are respectively 11820 µS/Cm and 3300 µS/cm, which indicates a high degree of mineralization and a high level of salinity in these discharges. This comes from the dissolution of chemical substances used



for analyses and is also due to the presence of mineral elements. Mineral degree of sample A is 3 times higher than that of B, thus indicating sample A is most charged with ions. The Ivorian standards is silent on the limit of the conductivity of wastewater; however, these values are higher than the limit value of direct discharge into the receiving environment, fixed at 3000  $\mu\text{S}/\text{cm}$  in Morocco (Idrissi et al., 2015). The conductivity of factory laboratory rinse water (sample C) is low (540  $\mu\text{S}/\text{cm}$ ) and indicates a low concentration of ionic species in these releases.

Turbidity and TSS of samples A and B follow roughly the same trends with very high values for B and even higher for A. Turbidity and TSS of sample C are low compared to the other two samples. According to a study by Dongo et al (2013), the turbidity and TSS values of the three samples do not meet Ivorian standard unlike certain industrial effluents in Abidjan. The TSS values of this study can be compared to those found by Dhimni et al. (2015) on industrial liquid discharges in Morocco, which were between 4,500 g/mL and 5,390 g/mL. Turbidity and TSS of liquid waste studied may be due to the presence of fine sugarcane fibers in the juices analyzed. In addition to the dark aspect of the discharges, a small part of turbidity may be due to the presence of colloidal materials of organic or mineral origin contained in discharges.

Likewise, concentrations of total phosphorus and total nitrogen in liquid waste studied exceed widely those set by the Ivorian standards except in sample C. These nutrients released in large quantities into environment are responsible for eutrophication. Nitrogen and phosphate are effective sources of nutrients for algae. The excessive presence of phosphate together with nitrates and potassium causes algal blooms, which cause the death of aquatic organisms (Bhateria and Jain, 2016). The high level of total phosphorus and total nitrogen can be explained, on the one hand by fertilization and soil amendments with fertilizers rich in phosphorus and nitrogen, and on the other hand by their presence in leaf solutions and the cane juices analyzed.

In addition, COD and BOD<sub>5</sub> of samples studied, except sample C, greatly exceed those of the Ivorian standards set to 500 and 150 mg/L respectively. COD (3000 and 1700 mg/L) and BOD<sub>5</sub> (2400 and 1500 mg/L) values of our samples greatly exceed the values obtained for industrial wastewater according to the study of some authors. This is the case with the average COD and BOD<sub>5</sub> values of 1180.64 mg/L and 728.17 mg/L respectively for industrial effluents in Abidjan (Dongo et al., 2013). The high COD and BOD<sub>5</sub> values in our study indicate a strong presence of organic matter (Dhimni et al., 2015) but also of mineral elements. In fact, COD makes possible assessment of concentration of organic or mineral matter dissolved or suspended in water, by determining the amount of oxygen required for their total chemical oxidation. Like the BOD<sub>5</sub>, the COD is an indicator of organic water pollution and expresses the level of biodegradability of wastewater. The COD/BOD<sub>5</sub> ratio gives values less than 2 for the different samples analyzed. The organic matter present in the liquid discharges studied is therefore easily biodegradable (Rodier et al., 2009). Indeed, a low value of the COD/BOD<sub>5</sub> ratio implies the presence of a large proportion of biodegradable materials and makes it possible to envisage a biological treatment.

In addition, the results of the analyses reveal that the liquid waste from this study is contaminated with heavy metals such as copper, zinc, mercury and lead. However, copper and zinc levels are not alarming as they meet the standards (0.5 mg/L for copper and 2 mg/L for zinc). In contrast, the IAU's liquid waste contains high concentrations of lead and mercury. Heavy metals are potentially toxic and their impacts can be felt in organisms at low doses (Todedji et al., 2020). Zinc, copper, lead and mercury are toxic at high concentrations (Aniyikaiye et al., 2019). Heavy metals are not biodegradable and therefore tend to accumulate in aquatic organisms (Malakootian et al., 2009). Sample A is the most contaminated with lead and mercury concentrations 160 times and 40 times higher than Ivorian standard. Sample B also contains very high values with 128 times and 34 times more than standard for lead and

mercury respectively. However, sample C showed less amount than the other two, but contains considerably more amount than the authorized norm with values 13 and 26 times respectively higher for lead and mercury. Heavy metals such as zinc, copper, lead and mercury are often detected in wastewater or industrial effluents in several studies (Bawa et al., 2006; Chofqi et al., 2007; Iram et al., 2013). The presence of these heavy metals in liquid discharges is mainly due to the use of chemicals such as lead acetate (more than 80% used for clarification of cane juice), mercury chloride (used for conservation of sucrose in juice for later analyses) and copper sulfate (for analysis of reducing sugars). These heavy metals are also present in the standard solutions used for the various assays in the IAU laboratories regularly all along the production campaign. In the light of the physico-chemical parameters results, a treatment of these liquid discharges is therefore necessary to avoid any pollution of the receiving environment. If the liquid waste produced by laboratories (sample A and B) are collected and treated separately, this is not the case for the rinsing water from factory laboratory (sample C) which ends up directly in wastewater circuit of the IAU. The results of this study show that the rinsing water must not be neglected and must be taken into account in the treatment of the liquid waste because it contains pollutants.

### Conclusion

The data from this study showed that the liquid waste produced by the agronomic and the factory laboratories does not meet national standards to be discharged into the environment. This waste is heavily laden with nitrogen, phosphorus, heavy metals (lead and mercury) and parameters for COD, BOD<sub>5</sub>, TSS, turbidity and conductivity are high and do not comply with the national standards. The non-standard values of these parameters show that this waste, produced in abundance on regard of its quantification, is a source of pollution if it is not treated before being discharged into the receiving environment. It is imperative to install a treatment system, which must not only reduce organic and mineral matters but also above all considerably reduce heavy metals, especially

lead whose concentration is very high in liquid discharges. Such a system should reduce the values of parameters below the standards.

### COMPETING INTERESTS

The authors declare that they have no competing interests.

### AUTHORS' CONTRIBUTIONS

The main writing was done by ABBK. The results presentation (tables and figures) was carried out by SSK. AOA was responsible for the quantification of liquid waste and the collection of analyzed samples. YFK and KFK designed and planned this study.

### ACKNOWLEDGEMENTS

We are grateful to Integrated Agricultural Unit (IAU) of Zuénoula for financial support and the National Laboratory for tests, Quality, Metrologies and Analyzes (LANEMA) for technical support.

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