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Full Length Research Paper

Quantification and characterization of faecal sludge produced in Kara

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In Kara (Togo), as in most major sub-Saharan African cities, there is very little sewerage and autonomous systems are the most commonly used. These autonomous systems produce faecal sludge that must be drained and treated adequately in order to preserve the health of the population and protect the environment. Indeed, the risks are real, given the use of fresh faecal sludge in agriculture and the potential dangers of their raw rejection in nature. The purpose of this study was to quantify and characterize the faecal sludge derived from autonomous sanitation system and make available to the district of Kara. Sludge emptying trucks have been followed during a three months' period to quantify the faecal sludge produced. At the end, samples were taken to the laboratory for analysis. The chemical analysis conducted were suspended matter (SM), chemical oxygen demand (COD), a five-day biochemical oxygen demand (BOD_5), ammonium (NH_4^+), nitrates (NO_3^-), nitrites (NO_2^-) and orthophosphates (PO_4^{3-}). The result showed that 41347.2 m^3/year of faecal sludge are produced and 14616 m^3/year are collected. Also, the chemical analysis of total suspended solids, chemical oxygen demand, a five-day biochemical oxygen demand, ammonium, nitrates, nitrites and orthophosphates showed that the faecal sludge of the district of Kara is biodegradable. The data from this study will form scientific bases for a better feasibility of setting up a faecal sludge treatment plant in Kara.

Key words: Faecal sludge, specific ratio, quantity of faecal sludge, autonomous systems.

INTRODUCTION

Increasing urbanization is a phenomenon sweeping across the world especially in developing countries (Ahamada et al., 2016). This growth of population in urban areas in developing countries causes sanitation challenges for the urban authorities. The main challenges are related to the collection as well as treatment of excreta, solid waste and wastewater for the protection of human health and the environment (Tilley et al., 2010; Katukiza et al., 2012). The concern is serious, particularly in the area of sanitation as many African countries are

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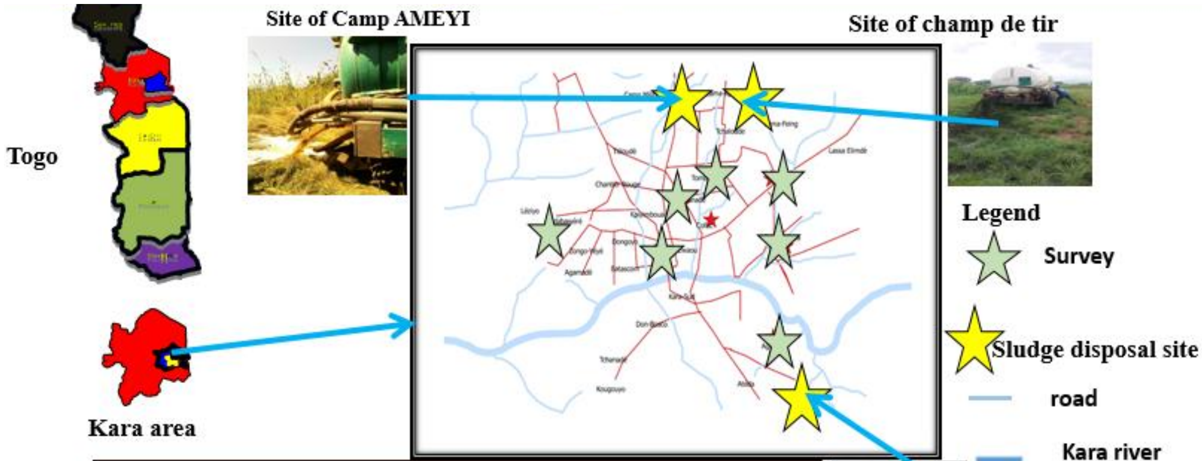

Geographic coordinates of faecal sludge disposal sites		
Sludge disposal site	Latitudes	Longitude
Site of Ateda	09°3137.94	01°1226.91
Site of champ de tir	09°3500.52	01°0907.78
Site of Camp	09°3447.31	01°1021.54

Figure 1. Study area.

unlikely to meet the Sustainable Development Goal (SDG) of halving the number of people without access to basic sanitation. The population of sub-Saharan African cities use autonomous sanitation (septic tanks) facilities for the management of wastewater and excreta (Bassan et al., 2013; Kajyibwami, 2018) which use self-sustaining wastewater treatment technology (Gnagne et al., 2019). This technology, although suitable for these cities, remains poorly implemented, suffering from the inadequacy of certain scientific database data (Gnagne et al., 2019). Usually, the sludge emptied in latrines and septic tanks is either dumped near the city or in the environment without treatment (Kouawa et al., 2015).

In Togo and most of the developing country, faecal sludge is openly dumped into the environment (Akpaki et al., 2016). These autonomous sanitations store large quantities of faecal sludge whose management is difficult (Ouédraogo, 2016). In Kara city, faecal sludge is emptied and most often dumped into the environment or reused without treatment in agriculture (Kodom, 2019). Some farmers are bribing septic tank truck drivers to dump faecal sludge into their field (Kodom, 2019). However, faecal sludge needs adequate treatment and disposal to safeguard public health and the environment (EAWAG, 2006). Recent studies in Sokodé (Togo) focused on economic potential show huge risks associated with sludge management in this city. However, there is limited or no information on the specific pollutant loads originating from the faecal sludge stream. Thus, the quantities of faecal sludge generated and the typical faecal sludge characteristics are difficult to determine due to the variety of onsite sanitation technologies in use, such as pit latrines, public tanks, septic tanks and dry latrines. The quantity and characteristic of faecal sludge also depends on the design and construction of the sanitation technology, how the technology is used, how the faecal sludge is collected and the frequency of collection. The objectives of this study are, therefore, to quantify and characterize the faecal sludge derived from autonomous sanitation system in district of Kara in order to propose an adequate treatment method. Decentralization has been effective in Togo since 2018; it is therefore up to each municipality to develop itself and development also takes into account issues related to sanitation and urban waste management. Moreover, autonomous sanitation is a credible choice for these districts for the decentralized treatment of faecal sludge waste in a very specific context. The results of this work will serve as scientific evidence to enable Kara Municipality authorities responsible for waste management to make informed decisions regarding municipal waste disposal and the establishment of a faecal sludge treatment plant.

MATERIALS AND METHODS

Study area

This study was carried out in the district of Kara located at 430 km from Lomé, the capital of Togo. The climate is of the Sudanese semi-humid tropical type, characterized by 2 distinct seasons: the dry and the rainy. The average annual temperature is around 37°C. Sludge is frequently dumped at the Atéda, AMEYI and shooting range sites located at 2, 3 and 4 km, respectively from the city of Kara where truck tracking and sampling were carried out (Figure 1).

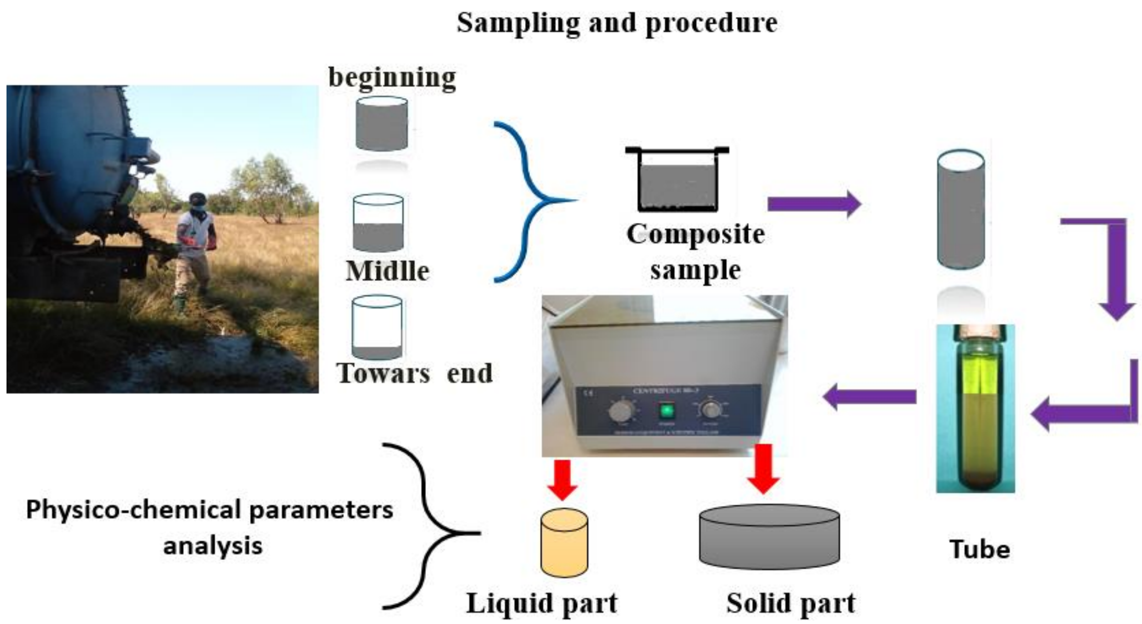

Figure 2. Sample methods and analyses.

Sludge samples are taken in a container at the start of unloading, when the tank is half empty and just before the end of unloading.

Surveys and observations

Field surveys use a questionnaire and observations made it possible knowing the existing emptying methods, the types of pits used, the emptying frequencies, the number of users, the number of trucks and the landfills.

Quantification methods of faecal sludge

In this study, two approaches were used to quantify faecal sludge. These methods were sludge production and sludge collection.

Method 1: Sludge collection

The study was conducted from June 24, 2020 to September 25th, 2020. During this period, the number of laps made and the quantity of sludge emptied by each truck was counted. The total quantity of drained sludge is obtained by cumulating the quantity of the two trucks according to Equation 1 (Talla et al., 2017; Koanda, 2006):

$$Q = \sum_{i} V_{ij} \cdot \eta_{ij} \quad (1)$$

where Q (m^3/month) is total volume of the sludge collected; Vij (m^3/rotation) is the useful volume of the i-truck for day j; ηij (rotations/truck) is the number of type i truck rotations for day j.

Method 2: specific production

The specific production of faecal sludge was obtained by Equation 2 (Koanda, 2006):

$$Q = 365 * \sum P_i * \frac{q_i}{1000} \quad (2)$$

where Q: total volume of the sludge; P_i: number of users for the tank I; and q_i: specific production of the tank i.

Sampling faecal sludge

In order to carry out some analysis on faecal sludge in Water Science and Environment Sanitation laboratory of University of Kara, the samples were prepared. For each sample, 1.5 L of sludge was measured at the beginning of the process of the truck, in the middle of the process and at the end of sampling. A total of, fifteen samples were collected. Five samples for each of the following type of septic tank were taken namely Domestic Septic Tank (DST), Public Septic Tank (PST) and Dry Latrines (DL). After mixing, 1.5 L which represents the composite sample is collected and sent to the Water Science and Environment Sanitation laboratory of University of Kara for analysis. For the chemical parameters, the liquid fraction was used (Klingel et al., 2002). The different phases of the sampling are schematized in Figure 2.

The physio-chemical analysis

The analysis method employed was adapted from the Standard Methods for the Examination of Water and Wastewater, as described by Rodier et al. (2009) and APHA (1998). The parameters analysed included: temperature, pH, electrical conductivity (EC), suspended matter (SM), chemical oxygen demand (COD), five-day biochemical oxygen demand (BOD_5), ammonium (NH_4^+), nitrates (NO_3^-), nitrites (NO_2^-) and orthophosphates (PO_4^{3-}).

Temperature, pH and electrical conductivity (EC) were measured *in situ* with the Multi HANNA HI 9811 parameters equipped with the different probes, following the same protocol by simply changing

Table 1. The amount of sludge produced during the companion.

Type of sanitation	Method 2: Specific production			Method 1: Sludge collection		
	specific production (L/day/pers)	Quantity (m^3/day)	Quantity (m^3/year)	Quantity (m^3/day)	Quantity (m^3/month)	Quantity (m^3/year)
DST	1	96	35040	42	840	10080
DL	0.2	2.88	1051.2	11.9	238	2856
PST	2	14.4	5256	7	140	1680
Total	-	113.28	41347.2	60.9	1218	14616

The results of this study show that the sludge produced is estimated to 113.28 m^3/day or 41347.2 m^3/year and that collected by truck to 60.9 m^3/day or 14616 m^3/year.

probes according to the parameter to be measured and the reading is done after stabilizing the display. The determination of the content of suspended matter (SM) was done using gravity after vacuum filtration with a microfilter of GF/C glass and drying in the oven at 105 ± 2°C. The evaluation of COD is based on open reflux colorimetric method. It was determined by oxidation with an excess of potassium dichromate in an acidic environment 150°C in the presence of silver sulphate as a catalyst. The value reading was made by a spectrophotometer of a mark GENESYS 10S UV-VIS. The five-day oxygen biochemical demand (BOD_5) was determined by the five-day incubation method in the dark and 20°C temperature using an OxiDirect (Lovibond). At the end of this incubation period, the value of BOD_5 was read directly on a BOD_5 scale on the bottle. Ammonia nitrogen (NH_4^+), nitrites (NO_2^-) nitrates (NO_3^-), and orthophosphates (PO_4^{3-}) were determined by using the colorimetric method with GENESYS 10S UV-VIS spectrophotometer reading at adequate wavelengths.

RESULTS

Management of faecal sludge in the district of Kara

Five trucks are involved in collecting of faecal sludge around Kara municipality. The dumping points are located at 2, 3 and 4 km from the center of Kara city.

Quantification of faecal sludge

Calculations of sludge produced considered the specific production to 1 L/person/day for domestic septic tanks, 0.2 L/person/day for dry latrines and 2 L/person/day for public tanks (Table 1).

The results of this study show that the sludge produced is estimated to 113.28 m^3/day or 41347.2 m^3/year and that collected by truck to 60.9 m^3/day or 14616 m^3/year.

Interpretation of physico-chemical parameters

The results of analysis of the physical and chemical parameters such as temperature, pH, electrical conductivity (EC), suspended matter (SM), chemical oxygen demand (COD), five-day biochemical oxygen demand (BOD_5), ammonium (NH_4^+), nitrates (NO_3^-), nitrites (NO_2^-) and orthophosphates (PO_4^{3-}) of the different types of sludge are recorded in Table 2.

Temperature, EC and pH

Temperature averages recorded for DL, DST and PST during the study period is respectively 26.2 ± 0.01, 27.8 ± 0.01 and 26.4 ± 0.01°C. Figure 3 shows the change in temperature between septic tanks.

Conductivity values show that the sludge is loaded into dissolved salts. Conductivity in the different sludge varied between 1641 and 16783 S/cm and the highest value is observed in the Public Septic Tanks (PST).

pH values obtained are 7.5, 7.3 and 8.4, respectively for DL, DST and PST, values consistent with the development of the bacterial that purify the sludge.

Suspended matter (SM)

The concentration of suspended matter (SM) is very high in sludge. As shown in Table 2, the concentration of materials suspensions at the different sludge varied for DL, DST and PST respectively 70 ± 20, 54 ± 2 and 75 ± 15 g/L.

Ammonium (NH_4^+), NO_3^-, NO_2^- and PO_4^{3-}

The degradation of organic nitrogen into ammonium is an integral part of the nitrogen cycle in nutrient production. High ammonium levels were found in the Public Septic Tank (Table 2).

The average nitrate concentration is 143 ± 7.54, 150 ± 0.4 and 406.3 ± 0.3 mg/L, respectively for Dry Latrine, Domestic Septic Tank and Public Septic Tank.

Carbon pollution: BOD_5 and COD

The results of analyses revealed that the ratio of the COD and BOD_5 average gives 2.35, 2.55 and 1.72 mg/L, respectively for Dry Latrine, Domestic Septic Tank and

Table 2. Physico-chemical parameters.

Parameter	DL		DST		PST	
	Average	SD	Average	SD	Average	SD
pH	7.5	0.01	7.3	0.01	8.4	0.01
EC (S/cm)	1641	0.2	2582	2	16783	3
SM (g/L)	70	20	54	2	75	15
Temperature (°C)	26.2	0.01	27.8	0.01	26.4	0.01
COD (mgO_2/L)	700	20	980	10	3400	264.57
BOD_5 (mgO_2/L)	297	36.055	384	4	1978	1
COD/BOD_5 (mgO_2/L)	2.35	0.97	2.55	0.51	1.72	1.4
NTK (mgN/L)	908	3	1610	15	4760	3
NH_4^+ (mgN/L)	337	1.73	347	22.5	850.94	0.1
NO_2^- (mgN/L)	14	1.02	13.4	2.69	17.7	1.71
NO_3^- (mgN/L)	143	7.54	150	0.4	406.3	0.3
PO_4^{3-} (mgP/L)	143	5.29	150	5	406.3	0.43

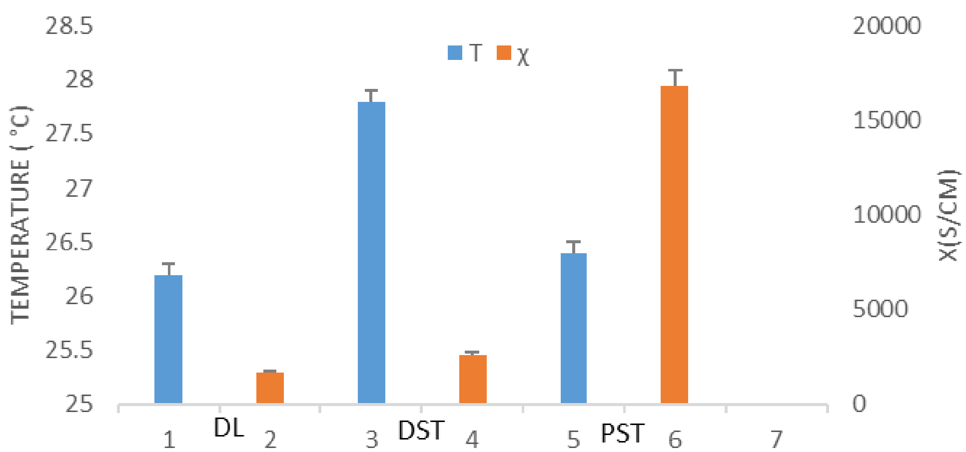

Figure 3. Electrical conductivity and temperature content.

Public Septic Tank. Figure 5 shows variations in BOD_5 and COD for different types of septic tanks.

DISCUSSION

Management of faecal sludge in the district of Kara

The study shows that mechanical emptying accounts for 92% versus 8% manual draining. This result proves that the predominant emptying mode is mechanical emptying and this is due to the permanent presence of trucks draining in the communality. The ideal would be to practice one 100% mechanical emptying to limit the risk of contamination of those who practice manual emptying. So the result obtained is more satisfactory compared to that of the city of Sokodé (Togo) where manual emptying is 24% and mechanical emptying 76%. The practice of manual emptying would be due to the fact that the populations lack financial means and also the difficulties of access to certain households by the emptying truck (Bissang, 2019).

Quantification of faecal sludge

The results of this study show that the sludge produced is estimated to be 113.28 m^3/day or 41347.2 m^3/year and that collected by truck to 60.9 m^3/day or 14616 m^3/year. The dumping activity is carried out without any control. The faecal sludge is spread into the environment sometimes anarchically. Some farmers living around the area use the sludge to irrigate their farms. The comparison of these two methods shows 26731.2 m^3/year or 65% of sludge is not drained. As in Kara, an average of 40.39 m^3/day of sludge is produced or 14

743.67 m^3/year in the city of Sokodé. The average quantity of faecal sludge collected is 8.68 m^3/day or 3168.20 m^3/year according to Water and Sanitation Project in Togo, Phase 2 (PEAT2, 2019). The quantity collected is very small compared to the quantity produced. Actions must be taken to strengthen the collection of faecal sludge in the town of Kara.

Interpretation of physico-chemical parameters

Figure 3 shows the change in temperature between septic tanks. It should be noted that the temperatures recorded in different tanks have a favourable microbial mineralization activity. Thus, it is noted that in hot period biological activity is more important than in winter, and it plays a major role on the kinetic reactions.

Conductivity values show that the sludge is loaded into dissolved salts. Conductivity in the different sludge varied between 1641 and 16783 S/cm and the highest value is observed in the Public Septic Tanks (PST). The conductivity values show that the effluent is loaded into dissolved salts. Indeed, anaerobic processes effectively mineralize organic matter and generate many dissolved salt, volatile fatty acids and hydrogen carbonates. This indicates that the sludge dumped in the district of Kara is highly mineralized, but still remains fermentable due to biodegradable organic pollutant levels. These average values are high than that found by Akpaki (2015) for Attidjin city (Lomé) and that found by Koné et al. (2016) at the Zagtouti (Burkina-Fasso). These results confirm that there is a high mineral salt content in the environment leading to the risk of surface water contamination resulting in an excessive increase in conductivity and a balance of the aquatic ecosystem (Koné et al., 2016). Wetzel (1983) showed that low conductivity (0 to 200 µS/cm) is an indicator of pristine or background conditions. Mid-range conductivity (200 to 1000 µS/cm) is the normal background for most major rivers. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or bugs. The results obtained in this study confirm that there is a strong presence of mineral salt in the medium. Taking into account the risks of contamination of surface water, an excessive increase in the conductivity of aquatic environments causes changes in the bacterial ecosystem and also has an influence on the survival of aquatic fauna and flora. In addition, too much salinity causes clogging of the soil (Koné et al., 2012), and negatively impacts the development of a large number of agricultural crops. For example, the excessive presence of salts causes a malfunction of the ion pumps allowing the plant, in normal times, to absorb this ion.

pH values obtained were 7.5, 7.3 and 8.4, respectively for DL, DST and PST, values consistent with the development of the bacterial that purify the sludge. The bacterial usually develop at pH between 5 and 9. The pH values obtained show that this faecal sludge are alkaline and their discharge into surface water could be dangerous for the survival of certain aquatic species such as fish, for example.

EC, pH and temperature can be limiting factors for the development of purifying bacterial.

Suspended matter (SM)

The concentration of suspended matter (SM) is very high in the sludge. These values greatly exceed the indicated standard which is 150 mg/L. Some authors have noted higher contents during similar work. Indeed, Mahamane (2011) reports an average SM value of 11,084 mg/L in Ouagadougou. This confirms the great variability in the characteristics of sludge with regard to its origin.

NH_4^+, NO_3^-, NO_2^- and PO_4^{3-}

The degradation of organic nitrogen into ammonium is an integral part of the nitrogen cycle in nutrient production. High ammonium levels were found in the Public Septic Tank (Table 2). This phenomenon is all more pronounced that the environment is alkaline and these values could be explained by the quality of the structure of the septic tank or latrine. Indeed, in these septic tanks, the anaerobic conditions favour the production of ammonium, which will oxidize in the aerobic conditions of the drying beds. Moreover, the longer sludge stays in the pit, the greater the mineralization. Nitrites an oxidized form on nitrogen is not stable; they evolve into nitrate in aerobic environment. The concentration of nitrite (15 mg/L) in this study is very high than (0.09 mg/L) from the study conducted in Zagtouti (Ouagadougou) by Koné et al. (2016) evaluating samples taken directly in the different basin. Figure 4 shows variations in nitrates and orthophosphates in different septic tanks.

The average nitrate concentration is 54, 56 and 85 mg/L, respectively for Dry Latrine, Domestic Septic Tank and Public Septic Tank. This indicates a good nitrification process when the sludge is dehydrated. Orthophosphates are undesirable when their levels become too high, although these are nutrients that can be used in agriculture. Nitrogen and orthophosphates contribute to the eutrophication of surface waters. Phosphorus in sludge in various forms (organic phosphorus, orthophosphates, etc.) can come from food but also from natural sources or from anthropogenic activities.

Carbon pollution: BOD_5 and COD

The results of the analyses revealed that the ratio of the COD and BOD_5 average was 2.35, 2.55 and 1.72 mg/L, respectively for Dry Latrine, Domestic Septic Tank and

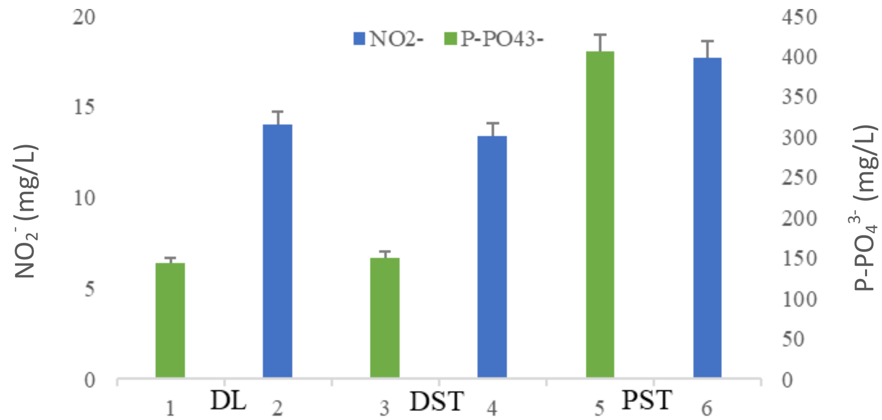

Figure 4. Nitrates and orthophosphate levels.

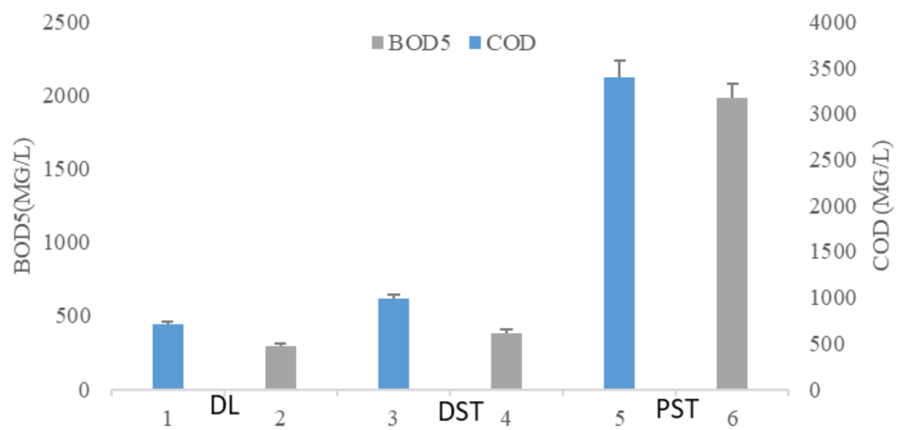

Figure 5. Values of COD and BOD_5.

Public Septic Tank, thus indicating the biodegradable nature of the sludge and the choice of biological applied treatment technology. These values obtained show that Kara district sludge is still biodegradable and undergoes mineralization. Figure 5 shows variations in BOD_5 and COD for different types of septic tanks.

Conclusion

The objective of this study was to know the characteristics and to estimate the quantity of the deposits of sludge produced in the city of Kara. To do so, it was necessary to carry out a sociological survey in the concessions and in the structures with high frequency, then to determine the physicochemical characteristics of the faecal sludge produced in the city of Kara. Two methods were used to assess the amount of sludge produced. The first method, based on specific production, shows that the estimated volume of sludge produced is 113.28 m^3/day or 41347.2 m^3/year. The second method based on the counting of trucks reveals that only 60.9 m^3 of sludge are emptied per month, that is, 14,616 m^3/year are emptied. The physico-chemical analyses focused on three types of septic tanks. The results of the parameters analyzed reveal that public septic tank latrines (PST) are more biodegradable than DL and DST justified by the fact that sludge from PST has a short residence time. This information is essential in the processing and sizing of structures. This work will be used by decision makers as an aid tool for decision making at the specific scale of the city of Kara.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Ahamada Z, Kimuli D, Banadda N, Kabenge I, Kiggundu N, Kambugu R, Wanyama J, Kigozi J (2016). Quantification of Physico-Chemical Characteristics and Modeling Faecal Sludge Nutrients from Kampala City Slum Pit Latrines. International Journal of Research in Engineering and Advanced Technology 3(6):129-141.

Akpaki (2015). Physico-chemical characterization of Attidjin faecal sludge (prefecture of the gulf-togo). Doctoral thesis, Chemistry of Water and the Environment, University of Lomé P 167.

Akpaki O, Baba G, Segbeaya KN, Koledzi KE (2016). Quantification and Biogas Valorization of Attidjin Lomé-Togo Sewage Sludge (Togo). Journal de la Société Ouest-Africaine de Chimie 042:30-35 ISSN 0796-6687.

American Public Health Association (APHA) (1998), Standard Methods for the Examination of Water and Wastewater. 20th Ed., American Public Health Association, American Water Works Association and Water Environmental Federation, Washington DC.

Bassan M, Tchonda T, Yiougo L, Zoellig H, Mahamane I, Mbéguéré M, Strande L (2013). Characterization of faecal sludge during dry and rainy seasons in Ouagadougou, Burkina Faso. 36th WEDC Int. Conf., Nakuru. Kenya pp. 1-7. https://www.researchgate.net/publication/255710132.

Bissang (2019). Characterization and quantification of faecal sludge deposits in the city of Sokodé. M.SC. Thesis, University of Kara, p.65.

Federal Institute for Water Supply, Wastewater Treatment and Water Protection (EAWAG) (2006). Towards an improved management of faecal sludge P 32.

Gnagne T, Kouame YF, Tenena M (2019). Sizing, operation and operation of Unsaturated Flow Drying Beds (LSENS) for the treatment of faecal sludge from septic tanks. International Journal of Biological and Chemical Sciences 13(5):114-121. DOI: http://dx.doi.org/10.4314:ijbcs.v13i.9S .

Kajyibwami (2018). Sustainable management of faecal sludge in Bobo-dioulasso (Burkina-Faso) P 99.

Katukiza AY, Ronteltap M, Niwagaba CB, Foppen JWA, Kansiime F, Lens PNL (2012). Sustainable sanitation technology options for urban slums. Biotechnology Advances 30(5):964-978.

Klingel F, Montangero A, Koné D, Strauss M (2002). Fecal Sludge Management in Developing Countries: A Planning Manual, https://sswm.info/sites/default/files/reference_attachments/KLINGEL%202002%20Fecal%20Sludge%20Management%20in%20Developing%20Countries%20A%20planning%20manual.pdf

Koanda (2006). Towards sustainable urban sanitation in sub-Saharan Africa : An innovative approach to planning faecal sludge management. Federal Institute of Technology in Lausanne. Ph.D. Thesis P 360.

Kodom (2019), Characterization and quantification of faecal sludge deposits produced in the city of Kara: specific ratio per household and per sector of activity, master's thesis, University of Kara P 61.

Koné M, Bonou L, Koulidiati J, Joly P, Sodré S, Bouvet Y (2012). Treatment of urban wastewater by infiltration percolation on sand and on a coconut substrate after an anaerobic lagoon basin in a tropical climate. Journal of Water Sciences 25(2):139-151.

Koné M, Ouattara Y, Service E, Ouattara P, Bonou L, Joly P (2016). Characterization of faecal sludge deposited on the zagtouli drying beds (Ouagadougou). International Journal of Biological and Chemical Sciences 10(6):2781-2795. DOI: http://dx.doi.org/10.4314/ijbcs.v10i6.30.

Kouawa T, Wanko A, Beck C, Mose R, Maïga A (2015). Feasibility study of faecal sludge treatment by constructed wetlands in Sahelian context: Experiments with *Oryza longistaminata and Sporobolus pyramidalis* species in Ouagadougou. Ecological Engineering 84:390-397, DOI: http://dx.doi.org10.1016/j.ecleng.2015.09.021.

Mahamane (2011). Contribution to the sustainable management of faecal sludge in the city of Ouagadougou: Characterization of sludge and evaluation of the sizing of STBVs in Kossodo and Zagtouli. Specialized M.Sc. Thesis 2iE, Ouagadougou P 68.

Ouédraogo (2016), Characterization of dried faecal sludge and treated percolate from the Zagtouli treatment plant with a view to agronomic valuation, master, Water and Sanitation Engineering Sciences, 2iE, Ouagadougou P 89.

Rodier J, Legube B, Merlet N (2009). « Water Analyzed ». 9th Ed.

Talla A, Sezawo R, Ngohe-Ekam PS (2017). Characterization of Depoted Faecal Sludge into the Environment and Design of a Suitable Treatment System: case of Nomayos Area in Yaoude City. Current Journal of Applied Science and Technology 21(2):1-12. DOI.10.9734/BJAST/2017/32755

Tilley E, Zurbrügg C, Lüthi C (2010). A Flow Stream Approach for Sustainable Sanitation Systems. Social Perspectives on the Sanitation Challenge, pp. 69-86. DOI: 10.1007/978-90-481-3721-3.5.

Water and Sanitation Project in Togo, phase 2 (PEAT-2) (2019). Quantification and characterization of faecal sludge deposits in the city of Sokodé: Specific production of faecal sludge per inhabitant. Report, University of Kara P 19.

Wetzel (1983). Limnology. 2nd Ed. Saunders College Publishing. 760 p.