



Quantification and characterization of faecal sludge from a tropical urban area: the case study of Douala, Cameroon

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ABSTRACT

Faecal sludge (FS) management is a challenging problem in low-income countries where the majority of the urban population relies on on-site sanitation systems. The design of treatment plants relies on accurate knowledge on FS quantities and characteristics. Due to the lack of information on the quality and quantity of FS in the Cameroonian context, this study aims at evaluating the quantity and the quality of FS produced at the city scale by mechanical trucks at the dumping site of “Bois des singes” in Douala. Quantification was done through enumeration of emptying trucks and emptying truck capacities during one-week period while in the laboratory, analyses of composite samples were performed by the determination of physico-chemical, bacteriological and parasitological parameters in samples according to the standard protocols. Results on the quantification of FS in the city of Douala revealed that the weekly volume of faecal sludge dumped in natural environment at “Bois de singe” is estimated at about 2,890 m³ with an average of 50 discharges per day by mechanical emptying trucks. Concerning the characterization of FS samples, FS exhibited high strength because of its higher concentration of organic, bacterial and helminth eggs loads. Therefore, there is need for proper health and environmental protection measures to prevent threats due to dumping of untreated faecal sludge into the environment after on-site sanitation technologies emptying by the construction of a treatment plant.

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Keywords: Faecal sludge management, treatment plant, FS quantification, FS characterization, tropical urban area, Cameroon.

INTRODUCTION

Faecal sludge (FS) management is still a challenge in densely populated urban slums of Sub-Saharan Africa (SSA) as 65 to 100% of households rely on on-site sanitation systems

that need faecal sludge management (Koottatep et al., 2001; Strauss et al., 2000; Tilley et al., 2014). On-site options can be more affordable and attainable than sewer systems to provide sanitation to urban populations (Dodane et al.,

2012; Koné, 2010). However, for adequate environmental and public health protection, a management plan is required for the collection, transport, treatment, end use and disposal of the faecal sludge (FS) from on-site systems. Collection and transport companies already exist in most African cities. However, there is a lack of proper infrastructure for the treatment of FS once emptied, and as a result, huge quantities of FS are disposed of directly into the environment (Cofie et al., 2006; Kengne et al., 2008).

In Douala, the economic capital of Cameroon, the majority of the population is served by on-site sanitation facilities including septic tanks, public toilets, VIP latrines, and bucket latrines (Bertheigne, 2012). These on-site sanitation technologies are not deep, the site being a coastal region with an altitude of less than 10 m above sea level, and are subjected to the rise up of underground water, all of which favours manual emptying. Sludge from on-site systems is collected and transported by private companies and dumped at the only current official faecal sludge dumping site:- 'Bois des singes', which is located near the mangrove close to the Wouri Estuary. At this site, untreated faecal sludge is discharged directly into the ocean without any treatment, thereby creating severe public health hazard, sight and olfactory nuisance and water contamination. To address this situation, the local authority, through the Douala Urban Council (DUC), is planning to construct two FS treatment plants in Douala, with the financial support of the World Bank. One of these FS treatment plant will be built in the current dumping site.

The design and sizing of FS treatment plants requires accurate data on FS characteristics and quantities. Unfortunately, such data are very limited or almost unavailable in Cameroon as well as in the city of Douala. This research work is a contribution to the study of FS generated in the city of Douala prior sizing and design of the coming treatment plants.

MATERIALS AND METHODS

Study site

The study was carried out in Douala, a coastal region and the economic capital of

Cameroon. The average temperature is 26.4 °C and the climate is the hyper humid equatorial type (Cameroonian type) with a single long rain season, particularly abundant and presenting local nuances moderated by the breeze of the sea (Feumba et al., 2011). The dry season extends from December to February and the rainy season from March to November. Douala receives approximately 4000 mm of water per year. Douala population is evaluated at approximately 3,000,000 inhabitants (BUCREP, 2012).

Quantification of faecal sludge at 'Bois des singes'

In order to quantify the sludge produced in the city of Douala so as to implement the oncoming treatment plant, the dumping activity have been observed at the 'Bois des singes', during a period of one week. At this period, the number and the capacity of each truck that passes through the check point and dump effectively the sludge at the disposal site was counted every day. This action was done each day from 6 am to 7 pm. At the end of this period, the total volume of faecal sludge discharged was evaluated using the following formula:

$$Q = \sum V_i^n$$

Q: is the total volume of the sludge discharged;

V_i : volume of faecal sludge in truck i ;

n : total number of trucks.

Faecal sludge characterization

Sampling method

In order to determine the characteristic of FS in the laboratory, seven composite samples were collected during one week between 6 am to 7 pm every day. From each truck reaching at the dumping site, 10 L of sludge were collected using a 15 L plastic bucket at the beginning, middle and end of the discharge process. These samples were then transferred in a 50 L buckets, stirred and 1 L of the mixture was collected and transferred in a bigger drum (100 L). The same procedure was done for each truck and at the end of the day the composite sample was obtained after stirring the sludge in the drum, of which 1.5 L was sampled for laboratory analysis with three

repetitions. The samples were transported in a thermostatic flask with ice cooler for laboratory analysis.

Samples analysis

Faecal sludge was analysed for electrical conductivity (EC), pH, salinity, total solids (TS), total volatile solids (TVS), chemical oxygen demand (COD), biochemical oxygen demand (BOD) and helminth eggs. Electrical conductivity, pH, and salinity were determined *in-situ* using a Hach HQ14d multimeter according to the manufacturer's manual. Total solids (TS) were measured using the thermo-gravimetric method by drying the sludge in an oven at 105 °C for 24 hours. Total volatile solids (TVS) were measured using a furnace at 550 °C for 2 hours. BOD was determined by incubating samples at 20 °C for 5 days. COD was determined through the dichromate reduction method and the complex read through a HACH DR 3900 spectrophotometer.

Data analysis

Data analysis was computed using the descriptive statistic in form of average and standard deviation.

RESULTS

Faecal sludge quantity

Truck capacity

A total of 41 trucks were found to operate in the city of Douala. These trucks belong to 36 private emptying companies. All of them are members of the AESL (Association of Emptiers and Sanitation of Littoral). These companies operate mainly within households and shared facilities (e.g. schools, markets, public and communal toilets).

The volume capacity of all these trucks ranged between 5 to 12 m³ (Figure 1). Trucks with 10 m³ were mainly represented in the study area with 14 trucks, followed by those of 8 m³ (11 trucks).

Trucks capacity numbers during the study period

The number of each truck capacity in the discharge site during the seven days of investigation was counted (Figure 2). The most frequent was trucks with a volume capacity of 10 m³ with 127 apparitions per week (37%)

followed by those of 8 and 7 m³ with 93 and 45 apparitions respectively. Trucks with a capacity of 6 and 5 m³ were counted only 13 and 10 times weekly respectively.

Total volume of faecal sludge discharged at "Bois des singes"

During the seven days of data collection at 'Bois des singes', a total number of 356 emptying activities were counted, which correspond to a total volume of 2 890 m³ when integrated in the formula of quantification. This volume corresponds to a daily volume of 413 m³ and an average emptying activity per day of 50 (Table 1). It also corresponds to a monthly average of around 12,523 m³, and an annual average of 150 693 m³ which can be rounded to 151,000 m³.

The periods of intense activity are Thursday and Saturday, period during which 66 and 72 discharge processes were recorded respectively, with volumes of sludge corresponding to 573 and 556 m³ respectively. Sunday is the period of low spill activity with 18 discharge operations.

Total volume of faecal sludge emptying and discharge per sub-division of Douala

Faecal sludge discharged on 'Bois des singes' originated from all five sub-divisions of Douala. The higher volume of faecal sludge (1,064 m³ i.e. about 37%) originated from Douala 1. The corresponding volumes for the other sub-divisions were respectively 446, 566, 427 and 406 m³ for the Douala 2, Douala 3, Douala 4 and Douala 5 respectively (Figure 3).

Constraint related to the mechanical emptying in Douala

The emptying activity in Douala faces many difficulties (Figure 4). In fact, according to emptiers, several constraints were noted, notably the road traffic (30%), police embarrassment (16%), the accessibility to households (14%), and other difficulties (12%) among which the presence of solid wastes in the pit latrines and the poor road maintenance.

Characteristics of faecal sludge

Physicochemical characteristics

The values for the major constituents analysed in the FS delivered to the dumping site, 'Bois des singes' by the emptying trucks

operating in Douala revealed that, there was not much variation in temperature (23.2 – 23.6) °C in all the samples, as well as in pH values which were slightly basic, varying between a pH of 6.2 to 7.3. These FS exhibited high variations in solids, organic and salt contents (Table 2). Indeed, on an average basis, Total solids (TS) and Total volatile solid (TVS) concentrations were respectively $1.9 \pm 0.6\%$ and $67.4 \pm 72\%$, while COD and BOD₅ concentrations were between 28.9 – 73.2 g/l and 1.1 – 1.8 g/l respectively which decreased as the amount of public toilet sludge emptied decreased. The biodegradability index of the sludge (COD/BOD₅) was 28. Ammonia concentrations ranged between 298.8 - 1310 mg/L (Table 2).

Faecal streptococci and faecal coliforms

The concentration in the FS samples was very high with mean concentrations of about 4×10^6 and 3×10^6 UFC/100ml for faecal streptococci and faecal streptococci respectively.

Helminth eggs

Results revealed a high variation of helminth eggs counts in raw FS (Table 3). The number of eggs varied from approximately 3000 to more than 8,000 eggs/L. Approximately 43% of the total egg counts belonged to *Tenia sp.* while 28% and 25% respectively were *Ascaris lumbricoides* and *Strongyloides stercoralis*, *Trichuris trichiuri* and *Trichostrongylus ovum* constituting the remaining 4%.

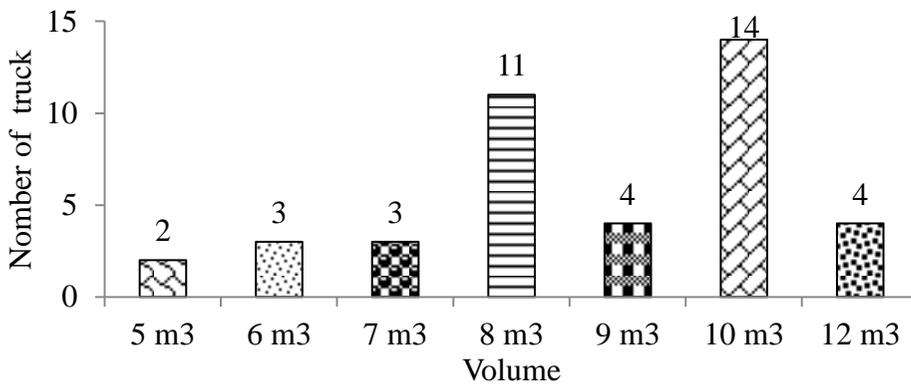


Figure 1: Trucks capacity in the study site.

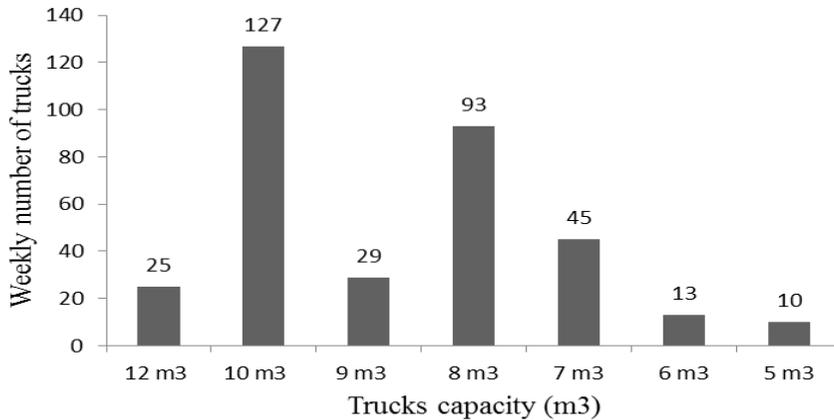


Figure 2: Weekly rotation of trucks.

Table 1: Daily volume of faecal sludge discharged in “Bois des singes”.

Periods	Daily volume m³	Number of discharged process
Tuesday 07 October 2014	398	46
Wednesday 08 October 2014	447	50
Thursday 09 October 2014	573	66
Friday 10 October 2014	384	46
Saturday 11 October 2014	556	72
Sunday, 12 October 2014	121	18
Monday, 13 October 2014	411	49
Total	2,890	347
Daily average	413	50
Monthly average	12,523	1,504
Annual average	150,693	18,094

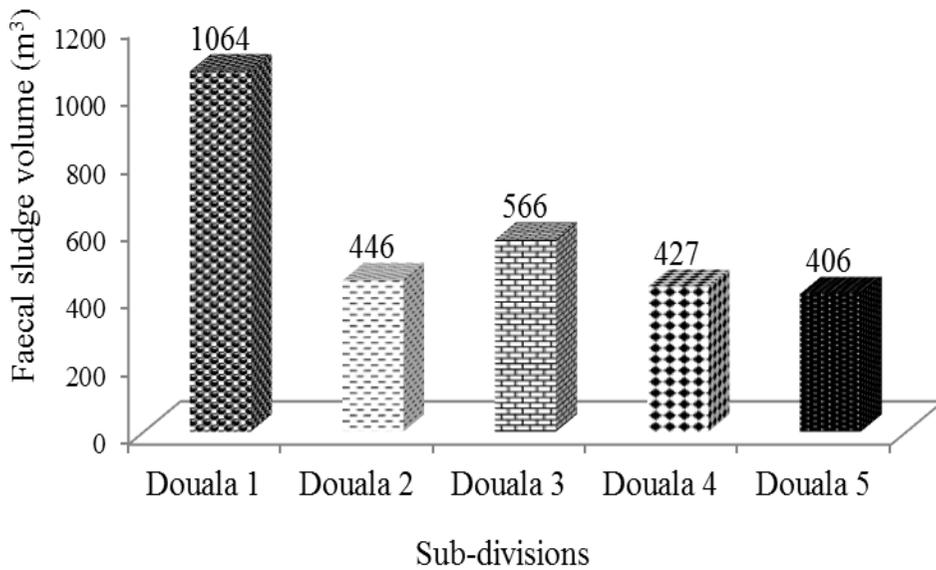


Figure 3: Faecal sludge volume discharged per Douala sub-division.

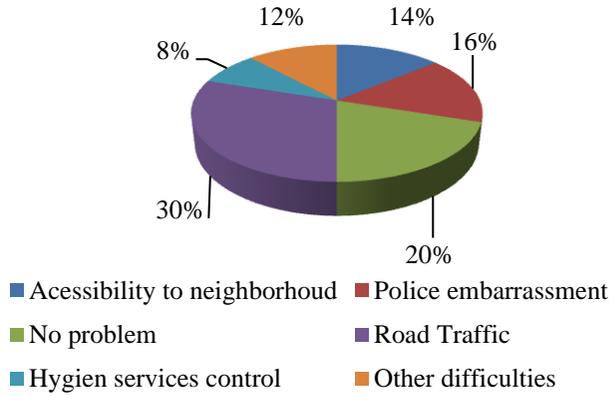


Figure 4: Difficulties faced by emptiers during their activities.

Table 2: Physicochemical characteristics of faecal sludge (n= 7).

Parameters	Mean	Standard deviation	Minimum	maximum
pH	6.6	0.3	6.2	7.3
Temperature (°C)	23.5	0.1	23.2	23.6
Conductivity (µS/Cm)	2,376.6	430.0	1,973.0	2,931.0
COD (mg/L)	39,925.7	15,034.6	28,900.0	7,3150.0
BOD ₅ (mg/L)	1,485.7	234.0	1,100.0	1,800.0
NH ₄ ⁺ (mg/L)	497.1	179.7	298.8	875.0
Sludge Indices (ml·g ⁻¹)	17.9	10.6	8.6	39.2
TS(g/L)	17.6	5,0	9.9	26.5
TVS(g/L)	11.9	4.0	7.3	20.3
MS (%)	1.9	0.6	1.0	2.8
MVS (%)	67.4	72	60.0	76.4
COD/MS	2.4	0.9	13	4.1
COD/BOD ₅	28	13.3	16.1	563
Faecal Coliforms (UFC/100mL)	3,701,429	4,274,800	190,000	1,3000,000
Faecal Streptococci (UFC/100mL)	2,992,857	2,151,827	1,300,000	7,000,000

Table 3: Parasites characteristics, Sd: standard deviation (n=7).

<i>Helminth egg species</i> (number of ova/L)	Average	Standard deviation	Minimum	Maximum
<i>Tenia sp.</i>	2,007	1,965	0	5,560
<i>Ascaris lumbricoides</i>	1,301	581	440	2,000
<i>Strongyloides stercolaris</i>	1,141	774	440	2,220
<i>Hymenelopsis nana</i>	31	83	0	220
<i>Trichuris trichiura</i>	126	215	0	440
<i>Trichostrongylus ovum</i>	31	83	0	220
TOTAL	4,639	1,782	2,890	8,000

DISCUSSION

Faecal sludge quantity

The predominance of 10 m³ difference can be attributed to the availability of such trucks on the market as well their capacity which permits to do more than one emptying activity per round. Such predominance for 10 m³ trucks was also noted in Dakar, Senegal (Faye et al., 2013). The total volume of sludge is lightly higher than that found by Berteigne in 2012 (108589 m³/yr.). This can be due to the fact that since then, the number of trucks might have increased as well the effect of sensitization of emptying companies on the maximization of the collect or the control of their dumping activities. The variation of the faecal sludge volume recorded per sub-division may be attributed to the proximity to the dumping site as well as to the standing and income of the household practising the mechanical emptying (Berteigne, 2012). This result shows that Douala 1 alone can host a treatment plant with regards to its FS production. Given that challenges in the emptying activity reduce the amount of FS arriving at the dumping site, it is important to consider these difficulties as solving them will certainly increase the quantity of sludge to be treated and hence the sizing.

Characteristics of faecal sludge

The obtained temperatures were all within the mesophilic range (25 – 40) °C which is ideal for bacterial activity (Vaishadi and Debarbrata, 2019). The pH range recorded for the different mixing ratios were within optimal ranges (6.5 – 9) required for biological degradation of organic matter by microorganisms (Kengne et al., 2008).

The high average values for TS and TVS recorded in FS are common with contents of public latrines whose sludge are fresh and less mineralized. TVS is very high due to the feeding habit of the inhabitants which is made of carbohydrates mainly and also to short duration of sludge in their containment, duration which did not allow their mineralization (Koné and Strauss, 2004; Bassan et al., 2013). The faecal sludge dumped in this area has an organics fraction (TVS/TS

ratio) of 61-80% indicating that a high amount of biodegradable organic matter is still remaining in the sludge. This ratio is higher than those reported in other comparable studies, with TVS to TS ratio of 53-61% (Bassan et al., 2013; Talla et al., 2017). This result also shows that it is suitable to apply biological techniques to treat the waste since it acts just on the organic pollution in the waste during the treatment.

The raw FS had high COD and BOD values ranging between 28.9 – 73.2 g/l and 1.1 – 1.8 g/l respectively which decreased as the TS ratio decreased (Table 2). Such high COD values have been recorded in FS from Bangkok, Manila and Accra (Ato et al., 2017). The concentrations of COD are several times (10 - 100) the strength of sewage (Strauss et al., 2000) confirming their high strength in the sense of Ato et al. (2017). The biodegradability index of the sludge (COD/BOD₅) is 28. This index is very high compared with values coming from some cities in developing country (Kone and Strauss, 2004). However, a study in Ouagadougou, Burkina Faso proves that there is a large variation in the samples, when evaluating this index (1 to 26) which did not give a substantial signification to this parameter (Bassan et al., 2013). This high value of 28 obtained in this study can be due to the fact that inorganic pollutants are being added to the latrines by users (e.g. engine oil, grease/kitchen/solid waste) which although can be oxidized are not through biochemical processes. The treatment of such sludge through biological processes may run into complications or may not give the expected treatment level.

Studies characterizing FS from septic tanks in West Africa have shown much lower concentrations of TS, VS and COD than this study. For example in Burkina Fasso, 11,820 mg/L TS, 6,855 mg/L TVS and 10,725 mg/L COD (Bassan et al., 2013). However, study in Vietnam observed similar characteristics to this study (31,470 ± 24,081 mg/L COD for cistern-flush toilets and 48,990 ± 12,808 mg/L COD for pour-flush toilets according to Anh et al., 2012).

The high values of nitrogen ammonia might result from the ammonification and mineralization of organic nitrogen (Epstein, 2003), which is a major constituent in faecal sludge. Ammonia concentrations ranging between 920 – 1310 mg/L as found in the raw sludge (Table 2) could hamper algal and bacterial growth. They also produce malodour and cause eye irritations in the treatment plants as additional problems (McGinn, 2003).

The average number of eggs found in this study (about 5,000) is too low compared with that found by Strauss et al. (2003) in tropical public toilets (about 30,000) in average. This is due to the fact that the sludge came mostly from household whose duration compared with that of public toilet is longer thereby enabling a greater die-off of helminth eggs. Helminthic infections are very common in most developing countries (WHO, 2006) thus the necessity of a treatment plant and safe household sludge disposal.

Conclusion

Weekly volume of sludge disposed at the dumping site of “bois des singes” is about 2,890 m³, with an average of 50 deposits per day. This sludge comes from all the sub-divisions of the Wouri Department, Littoral region. The sludge is of high strength with high microbial and parasites counts therefore stretching the urgency in setting a treatment plant as well as sensitization on faecal sludge handling and transport in order to ensure the safety of the stakeholders involved in the faecal sludge management.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

PDM was the main investigator of this work. ESK contributed in defining the topic and followed the field work. GVDW coordinated the lab analysis and data interpretation. WALN helped in reviewing the article. MNZ and GSL contributed as master researchers under an aspect of this topic. CW contributed to the coordination of the field

work. F and IMKN were co-supervisors of the work who secured funds and administration facilitations to conduct the work.

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