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Characterization of Depotted Faecal Sludge into the Environment and Design of a Suitable Treatment System: Case of Nomayos Area in Yaounde City

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Authors' contributions

This work was carried out in collaboration between all authors. Author AT designed the study, performed the statistical analysis, wrote the protocol and managed the analyses of the study. Author RS wrote the first draft of the manuscript. Author PSNE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of this study is to contribute to the establishment of a sustainable system of treating faecal sludge derived from autonomous sanitation system; this through co-composting with sawdust, using an analytical formula to obtain the appropriate ratio of mixing sludge and sawdust.
Study Design: In other to meet that objective, we have spent eight weeks in the site of Nomayos, area in Yaounde city, support of the present study. For this period, we followed the movement of the depotted trucks of faecal sludge then recorded the quantities these waste and taken samples for the analysis laboratory.
Place and Duration of Study: Physics and chemistry laboratory, University of Yaounde I and Research Center, National Advanced School of Public Work, between August 2016 and October 2016.

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Methodology: Data were collected and we counted 467 trucks emptying during this period. The analysis of these data collected from the field shows that the waste disposal site of Nomayos swallows up more than 140 m^3 per day of faecal sludge which correspond to 10 emptying per day. We also noticed that, 85.87% of the faecal sludge came from septic tanks where they had spent several years.

Results: The samples analysis showed that the faecal sludge dumps in this area had the organics fraction (TVS/TS) of 3.25% and the mineralization rates of 96.75%. This proves that, the waste had low organics fraction and had spent many years in the septic tanks before collection. The biodegradability index (COD/BOD5) of this waste was 21, greater than one showed that the waste was not totally biodegradable. We have proposed as recommended treatment system for this type of faecal sludge, considering ecological sanitation system for a sustainable development, the unplanted drying bed after which we performed co-composting with sawdust to stabilize the substrate and lagoon system for leachate treatment. This system presents a potential production of 21.0 tons per day of desiccated faecal sludge; 18.9 tons per day of compost and 120 m^3 per day of leachate treatment.

Conclusion: The realization of our proposed treatment system, will make it possible to solve this problem of pollution on a large scale.

Keywords: Faecal sludge; composting; drying bed; stripping; nomayos area; treatment system design.

ABBREVIATIONS

BOD_5 : Biochemical oxygen demand in five days
COD : Chemical oxygen demand
ECOSAN : Ecological sanitation
MW : Municipal waste
GPS : Global positioning system
PAH : Polycyclic aromatic hydrocarbon
TKN : Total kjeldahl nitrogen
TS : Total solids
TSS : Total suspended solids
TVS : Total volatile solids

SYMBOLS

$\%C_b$: Carbon percentage in dry sludge
$\%C_s$: Carbon percentage in sawdust
C_1 : Total carbon in dry sludge
C_2 : Total carbon in the sawdust
l/d/h : Litters per day per inhabitant
$L_{air}/kg_{TS}.h$: Litters air per kilogram total solid per hour
m/d : Meters per day
m^3/d : Cubic meters per day
m^3/h : Cubic meters per hour
$m^3_{air}/t_{TS}.h$: Cubic meters air per tons total solid per hour
m_b : Dry sludge mass
m_s : Sawdust mass
n : Total number of trucks
N_1 : Total nitrogen in dry sludge
Q :Total volume of the sludge or leachate
R_1 : Ratio C/N in the sludge before mixture
R_2 : Ratio C/N in the mixture sawdust and dry sludge
t/d : Tons per day
V_i : Volume of truck number i
V_{sur} : Surface loading rate

1. INTRODUCTION

Faecal sludge derived from autonomous sanitation system in general, is very difficult to handle in most Sub-Saharan country thoughmany solutions of treating this waste exist nowadays. Among these solutions, co-composting stands as the most sustainable solution because it helps to close the loop between man and the organics substances which he consumes. Studies carried out on helminths eggs inactivation efficiency by faecal sludge dewatering and co-composting in tropical climates proves that, during composting with solid waste, the turning frequency does not influence helminths eggs removal efficiency [1]. Another studies on composting of faecal sludge and organic solid waste for agriculture showed a preference of municipal waste (MW) over household waste (HW) and mixing ratio of 2:1 over 3:1 [2]. Sawdust has been proven to be a good bulking agent for sludge composting; however, studies on the most suitable ratio sawdust for composting are scare. For aerobie composting, the ratio 1:1 seems more suitable because it is more economical than the ratio 1:3 [3].

In general, faecal sludge is very dangerous for human and environment into which it is spread because it contains pathogens organisms, helminths eggs and other pollutants. But unfortunately in Yaounde city for example, all faecal sludge collected around the city is dumped in the area site of Nomayos without any treatment [4]. Government and council intervention are limited to tax collection where the money is not even used back in ameliorating the activity. This disposal site of Nomayos receives at less 10 trucks emptying per day, with one emptying cost 8.55 USD for a total income of 85.48 USD per day. 40% of this money goes to the local council and 60% to the residents of Nomayos area. For the money collected from this activity, nothing is reinvested in order to fight against the ambient pollution causes by this anarchical sludge dump in this site. All the disputes observed on the field just concern the sharing of the tax collected but not to fight against pollution and no governmental inspection is carried out to organize the activity. The work of scavengers in this city necessitates organization and this can only be achieved through the reinforcement of legislation whereby they are grouped into an association in order to safeguard their interest [5]. In the city of Yaounde, support of this study, the specific faecal sludge production is 0.7 l/d/h and the draining frequency range between 4 and 5 years [6]. Concerning the sludge dump in the area site of Nomayos, a solution of treating the waste as proposed by Berteigne in 2012 was the planted drying bed with a lagoon system to treat leachate.

Knowledge of properties of depotted faecal sludge deriving from autonomous sanitation is important in understanding the risk of contamination of the population and environmental pollution. It is also a valuable toll in designing a suitable system of treating the waste. Many authors have published results about studies concerning faecal sludge management [7,8,9,10,11,12,13]. But little information is available about characterization of depotted faecal sludge derived from autonomous sanitation system in under developing countries; and particularly when some users used inorganic substances (engine oil and other pollutants) in this system. On the order hand, suitable system of treating this kind of waste in Sub-Saharan countries is scared according to our knowledge. Therefore, in order to provide further contribution to this issue, we have quantified the sludge dumped and characterized the depotted faecal sludge using the case of Nomayos area in Yaounde city. Then we have established an analytical formula to solve the problem of the appropriate ratio for sludge and sawdust mixture during co-composting and finally, a suitable solution of treating the waste by a full dimensioning of the whole system was proposed.

2. MATERIALS AND METHODS

2.1 Materials

For the evaluation of physico-chemicals parameters in the sludge, we have used several materials among which we can name:

- A numerical multimeter of the brand HANNA HI 9811-5 pH/C/EC/TDS for pH and conductivity evaluation;
- COD tubes of the brand MERCK CAT 21259, a thermo reactor (Eco 8,VELPScientifica, Europe), a spectrophotometer of the brand HACH DR/ 3900 for the evaluation of COD and total suspended solids (TSS) in the sludge;
- BOD_5 device bottle of the brand HACH (model 2173 B) for the evaluation of BOD_5 in the sludge;
- A melting pot, an oven with a system to adjust the temperature for the evaluation of TS and TVS;
- A nitrogen distiller of a mark BUCHI K- 350 for the evaluation of total Kjeldahl nitrogen (TKN).

In order to realize the cartography of the area of study, we have used a GPS of the brand Garmin ETREX VISTA CX to georeference raster image of the area, and the cartography was done using MAP INFO professional 11.5 version software. For all the drawing in this work, we have used ARCHICAD 2016 software.

2.2 Methods

2.2.1 Quantification method of faecal sludge in Nomayos site

In order to quantify the sludge dumped at the disposal site of Nomayos, our research period has ranged from the 31 December 2015 to 20February 2016 that is approximately eight weeks. During this period, we have counted for every day the number and the capacity of each truck that passes through the check point and dump effectively the sludge at the disposal site.

At the end of the period, we have evaluated the total volume dumped using the formula:

$$Q = \sum_{i}^{n} V_i \quad (1)$$

Q: is the total volume of the sludge
V_i : volume of faecal sludge in truck i
n: total number of trucks

2.2.2 Physico-chemical analysis method of some parameters in the sludge

2.2.2.1 Sampling method

In order to carry out some analysis on the sludge in the laboratory, we have prepared two samples. For each sample we withdraw 500 ml of sludge at the beginning of the emptying process for a truck, in the middle of the process and at the end of the emptying. These volumes are placed in a big container. We repeat this process for a total number of eight trucks during their emptying process. After this, we mix together the sludge in the big container and from there we withdraw 500 ml of sludge which represent a sample that would be send to the laboratory for analysis. The aim of this method is to verify repetitivity in the result. The analyses were carried out in the laboratory of physics and chemistry in the University of Yaounde I in Cameroon.

2.2.2.2 Analysis method of the parameters

- Evaluation of pH and conductivity of the sludge

For these parameters, we used the numerical multimeter described above. Before the measurement, we standardize the device using a solution of $N_{a2}HPO_4/H_2N_aPO_4$, pH = 6.85 or $KHC_8H_4O_4$, pH = 4.01.

- Evaluation of chemical oxygen demand (COD)

The evaluation of this parameter is based on close reflux colorimetric method. This method uses COD tubes containing an excess solution of potassium dichromate, a solution of mercury sulphate and a solution of sulphuric acid. 1 ml of sludge is put in this tube and placed in the thermo reactor for two hours at the temperature of 120℃. After the oxidation, we used a spectrophotometer to read the value of the COD express in g/ml.

- Determination of biochemical oxygen demand in five days (BOD5)

The evaluation of this parameter is based on "manometric method" using BOD_5 device bottle. A certain volume of sludge is put in this bottle with some reagent and the bottle is incubated at 20℃ for five days. At the end of this incubation period, the value of BOD_5 is read directly on a BOB_5 scale mention on the bottle.

- Determination of total solid (TS) and total volatile solid (TVS) in the sludge

In order to evaluate these parameters, we have used 10 ml of faecal sludge corresponding to a mass of 9.5 mg. This sample is put in a melting pot and placed in an oven at temperature of 105°C for 24 hours. The difference of mass after this period corresponds to TS. After this, the TS obtained was placed in an oven at 500°C for 5 hours and the difference of mass gives us the value TVS.

- Determination of total suspended solids (TSS)

To evaluate this parameter, we have used "absorptiometric" method based on the capacity of the sample to disperse and to absorb a light beam due to the presence of particles in the solution. The value of this parameter is read directly on a spectrophotometer using pure water as reference solution.

- Determination of total Kjeldahl nitrogen (TKN)

In order to determine the TKN, the sludge sample was mineralized and distilled with a 40 % solution of sodium hydroxide (NaOH) in a nitrogen distiller. The nitrogen vapour obtained was collected in an Erlen-Meyer containing 20 ml of boric acid 40% with Tashiro reagent.

2.2.2.3 Interpretation method of some Physico-chemical parameters

For the interpretation of the parameters defined above, we havetaken some ratios between them in order to bring out information necessary to choose better treatment system of the faecal sludge in this site of Nomayos.

- The biodegradability index: it given by the ratio COD/BOD_5. It tells us how content the biodegradable fraction is, in the faecal sludge. Knowing that when this ratio equals to 1 all the waste is biodegradable but when it is greater than 1, some fractions are not biodegradable.

- The organics fraction content: It is the ratio TVS/TS. It gives us the rate of organics waste presenting in the faecal sludge.
- The ratio C/N: this parameter is very important because it assures the growth of micro-organism in a substrate during composting. It also enables good air circulation in the composting pile. The ideal ratio ranges between 20 and 30 [14]. In order to let this ratio lay in the interval 20 and 30, we need to know the mass of dry sludge to mix in to a certain mass of sawdust during co-composting. To solve this problem, let $R_1$and R_2be the ratio C/N in the dry faecal sludge and in the mix sludge with sawdust respectively. Since sawdust $(C_6H_{10}O_5)_n$ does not contain nitrogen, and has 44.44% of carbon, we can write these equations:

$$\begin{cases} R_1 = \frac{C_1}{N_1} \rightarrow (a) \\ R_2 = \frac{C}{N_1} \rightarrow (b) \end{cases} \tag{2}$$

In these equation, C_1 is the total carbon in dry sludge, N_1 the total nitrogen in dry sludge and $C = C_1 + C_2$ where C_2 is the total carbon in the sawdust. Dividing (b) by (a), we obtain the following relation:

$$\frac{C_1+C_2}{C_1} = \frac{R_2}{R_1} C_2 \leftrightarrow C_2 = \left(\frac{R_2}{R_1} - 1\right) C_1 \tag{3}$$

Let: % C_b be the carbon percentage in dry sludge and % C_s be the carbon percentage in sawdust. Considering this we can express this percentage in relation to the corresponding substrate mass as follow:

$$\begin{cases} \%C_s = \frac{C_2}{m_s}.100 \rightarrow \quad (c) \\ \%C_b = \frac{C_1}{m_b}.100 \rightarrow \quad (d) \end{cases} \tag{4}$$

From these two relations (c) and (d) we can express C_1 and C_2 by:

$$\begin{cases} C_1 = \frac{\%C_b.m_b}{100} \qquad (e) \\ C_2 = \frac{\%C_s.m_s}{100} \qquad (f) \end{cases} \tag{5}$$

Taking equations (e) and (f) into relation (3), we establish the relation between that mass m_b of dry sludge to mix with the mass m_s of sawdust to let the ratio C/N in the mixture lay between 20 and 30. The relation stands as follow:

$$m_s = \frac{\%C_b}{\%C_s}\left(\frac{R_2}{R_1} - 1\right) m_b \tag{6}$$

In this relation, we have:

- m_s: the sawdust mass;
- m_b :the dry sludge mass;
- R_1: the ratio C/N in the sludge before mixture;
- R_2: the ratio C/N in the mixture sawdust and dry sludge to be chosen in the interval 20 and 30;
- % C_b: the carbon percentage in dry sludge which represent 29% of TS [15];
- $\%C_s$: Carbon percentage in sawdust which is 44.44% according to the cellulose compound $(C_6H_{10}O_5)_n$ constituent of the wood.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Management of faecal sludge

Actually in this disposal site, nineteen trucks are effectively involved in collecting of faecal sludge around the city. This site looks like "an open air water closet" for the whole populations of Yaounde city where everybody comes and operates defecations. The dumping point is situated not far away from the river AVO'O as shown on the Fig. 1. This situation causes eutrophication phenomena in the river with oxygen depletion. Another major problem is that some trucks drivers collect and dump in this area sludge mixed with engine oil and probably some unidentified pollutants which can contain heavy metals and polycyclic aromatic hydrocarbons (PAH).

3.1.2 Quantification of faecal sludge

During the forty-three days of data collection in this site of Nomayos, we have counted effectively 467 emptying process of trucks which correspond to a total volume of 6054.3 m^3. This volume corresponds to an average of 140.79 m^3/d and to 10 emptying per day. The Fig. 2 shows the variation of dumping process and sludge volume in this site during the study period.

3.1.3 Physico-chemical parameters after the sludge analysis

Table 1 gives us the results of the laboratory analysis on the sludge samples, which were carried out in the physics and chemistry laboratory in the University of Yaounde I, in Cameroon.

3.2 Discussion

3.2.1 Dumping activity in the site of Nomayos

The dumping activity in the site of Nomayos is carried out without any control. The faecal sludge is spread into the environment anarchically. Some farmers living around the area practise agriculture and use the sludge to irrigate their farms. The study of the dumping activity also proves that some trucks drivers collect and dump in this site sludge mixed with engine oil and other unidentified pollutants as shown in Figs. 4 and 5.

3.2.2 Physico chemicals parameters interpretation

In order to better analyze these parameters, and to bring out some information's necessary to choose a good treatment system for the sludge dump on this area, we have combined some of these parameters by taking the ratio between them. The faecal sludge dumps in this area has the organics fraction (TVS/TS) of 3.25% and the mineralization rates of 96.75%. This result proves that, the waste has low organics fraction and has spent many years in the septic tanks before collection [16]. This result also shows that it is not suitable to apply classical biological techniques like active sludge process to treat the waste since it acts just on the organic pollution in the waste during the treatment. The biodegradability index of the sludge (COD/BOD_5) is 21. This index is very high compared to the values coming from some cities in developing country [17], but the study carried out by Bassan et al. [16] in Characterization of faecal sludge during dry and rainy seasons in Ouagadougou, Burkina Faso proves that there is a large variation in the samples, when evaluating this index, ranging from 1 to 26. This high value of 21 obtain in this study can be due to the fact that, faecal sludge is stored for long periods of time in the septic tanks before collection. It can also be a result of inorganic pollutants being added to the septic tanks by users (e.g. engine oil in the case of Fig. 4). When this sludge is discharged in the environment without any treatment, it will stay there for many years before total decomposition since it contains inorganic pollutants.

The composting process we have chosen to stabilize this sludge is indoor technology using active aerated pile. The substrates used in this process are: dewater sludge and sawdust. In order to know how to mix both the substrates, let use equation (6) knowing that % C_s is 44.44% and % C_b= 29% TS [15]. Let R_2= 20 chosen in the optimum interval 20 to 30 and $R_1 = \frac{C_1}{N_1} \approx 5$ calculated using physico-chemicals parameters in the table 1 where C_1 is the total carbon in the sludge and N_1 total nitrogen in the sludge. Taking these values in to relation (6) we have m_s= 1.95 m_b which is approximately equal to:

$$m_b = \frac{1}{2} m_s \tag{7}$$

The result coming out from this equation is confirmed by the previsions of mixing ratio proposed in 1981 by [18]; in "night soil composting" which shows that during co-composting using faecal sludge and wood chips, the optimum ratio during mixing is 1 wt FS for 2 wt wood chips.

Table 1. Physico-chemical parameters of the sludge dump in the area site of Nomayos in Yaounde neighbourhood, Cameroon

Parameters	Units	Average parameter values
pH	---	7.04
Conductivity	µS/cm	3970
Total Suspended Solids (TSS)	mg/L	16600
Chemical Oxygen Demand (COD)	mg/L	29072.50
Biochemical Oxygen Demand in five days (BOD_5)	mg/L	1400
Total solids (TS)	mg/L	6825
Total Volatile Solids (TVS)	mg/L	222
Total Kjeldahl Nitrogen (TKN)	mg/L	408.84
Biodegradability index (COD/BOD_5)	---	21
Organics fraction (TVS/TS)	%	3.25

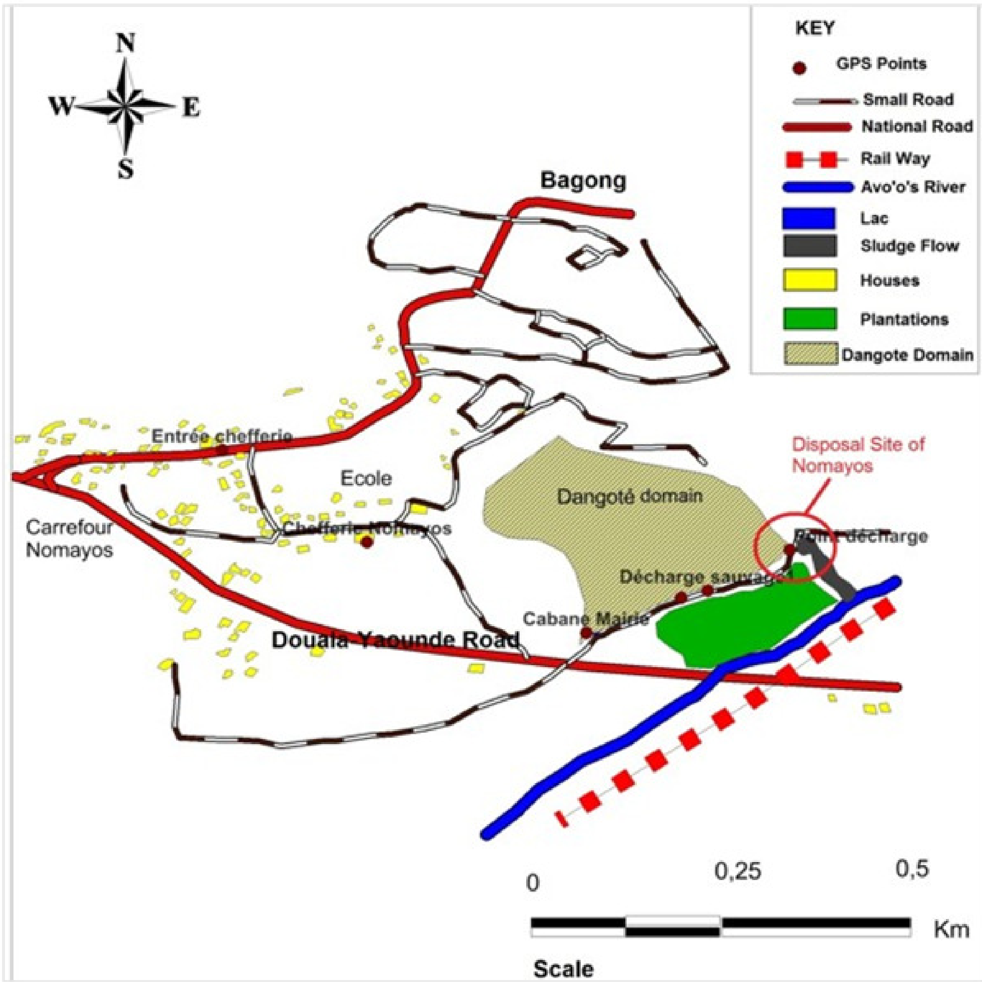

Fig. 1. Disposal site of Nomayos

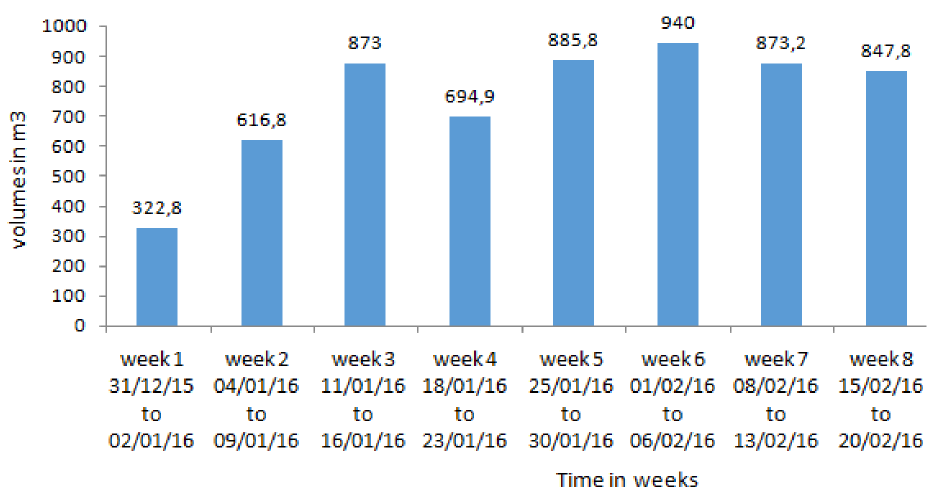

Fig. 2. Sludge volume variation per week during the study

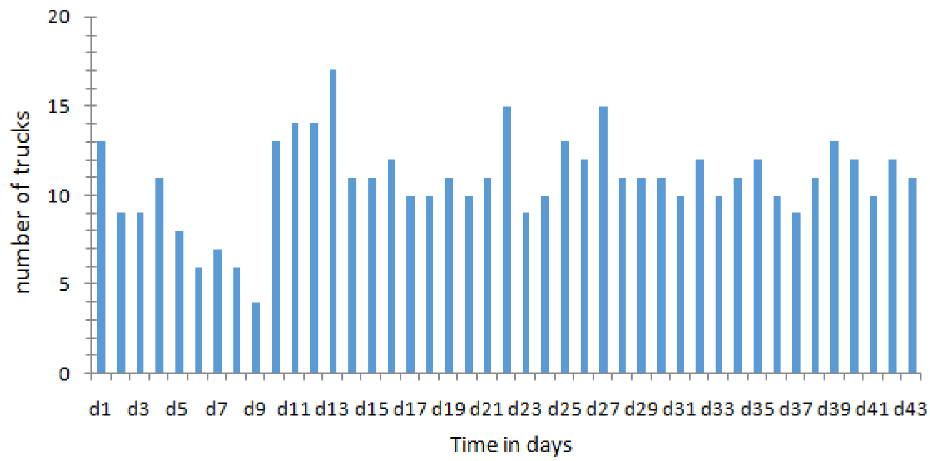

Fig. 3. Variation of number of trucks dump per day during the study

Fig. 4. Sludge mixed with engine oil spread into the environment in the disposal area

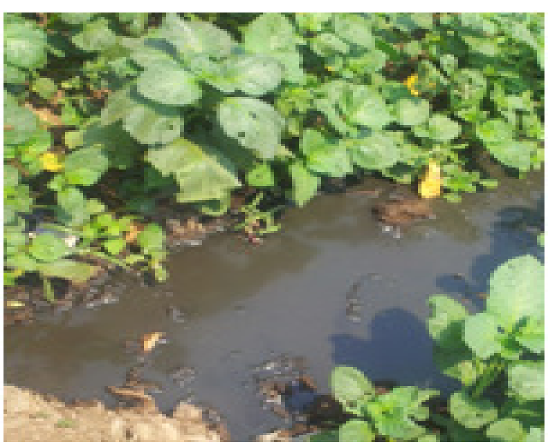

Fig. 5. Irrigation of crops with faecal sludge in the dumping site

3.3 Proposition of a Treatment System

Considering the information coming out from the parameters interpretation above, we can say that, among the different process of treating faecal sludge, active sludge system and anaerobie digestion has to be kept at side because the waste has 96.75% of minerals and only 3.25% of organics. In order to integrate ecological sanitation system to this treatment process, this is to find the mean through which we can close the loop between man and the organics substances that he consumes, we have proposed a sustainable solution that can only be achieved through faecal sludge composting. In order to meet this target, we have proposed as solution of treating the waste, the unplanted drying bed to dewater the sludge, a lagoon system to treat the leachate coming out from this process, and co-composting using sawdust to stabilize the substrate.

3.3.1 Pre-treatment zone

The pre-treatment zone is a concrete tank of 20 m^3 of capacity because the highest truck capacity in activity in this site is 14 m^3. In other to separate bulking solid fraction and some municipal solid waste in the sludge, we have designed a suspended basket grid on the top of the pre-treatment tank. In order to easily evaluate the volume of the sludge dump in the tank, we have chosen the basic surface of the tank equal to 2.5 m x 4 m = 10 m^2 and the high 2 m. To evaluate and control the volume and the quality of the sludge in the tank after every emptying process, we have designed a volumetric ruler and set an isolation gate for this purpose.

3.3.2 The drying bed sector

In order to dimension our drying bed, we consider that 80 % of the sludge percolates as liquid to the lagoon system according to [19]. The real quantity of sludge dump there is 140.79 m^3/d but we have designed the system to treat 150 m^3/d this correspond to an increment of 6.5% to consider the fluctuations due to seasons. Considering this, our drying bed will receive a maximum volume of 30 $m^3$of dewater sludge per day and the maximum thickness of sludge on the bed is 20 cm for a better drying process [19]. Knowing that the retention time on the unplanted drying bed is maximum two weeks [20], we have designed 13 beds and we fill one bed per day. On the 13th day, the first bed is cleaned and sent to the composting area. The bottom of this bed is full of gravel of different size to let the liquid fraction percolate into the drainage system made up of a big perforated pipe (HDPE) of 200 mm diameter.

✓ **The parameters in consideration to design the unplanted drying bed are as follow:**

- Thickness of the sludge on the bed: 20 cm;
- Length of the bed: 25 m;
- Width of the bed: 6 m;
- Drainage pipe (HDPE) length: 25 cm;
- Drainage pipe (HDPE) diameter: 200 mm;
- Gravel thickness (5/15 mm): 25 cm;
- Sand thickness (0.5 mm): 15 cm;
- Gravel thickness (8/10 mm): 20 cm.

3.3.3 Leachate treatment system

The leachate treatment system is based on lagoon system combining three ponds in series:

- The first pond is anaerobie and has the highest depth (4 m) amongst the three ponds. In this ponds the treatment process is assured by anaerobie bacteria which transform the organic carbon in to methane and can reduce up to 60% BOD_5 [19];

✓ **The characteristics for the design of the anaerobie pond are as follow:**

- Entering flow (Q_e= 80%Q): 120 m^3/d;
- HRT: 7 days;
- Depth of the pond (h): 4 m;
- Volume of the pond (V_1= Q_e.HRT): 840 m^3;
- Surface of the pond (S_1= V_1/h): 210 m^2;
- Surface loading rate (V_{sur}= Q_e/S_1): 0.57 m/d.

- The second pond is facultative because it combines both aerobie and anaerobie bacteria to consume the pollution in the waste water. It has 2 m depth and the nitrogenous pollution is consumed here by nitrification and denitrification process;

✓ **The characteristics for the design facultative pond are as follow:**

- Entering flow (Q_e= 80% Q): 120 m^3/d;
- HRT: 20 days;
- Depth of the pond (h): 2 m;
- Volume of the pond (V_2= Q_e.HRT): 2400 m^3;
- Surface of the pond (S_2= V_2/h): 1200 m^2;
- Surface loading rate (V_{sur}= Q_e/S_2): 0.05 m/d.

- The third and the last step of treating the leachate is the maturation pond. It is totally aerobie and its depth is 1 m; this let the sun light penetrate down to the bottom of the water favour photosynthesis which contributed to eliminate the pollution in the waste water. In order to avoid leachate infiltration down to the ground water; the bottom of the pond will be protected by geomembrane layer.

✓ **The characteristics for the design the maturation pond are as follow:**

- Entering flow (Q_e= 80% Q): 120 m^3/d;
- HRT: 14 days;
- Depth of the pond (h): 1 m;
- Volume of the pond (V_3= Q_e.HRT): 1680 m^3;
- Surface of the pond (S_3= V_3/h): 1680 m^2;
- Surface loading rate (V_{sur}= Q_e/S_3): 0.07 m/d.

3.3.4 Co-composting process

3.3.4.1 Estimation of substrate mass for composting

From the experiment carried out in the laboratory, the estimated density of the sludge dump is 0.95 t/m^3. Considering that the entering flow is 150 m^3/d then we have a total mass of 142.5 t/d for the sludge dump. Knowing that 80% of total volume percolates as water, then the total water mass is 120 t/d considering that the water is pure. Considering that the estimated MSW capture by different grid is 1.5 t/d, the approximate mass of dewater sludge to be treated is 21 t/d. According to relation (7), m_s= 2 m_b. So the sawdust mass to use is 42 t/d and the total substrate mass for composting is then 63 t/d.

3.3.4.2 Estimation of substrate volume for composting

Considering that sawdust density is 0.5 t/m^3, then the total sawdust volume is 84 m^3 and total dewater sludge volume is 30 m^3. We then have a volume of 114 m^3/d of substrate. Since the site is open six days per week, then total volume is 684 m^3 per week; which correspond to 378 t per week.

3.3.4.3 Dimensioning of composting piles

Considering the values above, in order to control the composting pile, we have designed tow piles of 342 m^3 each to be full every week. The composting pile will be built in concrete and its bottom will be filled with perforated pile for aeration. The characteristics of this pile are:

- Length of the pile: 23 m;
- Width of the bed: 5 m;
- High of the pile: 3 m.

3.3.4.4 Dimensioning of aeration system for composting

Considering the studies carried out by FERTIG in [21] on oxygen supply during composting, the oxygen supply for this system is 8 L_{air}/kg_{TS}.h. On the other hand, according to Mustin [21], 90% of the total oxygen demand is consumed during the fermentation phase and 10% during the maturation phase. The total duration of the composting process is 5 weeks since the aeration system is active. Considering this:

✓ **The parameters for the design of the aeration system for composting are as follow:**

- Substrate mass per pile: 189 t;
- Air supply for composting process: 8 m^3_{air}/t_{TS}.h;
- Air demand for the total period of composting (5 weeks)using the substrate mass, air rate and duration of composting: 1 270 08 m^3;
- Air supply rate per pile for the first three weeks of fermentation (3 weeks) representing 90% of total air demand: 2 268 m^3/h.

Since air supply rate per pile for maturation period (2 weeks) represented 10% of total air demand: 378 m^{3}about the capacity of the engine to pomp air in the system, according to [21], the air supply rate should be surestimated by 30% of the value calculated; this is to consider some air losses through the aeration system. Considering these facts, we will need pump of capacity 3 440 m^3/h. To achieve this flow rate, the pump will need a power of 12HP witch correspond to 9 kW.

Fig. 6 below presents the scheme of the faecal sludge treatment system showing the pre-treatment sectors, the drying beds, the composting area and the lagoon system for leachate treatment.

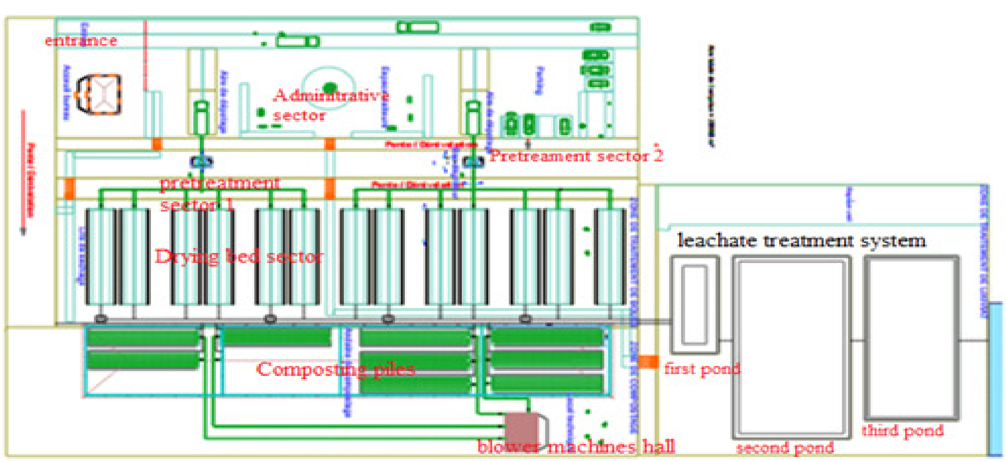

Fig. 6. Faecal sludge treatment system

4. CONCLUSION

This study has proven that faecal sludge derived from autonomous sanitation system in some cities in under developing country case of Yaounde city, is typically influenced by at least two major factors. The first major factor is the duration of faecal sludge in the septic tanks before collection, which can go above 10 years. The principal consequence of this duration is the high mineralization rate and low organic matter in the sludge; as proven by results in this study. The second major factor is the addition of engine oil and other inorganic pollutants by users in the septic tanks. These behaviours can be the raisons of high value of biodegradability index in the sludge analyze. The suitable system of treating this kind of waste can be based on bioremediation properties of toxic substances. For this reason, co-composting stands as the better sustainable solution to solve this problem; this is why we have proposed and design a treatment system based on this technique. Out of these results, there is a real need to assess these factors in some other cities to have an overall understanding of the characterization of faecal sludge coming from autonomous sanitation system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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