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Diagnosis of urban sewage sludge management in a tropical environment and analysis of improvement strategies: Case of the city of Ebolowa, Cameroon (Central Africa)

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ABSTRACT *This study aimed at analysing the faecal sludge management in the urban area of Ebolowa, capital city of the region of South Cameroon (Central Africa). More specifically, the research work analyzed the faecal sludge (FS) management current practices, characterized the faecal sludge samples, designed and sized a treatment station for the sustainable management of these wastes. For this purpose, a survey was conducted among 379 households, besides the interview of some main key actors in charge of technical services at the urban council of Ebolowa. Overall, ten (10) samples of faecal sludge were collected and the physicochemical (pH; Temperature; Conductivity; Salinity; Ammonium; Phosphate; Nitrate; COD; BOD_5) as well as bacteriological (fecal coliforms) analysis were carried out in the laboratory according to the standard methods. the main results of the survey indicated that all the households and public/private structures investigated were mainly equipped with autonomous sanitation facilities, with 47% traditional latrines (TL), 31% septic tanks (ST), 14% manual flush toilets (MFT), 6% improved latrines (IL) and 2% without sanitation facilities. It was observed that these structures were generally designed without standards and likely to expose groundwater resources to pollution and the public health to water bone diseases. The amount of sludge likely to be produced citywide was estimated to be around 19.710 m^3/ year. There were no emptying service at the city level. Yields, 23 % of populations said to have dug a new pits when the all one was full while 2% of manual emptying of were identified and the resulted wastes were dumped in the scrub near the houses without treatment, being therefore an enormous environmental threat and health risks with regard to the physicochemical quality of this sludge. The laboratory analysis revealed a high concentration of Ammonium (910.425 mg/l); Nitrate (2277.5mg/l), Phosphorus (114.25mg/l), organic matters: BOD_5 (1280 mg/l) and COD (16360 mg / l)); dry matter (6.37%) and in witness germs of faecal contamination, in particular fecal coliforms (6.23 $x10^7$ FCU / 100 ml). All of these parameters were very high compared to WHO standards. This waste thus discharged without treatment constitutes a potential danger to the environment and to public health. Furthermore, no FS treatment station was observed in the city. It was suggested to design and size and appropriate faecal sludge treatment system prior equipping the urban council with materials necessary to the evacuation of these waste to the controlled disposal site.*

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I. INTRODUCTION

The sanitation needs of more than 2.7 billion people worldwide are covered by non-collective sanitation structures (NCSS), a figure that is expected to reach 5 billion by 2030 (Strande et al., 2014). While it is commonly assumed that these NCSS facilities meet the sanitation needs in rural areas, about one billion of them are located in urban areas (Strande et al., 2014). In many cities in sub-Saharan Africa, NCS systems are much more widely used (65-100%) than sewerage systems (Strauss et al., 2000). Progress under the post-Millennium Development Goals (MDGs) has improved the rate of access to improved sanitation facilities, and this access does not stop with the construction of household devices. While the promotion of NCSS has significantly reduced open defecation, however, without solutions and funding for the collection, transport and treatment of sludge, it has also led in many cases to a crisis in the management of faecal sludge, with significant impacts on human health and the environment (Strande et al., 2014). For this reason, Sustainable Development Objectives (SDOs) now include the entire sanitation chain. CNSS can be considered as viable and more affordable solutions, but only if the whole sanitation chain is adequately managed, in particular collection, transport, treatment and safe recovery or disposal. If faecal sludge management (FSM) is not organised in an operational way, faecal sludge accumulated in latrine pits will probably end up in the local environment without having been treated. The result will be ubiquitous pollution of the environment with pathogens, with no barriers to prevent contact with people, and therefore no protection of public health. For example, in Dakar, only 25% of the sludge produced on a domestic scale is collected and transported to official sewage sludge treatment plants (BMGF, 2011). Thus, when developing sanitation objectives and implementing a project, it is imperative to consider the entire sanitation chain and not only intervene at household level by providing toilets. Halving the number of people without access to 'improved' sanitation was the goal of Sustainable Development Objectives (SDOs) target 7C. Improved access is defined here as access to a device that hygienically separates human excreta from the population. These include: flush toilets, connection to a sewerage system, connection to septic tanks, single-flush pit latrines, improved ventilated latrines and compost toilets. However, it is crucial to look beyond the 'upstream' link (toilet construction and use) and work on the sanitation chain as a whole. Efforts should also focus on the "intermediate" link (evacuation and transport) and the "downstream" link (treatment and disposal and/or recovery). In cities in Cameroon, for example in Bafoussam, excreta are collected in individual sanitation systems constructed at the house level (Defo et al., 2015, Letah et al., 2016). The sludge stored by these structures needs to be regularly disposed of and treated in a sustainable way. The city of Ebolowa is not spared from this situation, data on sanitation, especially on the management of faecal sludge, are almost non-existent. The collection and storage systems for faecal sludge (FS) are not effective as are those for collection and transport, and even more so those related to the discharge and/or treatment of these wastes. In this city, the dataset on the environmental management is scare and dispersed. Only a few data are available, notably on a diagnostic study of the city carried out by HTR (2015), which shows that 68% of households in the city of Ebolowa have traditional latrines; 31% of conventional latrines (VIP and TCM) and the rest do not. The lack of a sewage disposal service is for excreta disposal, yet if this sludge is not disposed of regularly, transported and treated in a sewage treatment plant, it can cause serious environmental and public health damage (Klingel et al., 2002). All these problems could be avoided by an appropriate system of sewage sludge management involving adequate emptying of sewage systems with minimum risk during handling and transport and providing a sludge treatment system leading to safe disposal or reuse in agriculture (Heinss et al., 1998). In order to overcome this deficiency in the management of the~~is~~ sanitation sector, the present study was initiated on the diagnosis of the management of FS in the municipality of Ebolowa, with a view to proposing a sustainable management. It is in this perspective that the choice of the theme proposed for our study is situated. The general objective of this study is to contribute to the sustainable management of faecal sludge in order to guarantee the well-being of the populations of the town of Ebolowa, therefore, the purpose of this study was to examine the faecal sludge ~~is~~ management ~~ed~~ in the city of Ebolowa; to characterise the collected faecal sludge; and to design a faecal sludge treatment plant for the sustainable management of the city.

II. MATERIALS AND METHODS

2.1 Location and description of the study area

Ebolowa is located in the South Cameroon Region of which it is the capital. This Region is bordered by the Centre Region in the North; the East Region in the North-East and East; the Coastal Region in the North-West; the Atlantic Ocean in the West and Gabon and Equatorial Guinea in the South- East. The city of Ebolowa, capital of the Mvila Department is bordered to the west by the Ocean Department; to the south-west by the Ntem Valley Department; to the south by the Atlantic Ocean and Equatorial Guinea; to the east by the “Dja et Lobo’’ Department and to the north by the Nyong and So'o Department. The Mvila Department extends between 2°20' North latitude and 3°10' South latitude, from East to West, it stretches between 10°40' East longitude and 12°10' West longitude. On the other hand, the town of Ebolowa is located at longitude 2°54'37.40″ North and latitude 11° 8'55.11″ East and is situated 168 Km from Yaounde (Figure 1).

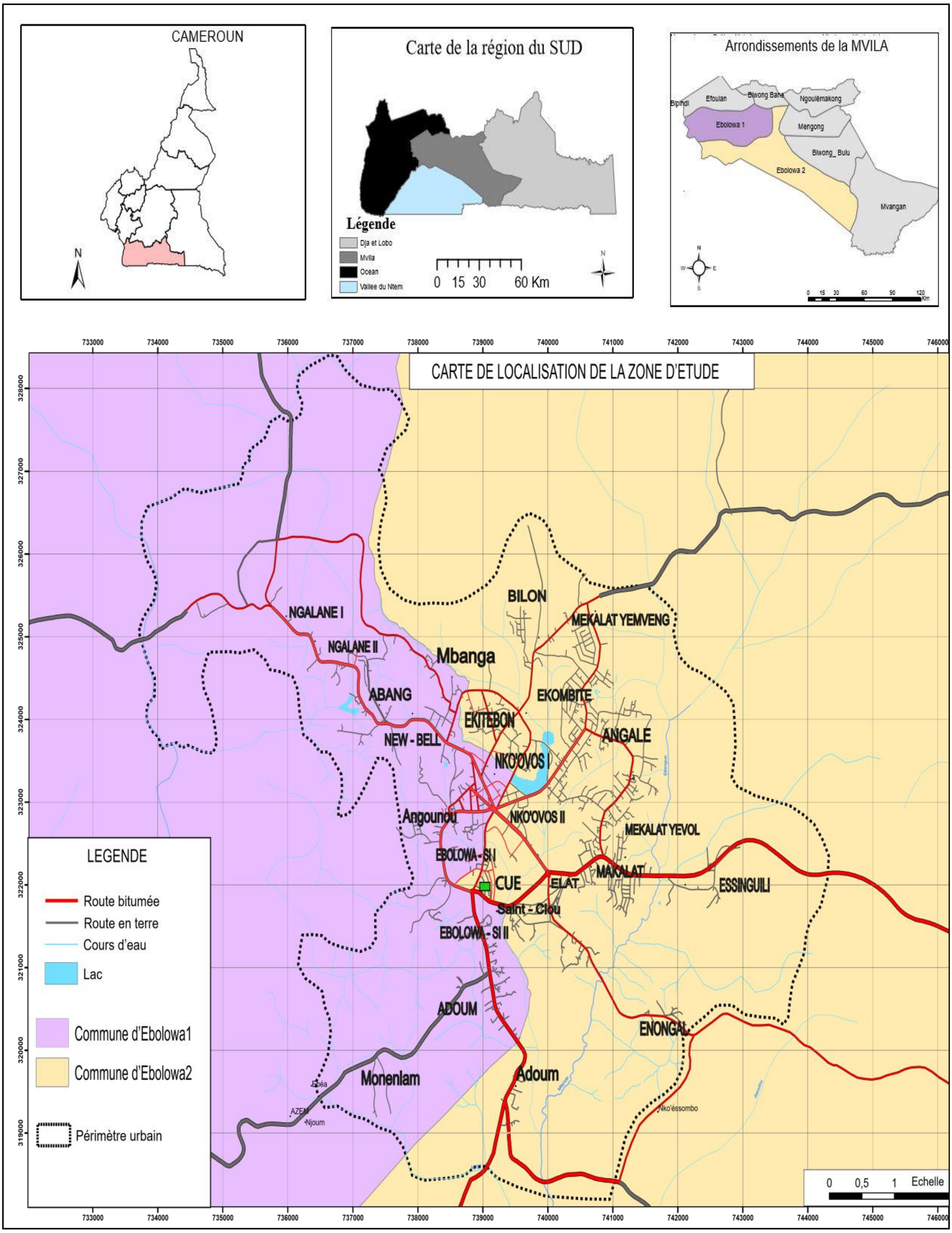

Figure 1. Location of Ebolowa city (PDU, 2015)

At the administrative level, Ebolowa is a town headed by a Mayor elected by the major municipal councillors. Since April 2007, Ebolowa has had a new administrative organisation with the creation of the Urban Community of Ebolowa, which is subdivided into two borough municipalities: Borough Municipality of Ebolowa I whose head office is Ebolowa-Si 1 and Borough Municipality of Ebolowa II whose head office is Angalé. The urban area of Ebolowa is made up of 32 districts covering an area of 15,000 km^2.

2.1.1. Description of the physical environment

Climate

The department of La Mvila has a warm and humid equatorial (Guinean) climate characterised by four seasons: two rainy seasons (a large one, from mid-August to mid-November and a small one, from mid-March to mid-May), two dry seasons (a large one, from mid-November to mid-March and a small one, from mid-May to mid-August) with an average temperature of 25°C. The department's hydrographic network is made up of swamps and low-flow rivers, the most important of which are: Mvila, Tsangué, Lo'o, Menou'ou (PDU of Ebolowa, 2015).

Pluviometry

The South Cameroonian plateau is characterized by an annual rainfall of 1500 to 2000 mm while Ebolowa city has a rainfall of 1708 mm per year. Because of the climatic variations influencing rainfall, Ebolowa is called a bimodal rainfall zone.

Relief

The relief of the Mvila is dominated as a whole by hills and a monotonous succession of convex hills, the highest of which are Mount Ebolowa and the Ntem hills elevated at 1100 m above sea level (PDU Ebolowa, 2015). The Mvila department is covered with dense equatorial and stratified forest vegetation, consisting of shrubs, invasive tall grasses, large trees, undergrowth plants and lianas (PDU d'Ebolowa, 2015).

Pedology

As far as the soil is concerned, red ferralitic soils; yellow ferralitic soils on Gneiss cover most of the territory and a sedentary plain along the coast.

2.1.2 Description of the socio-economic environment

The population and housing censuses carried out in 1976, 1987 and 2005 estimated the population of Ebolowa City at 18,300; 34,900 and 65,000 inhabitants in urban areas respectively. From 2005 to 2010, the National Statistics Institute estimated that the population of Ebolowa is reduced from 3.5% to 2.6%, and ~~that it~~ should grow by 3.0% between 2010 and 2015. With the development induced by the 2011 agro-pastoral show, the population is growing steadily. According to the Ebolowa PDU (2015), its implementation should stimulate development in Ebolowa and the surrounding neighborhood. Thus, the population may grow up to a maximum rate of 4% between 2016 and 2035. According to the data of the Ebolowa PDU (2015) survey, the town of Ebolowa has an average of 5 persons per household, for a total of 20,045 households in the urban area.

Urban typology

The Ebolowa PDU (2015) defines four levels of housing in the city and their characteristics: **i)** High standard housing: ~~is~~ characterized mainly by urban planning and building regulations, modern architecture, final and valuable building materials, connections to water and electricity networks, modern sanitation facilities. In the Ebolowa city, this observations are applicable for quarters such as: Angalé, Bilon, Ekombité, John Holt, Mekalat Yevol for the most part, and a small part of Mekalat Yemveng under occupation. **ii)** Medium standing housing: mainly characterized by modern architecture, ordinary final building materials, connections to water and electricity networks, internal toilet facilities, sewage disposal by septic tank. In Ebolowa city, the quarters concerned are: Nko'ovos I, Ebolowa Si I, Ebolowa Si I, Enongal, and Mekalat Yevol **and iii)** Low-standard housing: ~~is~~ characterized by any kind of architecture, final or semi-final building materials, all types of lighting, external toilet facilities, sewage disposal in nature. In this category, the quarters concerned are: New Bell, Nko'ovos II, Amang, as well as occupied swampy areas.

Sector of activity

According to a survey of households in the Ebolowa city carried out by the urban council, the economic activity is generally divided into four sectors: i) The primary sector, which includes all activities which purpose is the exploitation of natural resources (agriculture and extractive activities) (26.9%); ii) The secondary sector, which includes all activities that transform natural resources into more or less elaborate products with a view to adding value (12.4%); iii) The tertiary sector is a vast field of activities ranging from trade to administration, transport, financial and real estate activities offered by the private and public sectors (53.1%) and iv) the quartenary sector which designates advanced high technology and research activities. The importance of the latter sector is an indicator of a strong economy (7.6%).

2.2 Data collection

The data comes from the documents consulted and the information collected in the field according to the objectives of the study. Documentary research is a step that has made ~~it~~ possible to obtain basic information relating to the subject being dealt with. This documentation consisted in the collection and analysis of articles, dissertations, theses concerning the management of sewage sludge and related topics in Africa in general and Cameroon in particular. In addition, field data was collected through survey sheets, interviews, collection of sludge samples and their analysis in the laboratory.

2.2.1. Development of data collection tools

In order to collect information on the sewage sludge management system in the town of Ebolowa, materials in the form of tools have been developed. These are: i) the household survey questionnaire (379 copies) which allowed the collection of data on the recovery rate in sewerage works, the typology of the works, the emptying practices and the places where the sludge wastes are disposed of; **ii)** the structure survey questionnaire (hotels, motels, prisons and health centers) with which data related to the sanitation coverage rate in these places as well as their typology were collected and iii) the interview guide with council officials.

Sampling

The sampling method used for the household survey is the probabilistic method, which is based on the random selection of population units (Fellegi, 2003). The probability sampling technique used is systematic sampling which consists of selecting units at regular intervals from the target population. Households were selected at an interval k, also known as the number of steps with
k= N/n where N represents the number of households and n the sample size.
Determination of sample size
The sample size was determined by the following formula from (Fellegi, 2003):

$$n = \frac{\left(p * (1-p) + \frac{e^2}{Z^2}\right)}{\left(\frac{e^2}{Z^2} + p * \frac{(1-p)}{N}\right)} \qquad (1)$$

With: P_max = 0,5 Reliability level = 95%. So according to the table of the reduced centred Normal Law: Z = 1.96 Margin of error (e) = 5%. Number of households (N) and sample size (n)
Then the sample size will be: n= **379** households. Thus, the number of not respected is: k= 20.045/379=53

Administration of data collection tools
Data collection took place at the household and structural level.

Questionnaire surveys

The surveys consisted of asking the target persons a series of questions on the basis of questionnaires. This method was used to analyze the practices and perceptions of the management of faecal sludge by the populations, the working conditions of the faecal sludge operators, and to determine the number of users of sanitation devices within households for the quantification of the sludge produced. The surveys concerned households and structures. The household surveys, which took place from 23 March to 20 April 2020, after having received authorization from the Mayor of the city for data collection, gave an idea of the sanitation situation in the city, and provided information on the equipment of households with sanitation facilities, as well as their practices in terms of management of emptying sludge. The household questionnaire was addressed primarily to the head of the household or any person able to provide information on the households. The indirect survey technique was used to fill in the questionnaires: the interviewer asked the respondent questions and noted the answers on the questionnaire form. The facility surveys were carried out at the same time as the household surveys by the same interviewers using the same tools. Their main purpose was to list the types of sanitation facilities available at these sites and the management of these facilities. These surveys concerned structures in the city such as: hotels, motels, prisons and health centers.

Interview approach

The interview sheets developed for the interviews included both open-ended and closed-ended questions. The interview sheets were sent to the Technical Service in charge of hygiene and sanitation at the EUC level and to the persons in charge of hygiene issues at the Town Halls of the two Communes. The aim of these interviews was to collect information on the contribution of these services in the management of faecal sludge in the town. These different interviews allowed us to have a wider vision of sludge management in the town and to have an overview of the different actors involved in FSM in Ebolowa and their roles.

Direct observations

In addition to the surveys, field visits were made and consisted of field observation of FS evacuation practices by households during which photographs were taken.

2.2.2 *Qualitative characterization of sewage sludge Origin of the analyzed sewage sludge*

The faecal sludge analyzed comes from the traditional full-bottomed latrines and septic tanks that are the main excreta collection devices in the town of Ebolowa. A total of ten (10) FS samples were taken from all of them, with 5 samples per type of structure considered. Two (02) composite samples were subsequently obtained after mixing the five samples corresponding to each type of structure. To do so, equivalent quantities (500ml) of FS were mixed in a 5 liter container, after homogenization, a volume of one liter was taken and transported to the laboratory for analysis.

Sludge removal

The sampling and analysis of the FS in the laboratory made it possible to determine the essential characteristics for the town of Ebolowa. Given the variability of the sludge, it is essential to take as many samples as possible in order to obtain meaningful results. Ten FS samples were taken in jars of 500 ml capacity each. In order to carry out a representative sampling, the latrines for sampling were chosen with the concern to vary the geographical areas within the same commune and to favour latrines with pits at least 75% full. Samples were taken on 5 June 2020. They were taken directly from the pits and from the latrine opening. The material used for this purpose, designed by Letah et al (2016), was a metal bar one (01) meter long, 3cm in diameter and weighing 10kg, at the end of which was welded a hollow metal box 10cm in diameter and 20cm high. This box is located at the lower end of the metal bar and is used to collect the sludge when the device is introduced into the pits. The upper end is connected to a string measuring more than 15 m long. The use of the twine makes it possible to bypass the hazards that may be due to the great depths of the investigated structures. The 10 kg metal bar made it easy to bury it in the faecal matter of the pits and also to homogenise the faecal matter in the pits when the sludge was collected. Without forgetting the personal protective equipment (gloves, boots, buckets, coveralls, nose mask, etc.) for the protection of the sampling personnel.

Technique for sampling and analysis

Sampling was carried out according to the methodology described by Dodane et al. (2011), which takes into account a number of parameters, including: i) non-destructive intervention of the sanitation devices during sludge collection via the latrine opening; ii) cleanliness and easy cleaning after the sampling operations; iii) choice of sampling depth. The faecal sludge was collected by inserting the sampling device into the pits through the opening of the latrine. Sampling was carried out by following the steps described below:

1. Introduce sampling material through the hole in the latrine slab;
2. Vigorously agitate the sampling area ;
3. Extract a sample fraction (about 0.628 l) ;
4. Decant into 500ml watertight polyethylene jars for easy transport;
5. Store in a refrigerated cooler the sludge collected to the laboratory for analysis.

All the jars have been clearly identified with a felt pen and a clearly visible label to indicate the type of material (sewage sludge) they contain, the work where the sampling took place, the municipality, the district and the date of sampling. The collected sludge was then mixed and the samples were extracted in 1-litre jars and transported to the laboratory for analysis.

Analysis of sewage sludge

The samples taken were transported to the laboratory of the WasteWater Research Unit at the University of Yaoundé 1. The analyses concerned the physicochemical and bacteriological parameters of the sludge including: pH, temperature, dry matter (DM), dry volatile matter (DVM), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), electrical conductivity, salinity, ammonium ions (NH_4^+), nitrate ions ($N0_3^-$), phosphate ions (PO_4^{3-}) and faecal coliforms (FC). The physical parameters of the water such as pH and conductivity were measured using a multi-parameter method. BOD_5 is determined by the respiratory method using a BOD meter placed in a BOD_5 incubator. COD is determined by oxidizing oxidizable materials, biodegradable or not, for two (02) hours, in an acid medium, by the excess of potassium dichromate. Nitrate is determined by the Nitravers 5 method. Ammonium was determined by the Nessler method. The bacteriological parameters, in particular faecal coliforms, were determined using the membrane filtration technique and enumeration according to the protocol described by Rodier (2009).

Quantification of sewage sludge

Knowledge of the quantities of faecal sludge (FS) produced is essential for optimal FS management. For municipal authorities and public institutions, it allows planning of all management components and for private organizations and companies, it allows market evaluation. Four (04) groups of methods for evaluating the quantities of FS produced at the scale of a locality can be found in the literature. These methods are recommended, according to the need, to one of the actors (planner, technician, emptying operator) in the management of faecal sludge. However, they require data that is notalways available without an in-depth study or recurrent statistics. In this study, the specific production method based on the sludge accumulation rate is the most suitable for a simple and quick estimation of the quantities of FS produced in a locality. The evaluation of the rate of accumulation or specific production of sludge in pits is generally done by successively measuring the height of sludge accumulated over time using a rule designed for this purpose (Blunier et al., 2004). The quantification of sludge from sludge accumulation rates is given by equation (2).

$$Q = 365.\sum_{i} P_i \cdot \frac{q_i}{1000} \quad (2)$$

Q: annual quantity of sewage sludge (m^3/year);
i: type of structure (traditional latrine, improved latrine, septic tank, etc.)
Pi : number of people using the type of work i ;
qi: sludge accumulation rate in structure i (l/day/inhab).

2.2.3 Sizing a sewage sludge treatment plant

This part is closely related to the characterisation and quantification of the sludge produced. In fact, the dimensioning first takes into account these two elements. A sludge treatment plant for an agglomeration includes a treatment chain whose complexity depends on the degree of treatment deemed necessary. Justification of the choice of the treatment process to be used for the town of Ebolowa: the FS treatment process chosen for this study is the macrophyte planted drying bed (MPDB). Although the majority of the MPDB treatment of FS has only been tested in pilot plants, the purification performance of the system has been demonstrated by several authors (Kengne Noumsi, 2006). The quality of the sludge obtained by this treatment allows the direct use of dewatered sludge in agriculture without additional treatment. In addition, the plants could also be valorised. Indeed, they are good fodder for animals (Kengne Noumsi, 2006). The same author highlights the choice of the species *Echinochloa pyramidalis* as one of the plants with high fodder potential that could be used on the station. Thus, the planted drying bed treatment of *Echinochloa pyramidalis* is the one that seems best suited to the context of Ebolowa, where one of the main sectors of activity is agriculture. This process would allow:

1. treatment of sewage sludge;
2. the reduction of diseases related to faecal peril;
3. obtaining quality amendments for farmers;
4. generate income from the sale of fodder for the animals;
5. job creation on the station.

2.3 Data processing

The analysis of the survey forms was carried out using Ms-Excel 2013 software. With the help of Excel software, the data entered was cross-referenced in order to extract the relevant information. The location map of the study zone was produced using Arcgis 10.2.1 software. The data collected during the interviews were retained for the future after cross-checking with the other actors and during field visits. The data processing made it possible to identify trends and useful information for the elaboration of this end-of-study report.

Table 1 summarises the data processing procedures.

Objectives	Data	formulas	Variables
Characterise collecte sludge	Dry matter	$MS = \frac{M3-M1}{M2-M1} * 100$	MS: dry matter (%) M1: crucible empty mass (g) M2: gross sludge mass (g) M3: mud mass after drying (g)
	Dry Volatile Matter (DVM) (%)	$MVS = \frac{M3-M4}{M3-M1} * 100$	M4: sludge mass after drying (g)
Sizing a sewage sludge treatment plant	Truck opening area (S) (m)	$S = \frac{Pi * D_2}{4}$	*Pi*: constant 3.14 D: Diameter of truck opening
	Drain rate (QV) (m 3/s)	$Qv = S * Vm$	Vm: maximum speed (m/s)
	Total width of the air gap through the grille (w) (m)	$w = Su / Vp$	
	Number of spacings (N)	$N = \frac{w}{Es}$	Es: spacing between bars (mm)
	Number (Nb) of bars	Nb= (lg-Es)/(Es+Eb) (	lg: width of the grid (m) Eb: bar thickness (mm)
	Coefficient clogging of	Eb / (Eb+Es) (.15)	
	FS (CMS) (Kg/m3)	CMS = [MS (%)]*10	DM (%)]: concentration of DM in Kg/m3
	Total annual load in MS (TC)	CT = CMS*QB (17)	CTin Kg MS/year
	Total area required for beds (ST) (m2)	ST= CT /CS (18)	CS: admissible surface load in Kg MS/m2/year
	Surface of a bed (SL) (m2)	SL= L*1	Bed length in m Bed width in m
	Number of beds (N)	N = ST/ SL (20)	
	Sludge volume per bed (LV) (m3)	VL = e* SL (21)	e: thickness of sludge in the bed in m
	Bed depth	H+R+e (2 2)	H: height of the gravel pack in m A: revenge in m
	Useful screen area (Su) (m2)	$Su = Qv / Vp$	Vp: speed of passage between the bars
	Daily flow to be percolate treated (Qp) (m³/d)	QP = P x Qj (23)	QJ: Average daily flow rate (m³/D) P: Proportion of percolated volume (%)
	Useful area of lagoons (Su)	SU = QP/ (Ts*E/1000) (24)	Ts: length of stay (J) E: Sludge spreading time(J)

Table 1. Recapitulation of data treatment procedures used

III. RESULTS

3.1 Diagnosis of sanitation systems in the town of Ebolowa

3.1.1 Status of household occupants

The heads of household surveyed in the town of Ebolowa are predominantly tenants (45%) of their dwellings, compared to 55% owners (Figure 2).

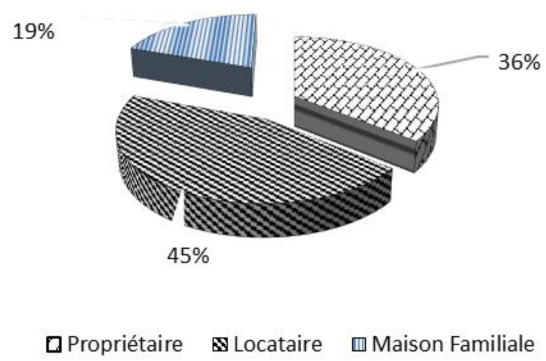

Figure 2. Land status of occupants

Among the owners, 19% are in family dwellings. The predominance of renter households (45%) is explained by the fact that the investigations are carried out in urban areas where the heads of households do not always own their dwelling; this may have an impact on the decisions that need to be taken when filling the sanitation system, as some of them say that they always call on the landlord if there is a problem with their system. On the other hand, as Ebolowa is a primary town, it happens to be the village of some people, which explains why 19% of the respondents live in family homes.

3.1.2 Housing standards

The study shows that three main types of housing (Figure 3) were identified in Ebolowa town, depending on the status of the households, including low-standard housing (36%), medium- standard housing (42%) and high-standard housing (22%).

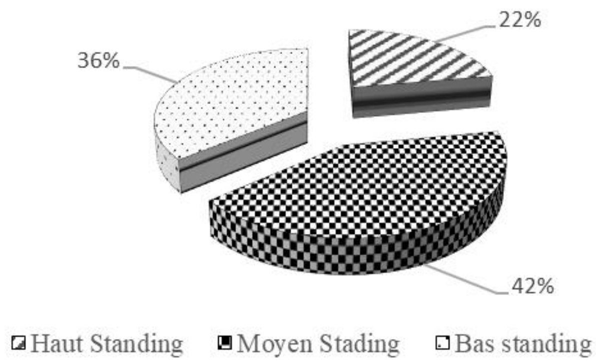

Figure 3. Presentation of occupants' standing

The standard of housing has an influence on the type of structure found in households. In high-standard dwellings where the population has a high income there are usually septic tanks connected to the water network. In this type of housing, one can find dwellings with both a septic tank and a latrine (which can be used in case of a water cut). On the other hand, in low income housing where the population has a low income, there are traditional latrines covered with cement or wooden slabs, and gun latrines for those in flood-prone areas that discharge their contents directly into the stream. These results are similar to those obtained by Defo et al (2015) working on the collection and disposal of faecal sludge in the town of Bafoussam.

3.1.3 Status of interviewees within households

The majority of the people surveyed are the heads of the household (51%), followed by the women in the household (43%) and the children in the household (6%) (Figure 4).

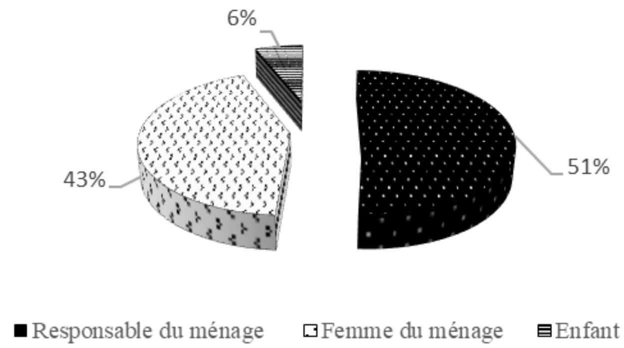

Figure 4. Respondent status within the household

3.1.4 Level of education of the interviewee

Half of those surveyed have a secondary level of education (50%), compared with 17% with a higher level of education, 17% with a primary level and only 3% with no level (Figure 5).

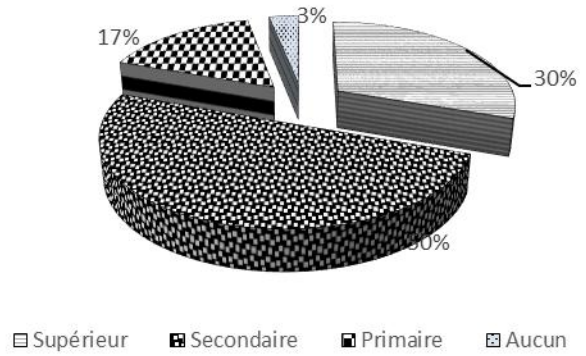

Figure 5. Level of study of respondents

The level of education of the respondents influences not only their understanding of the subject of study, but also the level of participation in the survey.

3.1.5 Household size

The average household size, i.e. the number of people living permanently under the same roof, is seven, with a minimum of six and a maximum of ten (Figure 6).

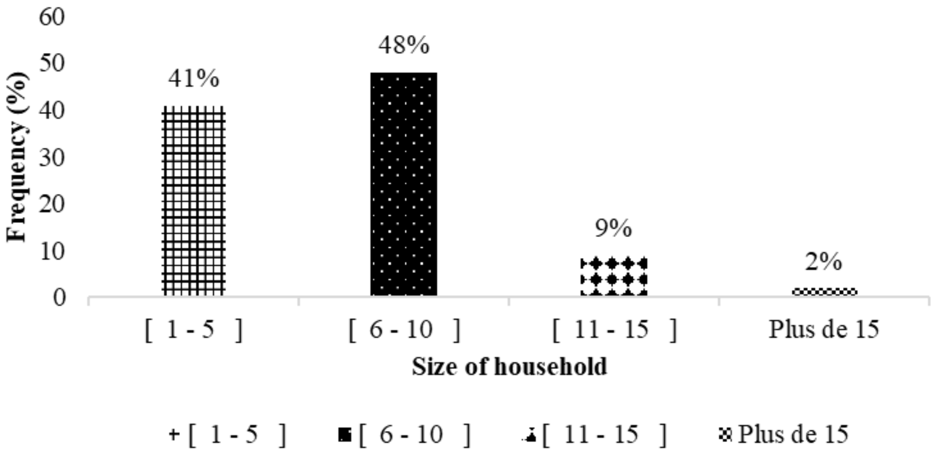

Figure 6. Size of household

The resulting variability in household size and within the study area is thought to be explained by the ethnic diversity of the populations that influences family planning (Ambassa, 2005). According to Bakary (2000), working on the impact of autonomous sanitation systems on water resources in informal settlements in Yaoundé, household size varies somewhat according to the urban fabric. Indeed, Buckley et al (2008) showed that the number of users of a latrine plays a major role in the rate of accumulation of faecal sludge, as an individual would produce between 0.12-0.40 litres of faeces and 0.6-1.5 liters of urine per day, which corresponds to an average of 110 liters of faeces and 440 liters of urine per person per year.

3.1.6 Typologies of household excreta collection systems

According to survey results, the predominant sludge collection devices in households are traditional full-flush latrines (41%), followed by modern toilets with septic tanks (31%), pour-flush latrines (14%), VIP latrines and barrel latrines (6%) respectively, and 2% have no sanitation facilities at all (Figure 7).

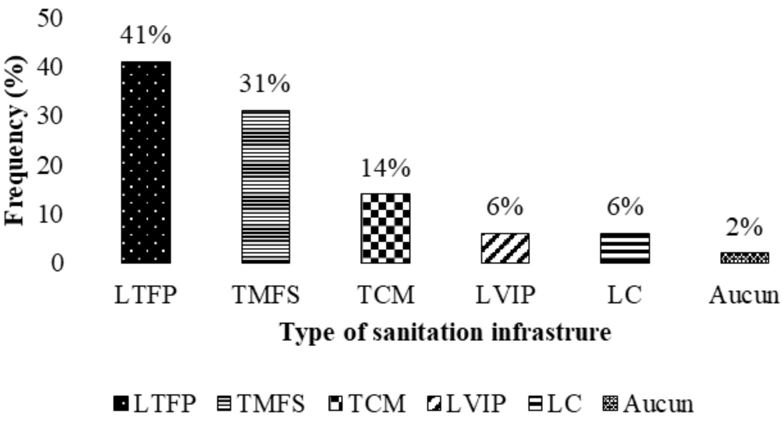

Figure 7. Typology of collection systems

However, 22% of the households surveyed own two (02) sanitation facilities. Most of these sanitation facilities are moderately equipped (41%). In addition, 27% of these facilities are well-developed and 32% are not developed. Autonomous sanitation is the predominant system in the town of Ebolowa, with the main structure being the traditional full-bottomed latrine (41%). Similar results were obtained by Defo et al (2015) for the city of Bafoussam where they showed that the full-bottomed latrine is the main method of excreta disposal with 59% and 76.1% respectively. This type of structure is the most widespread in Sub-Saharan Africa (Franceys et al., 1992, Eau Vive, 2010). The main drawbacks for this latrine are odour and fly proliferation and it is subject to high health and environmental risks. There is also a high risk of groundwater pollution because it is deep and not watertight. The use of concrete as a construction material for the latrine slab (83%) is explained by the desire to make the latrine watertight in order to limit the dispersion of a highly pathogenic product, excreta. Indeed, Chaggu (2004) working on the characterization of traditional latrines in Tanzania showed that about 70% of the latrines investigated had a concrete superstructure and Jinkens et al. (2014) working on the importance of using adequate sanitation systems mentioned that one of the keys to preserving the health and hygiene of people in developing countries is the use of an appropriate excreta storage device. Respondents' opinions are almost divided on the use of water by households for excreta disposal. In fact, 59% of these households use water to flush excreta, compared to 41% who do not. It was noted that of these different percentages, those using water are in the majority because they are in urban areas.

The high rate of water use for excreta disposal (59%) is said to be due to the fact that the majority of these latrines are water-operated and some are connected to a water supply network, while others are not. Indeed, non-collective sanitation technologies can be wet or dry. Wet technologies need to have water in the concession in order to work. However, 41% of the devices that do not require a permanent source of water for excreta disposal are called "dry latrines". Indeed, Lewis et al (1982) working on the risks of groundwater pollution from on-site sanitation systems in developing countries mentioned that traditional latrines are particularly appropriate when water is scarce and where the groundwater table is low.

3.2 Analysis of the faecal sludge management in the city of Ebolowa

3.2.1 Recommended solutions when filling the sanitation system

The choice of the option to be undertaken when filling the device is decisive as it influences the quantities of sludge that can be discharged to a sludge treatment plant. In the entire population surveyed, 43% of the households surveyed opted for emptying. However, 23% of the households proposed the construction of a new device, while 12% suggested the use of a product such as carbide, ash and lime to reduce the volume of sludge in the device and 22% suggested other solutions (calling on the landlord, moving) (Figure 8).

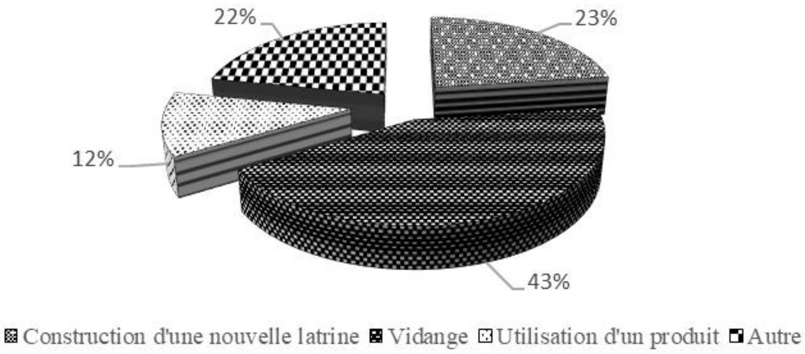

Figure 8. Current applied solutions when the sanitation system is full

The proportion of households that plan to build a new toilet if the old one is filled is 23%, with some reporting the non-existence of an emptying service in the town of Ebolowa (54%) and others mentioning the problem of the cost of emptying (46%) coming from Yaoundé. However, the option recommended in case of filling the structure varies according to the sanitation system (Figure 14).

Indeed, for those households with traditional and Improved latrines (VIP), the construction of a new latrine predominates by almost 70%. For those households that choose to build a new facility, the cost of building a new latrine is lower than the cost of emptying it. They say they spend about 3 000 (three thousand) CFA Francs per meter of excavated earth, i.e. about 30 000 (thirty thousand) CFA Francs to dig a structure about 10 m deep and CFAF 20 000 to build the concrete slab and the superstructure, i.e. a total of 50 000 (fifty thousand CFA Francs). Nearly 80% of households with septic tanks and hand-flush toilets opted for emptying (Figure 8).

3.2.2 Criteria for choosing mechanical emptying

The households surveyed prefer mechanical emptying (75%). Only 25% opt for manual emptying by family members. Among the households that opt for mechanical emptying, the first criterion that is highlighted is the quality of the service that should be provided to them (Figure 9).

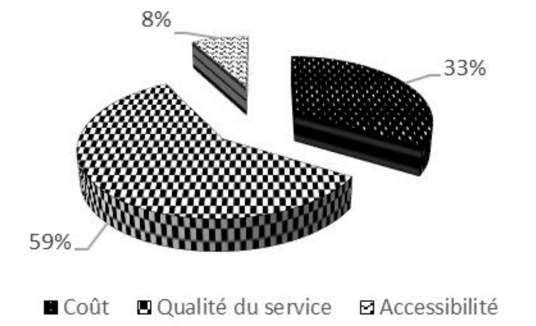

Figure 9. Selection criteria for mechanical emptying

In fact, almost 59% of the households interviewed stated that the quality of the service would be the first criterion that should lead them to opt for this method of emptying. On the other hand, 33% and 8% opt for cost and accessibility respectively. The survey shows that only 2% of households have emptied their sanitation systems (or more precisely their septic tanks), compared to 98% who have never done so (all works taken together). This is linked to the fact that for a number, they change their pit every time it is full; this practice is more related to traditional latrines, and for the rest they have new pits and sometimes these are not full. The 2% of households that have already emptied their pit report that they have used manual emptying for some and mechanical emptying for others. The manual emptying that is most common here is done by family members themselves. The fact that manual emptying is the most practiced would be due to the fact that the Community lacks a service or provider for emptying. The equipment used for manual emptying is outdated. Emptyers are usually equipped with old shovels, ropes, buckets, wheelbarrows and the emptied sludge is dumped behind the house into the bush. On the other hand, households that have already carried out mechanical emptying say that they have taken advantage of private trucks from the city of Yaoundé to carry out the emptying of structures such as hotels and the regional hospital. As these operations were carried out several years ago, the interviewees say they do not remember how much money was spent.

3.2.3 Willingness to pay for an emptying by households

Households were asked about their willingness to pay for an emptying of their home and various sums were recorded. Thus, minimum costs ranging from 5000 to more than 50,000 FCFA are proposed: 45% propose costs ranging from 5 000 to 10 000 FCFA, 25% of households propose 15 000 to 25 000 FCFA, 20% propose 30 000 to 50 000 FCFA and 10% are in favour of paying costs of more than 50 000 FCFA (Figure 10).

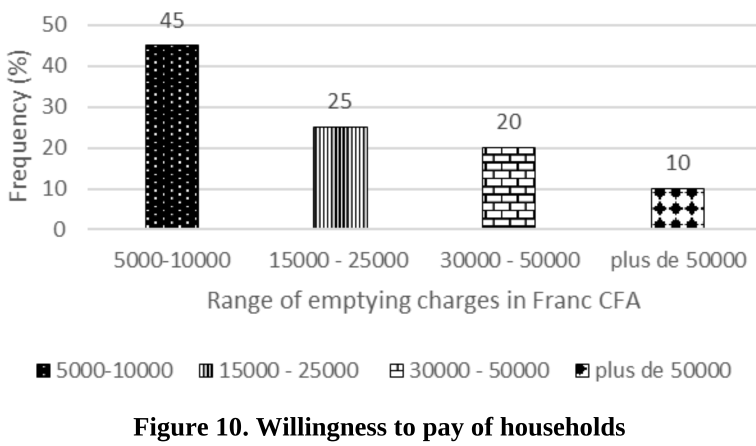

Figure 10. Willingness to pay of households

Almost half (45%) of the households surveyed would like to pay for mechanical emptying at a lower cost. The reasons given by the households are mostly financial, as they consider the price of an emptying service from the providers who come from Yaoundé too high. These households propose costs that take into account their financial capacity based on their level of income, and this situation can force them to empty their pits themselves, to the detriment of their health, or not to empty them at all. On the other hand, 10% are in favour of paying amounts higher than 50,000 CFA francs because they say they have already had to pay for an emptying service in cities such as Yaoundé where the average price charged is 80,000 CFA francs (Berteigne, 2012). These results show the willingness of the population to pay for emptying services.

3.2.4 Surveys of non-household structures

From the interviews carried out with the structures and services (Hotel, Regional Hospital, Urban Integrated Health Centre, Ebolowa Urban Council, Central Prison) the information recorded in Table 3 emerges. It follows that these structures have already declared having used a mechanical emptying service and have paid variable costs for this service ranging from 200 000 FCFA to 300 000 FCFA. These high costs can be justified by the fact that the emptying trucks are privately owned and operate from the city of Yaoundé, 168 km from Ebolowa. While the households interviewed in the surveys say they have had recourse to manual emptying because of the non-existence of an emptying service in the city.

Table 2 presents the results of the surveys of facilities and services.

Structures	Capacity reception	Type of sewerage works	Number of latrine	Volume (M3)	Year of stake in place	Number of drains carried out	Date of last oil change	Emptying mode used	Cost of emptying
MOTEL	10	TCM	12	8	2009	0	/	mechanics	/
	8	TCM	8	7	2001	1	/	mechanics	unknown
	15	TMFS	16	10	2015	0	/	mechanics	/
EUC	10	TMFS	1			0		mechanics	/
PRISON	**200**	**LCM**	**14**	**7**	**1935**	1	more than years old	mechanics	200 000
						several	less than 6 months 3	Manual	works held
HOSPITAL	162	TMFS- LVIP	50	/	1962	several	more than 10 years old	mechanics	/
	20	TMFS-LVIP	4	/	1970	/	/	mechanics	/
HOTEL	20	TMFS	24	30	2010	0	/	mechanics	/
	47	TMFS	52	45	2006	0	/	mechanics	/
	250	TMFS	260	60	2010	several	less than 6 months	mechanics	300 000
	115	TMFS	120	45	2008	several	less than 6 months	mechanics	200 000

Table 2. Results of survey conducted in different structures and services

EUC =Ebolowa Urban Council; TCM=Toilet with Manual Flushing System; TMFS- =Modern Toilet with Septic Tank; LVIP=Improved Latrines; LCM=Latrine with Manual Flushing

3.2.5 People's perception of sludge management

Throughout these household surveys it was found that there was total household dissatisfaction with Faecal Sludge Management (FSM) in Ebolowa. For this reason, it was necessary to determine the shortcomings in the FSM chain, i.e. emptying, evacuation and treatment. The problems related to the emptying, evacuation and treatment of FSM are of a financial, material and organisational nature. The majority of households surveyed have a very low savings capacity. There is no emptying service, which means that emptying costs are high because the providers of this service have to come from the city of Yaoundé and from a treatment centre for the recycling of household waste. The respondents ask for help from the Urban Community and the town halls of the two communes of Ebolowa to improve their organisation, in particular by setting up an emptying service in the town, by raising awareness of FSM, by setting up a health brigade and finally by repressing bad behaviour.

3.3 Quantitative and qualitative analysis of the sludge produced in the town of Ebolowa

3.3.1 Quantity of sewage sludge produced

Based on the survey results, 10% of households with dry latrines and 80% of those with wet water- based systems said they would be willing to empty the latrine if it was filled (Table 3).

Types of latrines Settings	Dry latrines	Water powered device	Total
Percentage	47	45	
Number of users	47 106	45 101	92 207
Specific production (l/hbt/D)	0,2	1	1.2
Sludge produced (m3/D)	9	45	54
Sludge produced (m3/year)	3 285	16 425	19 710
Willingness to empty (%)	10	80	45
Sludge that can be emptied annually (m^3)	329	13 140	13 469

Table 3. Faecal sludge quantity produced

The daily amount of mud produced at Ebolowa is estimated at 54 m3/day and 19710 m^3 /year. The quantities of faecal sludge produced and likely to arrive in a treatment plant have been estimated at around 14 000 m^3/year. Estimation by this method has the advantage of being simple and quick because it does not require in-depth data or recurrent statistics as opposed to other methods. The use of this method isrecommended for decision-makers who are generally interested in quick and simple estimates for better decision-making (Koanda, 2006). The quantities of sludge produced are much lower than those produced at the Nomayos site in Yaoundé (51 247.56 m^3/year) and the "Bois des Singes" site in Douala (138 720 m^3/year) (Berteigne, 2012). This strong disparity could be justified by the high population density in each of these cities.

3.3.2 Physicochemical and bacteriological characteristics of the sludge analyzed

The characteristics of the collected and analyzed sewage sludge are presented in Table 4.

Settings	Septic tank sludge	Sludge from traditional latrines
T(oC)	26.7	27.3
pH	7.71	7.14
Conductivity (mS/Cm)	18.73	41.3
Sal (‰)	10.98	23.9
Nitrates NO_3^- (mg/l)	480	4075
Phosphates $PO4_3^-$ (mg/l)	116	112.5
Ammonium $NH4^+$ (mg/L)	383.33	1437.5
Chemical Oxygen Demand COD (mg/l)	3590	29130
Biochemical Oxygen Demand BOD_5 (mg/l)	160	2400
Dry matter DM (%)	1.43±0.2	11.36±0.14
Volatile dry matter VDM(%)	72.40±2.5	71.25±1.53
COD/DBO_5	22.44	12.14
Faecal Coliforms FC (FCU/100ml)	95x105	115x106

Table 4. Physico-chemical and bacteriological characteristics of faecal sludge samples studied

The temperature value for the pits is 26.7 ^{o}C and 27.3 ^{o}C for the latrines, and the pH of the sludge in Ebolowa town is 7.71 and 7.14 for the pits and latrines respectively. These parameters have roughly the same values for dry latrines as for septic tanks. Regarding conductivity, high values were recorded for traditional latrine sludge 41.3 mS/Cm and for pits 18.73 mS/Cm. Overall a high conductivity value reflects the richness of the analysed sludge in organic particles undergoing excessive mineralisation. Nitrate gave 480mg/l and 4075 mg/l and phosphate 116 mg/l and 112.5 mg/l for the pits and latrines respectively. A disparity was also observed in the COD and BOD_5 values of the FS of the on-site sewerage works. The COD and BOD_5 values of the collected sludge are 3590mg/l; 160 mg/l and 29130 mg/l; 2400 mg/l for septic tanks and latrines respectively, with a COD/BOD ratio of 22.44 for the tanks and 12.14 for the latrines. Similarly, the amount of ammonia nitrogen NH_4^+ follows the same trend as COD and BOD_5. It is 383.33mg/l and 1437.5 mg/l for pits and latrines respectively. Compared to septic tanks, dry matter is very high in traditional latrines. The amount of DM is 11.36% for latrines and 1.43% for pits. As for faecal coliforms, which are control germs for faecal contamination, they are 115x106(FCU/100ml) for latrines and 95x105(FCU/100ml) for pits. The quality of the analysed sludge is very variable depending on the device from which it was taken. The pH of the analysed FS is around 7 (neutral), which is in line with the MINEPDED (2019) discharge standard, which varies from 6 to 9. A pH outside the range 6 to 9 is indicative of a disturbance of the biological process, resulting in an inhibition of anaerobic digestion and methane production, which may be due to a variation in the hydraulic loads received by the sanitation devices (Strande et al., 2014). With regard to conductivity, the high value recorded in traditional latrines reflects the richness of the analysed sludge in organic particles undergoing excessive mineralisation, indeed Moussa (2005) showed that there is a relationship between conductivity and mineralisation; therefore, a conductivity >1000 µS/cm reflects excessive mineralisation of the effluents. The high COD/BOD ratio (>3) of Ebolowa sludge means that it is not susceptible to biological treatment. In fact, a COD/BOD ratio > 3 could be explained by the low biological activity of the micro-organisms included in the FS mineralisation process (Bassan et al., 2013; Letah et al., 2016). This low biological activity of microorganisms on biodegradability depends on how the latrine is used, e.g. use of disinfectants to reduce odours, plastic waste, sanitary napkins that reduce the contact surface of microorganisms with faeces (Still et al., 2012). The oxygen demand of the faecal sludge is an important parameter to monitor. The discharge of faecal sludge into the environment can lead to the depletion, or even exhaustion, of the oxygen content of surface waters and lead to the death of aquatic fauna (Strande et al., 2014). The slightly higher value of phosphate in pits compared to toilets may be due to the use of detergents and many cleaning products in toilet maintenance. If this sludge is dumped into the environment without prior treatment, it could lead to eutrophication and algae growth in surface waters. Ammonium and nitrate concentrations are higher in latrines than in pits. However, these two values are higher than the norm in both devices and can contribute by infiltration to the contamination of the water tables (nitrates lead for example to methaemoglobinaemia). For this reason, faecal sludge is a danger to the environment and the health of the population. Compared to the septic tank, the MOH of traditional latrines is very high. This is due to the high percolation of water in the latrine compared to that of the septic tank. Latrine sludge is less diluted than septic tank sludge. Furthermore, the septic tank is a modern pre-treatment facility (settling and digestion) for faecal sludge and it is understandable why it has lower pollutant concentrations than latrines. These results are similar to those of Defo et al (2015) for the city of Bafoussam. As for faecal coliforms, they are very high compared to the norm.

3.4 Presentation of the treatment plant

3.4.1 General presentation of the treatment process

The treatment system proposed by this study is the treatment of FS using a macrophyte-planted drying bed (MPDB). The development plan of the proposed process is as follows:

A reception facility: this is designed to facilitate the removal of gearboxes by emptying Lorries. It will be covered by a device equipped with three openings to avoid splashes and overflowing of the emptying sludge caused by the too high flow rates observed at the beginning of emptying. These openings will also allow several trucks to empty at the same time. This structure will also make it possible to regularly record the volume of sludge brought to the site as well as the possibility of sampling and visual inspection. The flow of the FS towards the screening channel as well as the transfer between the other treatment units will be done in a gravitational way in order to limit expenses.

A pre-treatment facility: the pre-treatment of the FS will be carried out by a screen which will be used to eliminate the coarse elements sucked up during the emptying of the pits (paper, plastic bags, and various residues) and thus protect the downstream installations. It mainly consists of removing all incoming solid waste. This work is periodically scraped with a rake by a worker and the screenings will be evacuated to a household waste treatment system.

A storage tank: this is designed to receive and store the day's sewage sludge before it is injected into the MSPLs. The volume of the tank must be large enough to be able to regulate the volumes of sludge received on site during peak periods.

Macrophyte planted drying beds (MPDBs): the solid-liquid sludge separation phase is carried out by the LSs before transfer to the percolate reception basin.
The percolate reception basin: this structure is designed to collect the liquid part of the sludge before its treatment.
Works for the post-treatment of percolate: This will be an assembly of 3 basins in series which will be used for the treatment of percolate by lagooning.

3.4.2 Characteristics of the works designed

Pre-treatment works

a) Reception work

Settings	Values	units
Volume of sludge that can be emptied (Vbsv)	37	m^3/d
Height (Hr)	0.8	m
Useful area (Su)	46.3	m^2
Length (Lr)	9.3	m
Width (lr)	5	m
Convergent zone length at the channel (Lzc)	1	m

Table 5. Dimensions of the reception basin

b) Screen

The screen opening diameter sized was 0.120 cm.

Truck opening area (S)	0,011	m2
Maximum speed at the exit of the truck (Vm)	4	m/s
Drain rate (Qv)	0,044	m3/s
Useful screen area (Su)	0,073	m2
Speed of passage between the bars (Vp)	0,6	m/s
Total width of the air gap through the grille (W)	0,122	m
Spacing between bars (Es)	30	mm
Number of spacings (N)	4	
Bar thickness (Eb)	10	mm
Width of the convergent zone at the channel (lzc)	0,162	m
Tilt angle Â	70	(°)
Grid height (H)	0,78	m
Grid width (lg)	0,16	m
Number of bars (Nb)	3	
Coefficient of clogging due to wastewater (C)	0,3	
Coefficient of clogging due to the size of the bars (Ce)	0,25	
Wet section (Sm)	0,13	m²

Table 6. Screen dimensions

c) Storage pit

The volume of the pit must be large enough to be able to contain the volumes of sludge received in the plant during peak periods (by 3 trucks) and even storage for about 2 days to allow the regulation of the volumes of sludge deposited by the emptyers and to ensure the regular feeding of the drying beds. On the basis that one tanker truck can hold a maximum of $15m^3$, a pit with a volume of 72 m^3 (diameter 7 m and height 4 m) is required due to a daily supply of 12 m^3.

Drying beds planted with macrophytes

The bed filter bed consists of a layer of gravel surmounted by a layer of sand of varying thickness and grain size. In this study, the design of the structures conforms to the dimensions given by Kengne Noumsi (2008), i.e. a 30 cm layer of coarse gravel (15≤d≤25mm), topped by a 20 cm layer of fine gravel (15≤d≤25mm), and on the surface a 15 cm layer of sand (15≤d≤25mm) in which the plants (*Echinochloa pyramidalis)* are transplanted.

Table 7 summarises the dimensions of the macrophyte drying beds at the plant.

Settings	Values	units
Sludge flow rate that can be treated (Qb)	13469	m3/year
Permissible surface load (CS)	200	kg MS/m²/year
Average MS concentration in the sludge (CMS)	128	Kg/m^3
Total annual MS load (TC)	1724032	KgMS/ year
Total area required for Beds (ST)	8620	m^2
Length of beds (L)	50	m
Width of beds (l)	20	m
Surface of a bed (SL)	1000	m^2
Number of beds (N)	9	Beds
Sludge thickness in the bed (e)	0.5	m
Sludge volume per bed LV	500	m^3
Revival of a bed (R)	0.8	m
Solid height (H)	0.65	m
Bed depth (PL)	2	m
Bed feeding frequency (F)	3	J
Sludge spreading time (E)	1	J

Table 7. Dimensions of drying beds planted with macrophyte

The cuttings will be taken from the riverside and must have at least two knots and be between 15 and 20 cm long. The dimensioning of the planted beds is based on the tropical experiment mainly reported by Kengne Noumsi (2006), in which an admissible load of 200 kg MS/m²/year is deemed possible, based on the experimental results and in a given context. In order to take into account rainfall and a phase of dewatering and then plant recovery during which not all the sludge can be sent to a bed, the feeding frequency will be twice a week, corresponding to one feeding day and three days of rest. They will be rectangular in shape with 1/2 slopes. The beds will be separated by 1 m and the percolating drainage network, bed feeding and aeration pipes will be made of PVC.

Secondary treatment of percolate by lagooning

The lagoons are 03 in number and are composed of several watertight basins operating in series. They will ensure a good level of operational reliability for the elimination of organic matter. The daily applied surface load is of the order of 4.5 g BOD_5 per m^2 of total surface area, which corresponds to a surface area of water bodies of the order of 4 to 6 m^2/EH. The sizing will be carried out based on the maximum traffic in the peak month. For the second and third lagoons, these two basins must be of similar dimensions and the total surface area of the two bodies of water must be equal to 2 m^2/EH. The height of water must be 1 ± 0.2 m. Their general shape can be quite variable according to the topographical constraints and the rules to be respected in order to obtain a good landscape integration.

Sludge spreading time (E)	1	J
Settings	Values	Units
Average daily flow rate (ADF)	37	m^3/d
Proportion of volume percolated (P)	50	%
Daily flow rate of the percolate to be treated (Qp)	18.5	m^3/d
Length of stay (Ts)	7	J
Useful area Su	2642.86	m²
Minimum depth (Pm)	0.1	m
Number of pools (Nb)	3	
Pool surface area (Sb)	881	m^2

Table 8 summarises the dimensions of the lagoons in the station.

In view of the dimensions of the structures selected, i.e. the reception and storage basins, the 09 drying beds planted with macrophytes and the lagoon basins, the right-of-way is approximately 1.2 hectares. An area of about 2000 m^2 should also be provided for co-composting with solid waste and a platform for a technical room. The total area will therefore be 1.5 hectares.

IV. DISCUSSION AND CONCLUSION

The study found that on-site sanitation is dominant in Ebolowa town. with a predominance of traditional non-reusable latrines (41%). These latrines are more or less well equipped. with a predominantly concrete slab (83%). concrete/parpa/brick superstructures (66%) and mostly water- based (59%). The sewage sludge system in the town of Ebolowa suffers from many shortcomings. In particular the structuring and financing. This sector has no specific budget line. Also. the municipality of Ebolowa has neither a technical service nor a sewage disposal service in the town. The absence of an emptying service in the town leads some households (23%) to change pits every time the other one is full and others to empty their pits manually (2%) themselves. to the detriment of their health. The quantities of sludge currently produced are around 20.000 m3 per year. Physicochemically and chemically. Ebolowa's sludge is variable both in appearance and quality. In addition. in order to preserve a treatment system using drying beds planted with macrophytes (*Echinochloa pyramidalis)* followed by lagooning for the percolate and co-composting of the solid fraction with household waste. a system of treatment by drying beds planted with macrophytes (*Echinochloa pyramidalis)* followed by lagooning for the percolate and co-composting of the solid fraction with household waste has been proposed. It emerges from this work that an area of 1.5 ha is required to build a sewage sludge treatment plant for the town of Ebolowa. One of the advantages of this method is that it offers the possibility of valorising the by-products. the dried sludge which can be used as organic fertiliser. and the plants in the beds as cattle fodder. The observations made in the field and the results obtained make it possible to make the following recommendations to the public authorities: i) Set up a functional system for the management of FS through institutional organisation and the drafting of laws adapted to the local context. ii) Institutional actors must ensure the application of specific regulations for the management of faecal sludge. iii) It is necessary to promote training. education and awareness-raising for municipal staff. the emptyers and the population on autonomous sanitation and management of FSM; iv) strengthen the capacities of the contracting authority and support the emergence of a local market; v) promote cooperation between the different actors involved in the management of faecal sludge; vi) establish financial administrative-technical management of a FSM system and vii) improve the functional state of existing structures through daily maintenance. The hygiene situation as perceived in this study led to the selection of two types of excreta sanitation works to be popularised in the town of Ebolowa. The existence of full and abandoned latrines in favour of new ones reinforces the pathogen complex linked to faecal peril. the pollution of soil water resources and the spread of odour nuisances in the districts of the city. Thus. in view of all the factors related to health. the prevalence of the type of habitat. the standard of living of the population. the mode of water consumption. and in order to respond above all to the expectations of this study. which proposes the installation of improved VIP-type double pit latrines and ECOSAN latrines as a work in progress. In addition. it is urgent to proceed with the construction of a controlled de-sludging site through the setting up of a sludge treatment plant in order to protect the environment and preserve the health of the population due to the uncontrolled dumping of faecal sludge and the development of a channel for the valorization of treated sludge.

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