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Research Article

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Characterization of Faecal Sludge from Septic Tanks and Latrines in the City of Lomé for a reliable Treatment Plant Establishment

AYITE Komlan, AYAH Massabalo, KODOM Tomkouani, BAWA Limam Moctar and DJANEYE-BOUNDJOU Gbandi

Laboratoire d'Hydrologie Appliquée et Environnement, Faculté Des Sciences, Université de Lomé, BP: 1515 Lomé, Togo

Abstract Quantifying and characterizing the faecal sludge prior to an efficient treatment is an essential prerequisite for the design of a faecal sludge (FS) treatment plant. The precise determination of the volume of sludge produced is essential for the correct sizing of the required infrastructures, both for the collection and transport of sludge as well as for the dumping sites, the treatment stations and their reuse or disposal. Data was collected from 2017 to 2019 and the method used consists of sludge collection from formal and informal companies that reject faecal sludge on the study area. The amount of FS was determined by counting the trucks received daily on the study area. The quantity was 562966.80 m^3, 610103.80 m^3, 627472.80 m^3 respectively 2017, 2018 and 2019 showing an increase about 47.137 m^3 from 2017 to 2018 and 17.369 m^3 from 2018 to 2019. The large variability in the characteristics of faecal sludge makes it necessary to obtain site-specific data in order to design the sludge treatment process. To be in phase with the requirements of the faecal sludge treatment systems and hence achieve the expected results for this study, the samples were taken at different points on the faecal sludge removal site, called DP1, DP2, DP3, DP4 and DP5, as well as a control point, called DPT. The results show that the COD values decrease significantly from DP1 to DP5. Indeed, from June to December 2018, removal yield of COD following DP1 to DP5 was about 68.17% and for the same period in 2019, following DP1 to DP5, the removal yield was about 58.75%. Natural process including the phyto-assimilation from *paspalum vaginatum sw* occurs in the site leading to pollutants removal. However, the remaining pollutants are still high and thus a well-designed treatment plant should be built to fit well environmental requirement of FS sludge rejection from a river.

Keywords Autonomous sanitation, Faecal sludge, local quantification and characterization, *Paspalum vaginatum Sw*

Introduction

On-site sanitation is now the predominant solution available to households in developing countries. Indeed, collective sanitation networks represent very significant investments and are difficult to maintain and manage. Due to the configuration of many cities in Africa, collective sanitation is therefore a convenient sanitation of the populations of large conurbations. On the contrary, onsite sanitation (autonomous sanitation: traditional latrines or pits septic tanks) is the most technical practice in small towns and urban outskirts characterized by low capacities in terms of technical, human and financial means to set up and manage sewer networks.

According to the National Action Plan for the Water and Sanitation Sector (PANSEA 2018-2030), 2017, 55% of households outside Lomé have latrines while 91% of the inhabitants of the capital and 66% of the inhabitants of "Grand Lomé" have access to a sanitation system in 2015. In addition, the lack and well-organized emptying services associated with poverty, poses a problem for the evacuation of excreta. Emptying services are usually provided by private companies whose service delivery costs are not within everyone's reach. In addition to the high service costs, there is no deposition and treatment unit plant for faecal sludge in Lomé. As a result, sewage sludge is dumped in an anarchic and clandestine way without any prior treatment on public roads, in gutters and on vacant lots. This bad management exposes populations to health and environmental hazards. On the other hand, for soil amendment needs, faecal sludge (FS) is reused without prior treatment to increase agricultural production through the development of gardening and globally for vegetable growth. Autonomous sanitation works in cities produce a large volume of faecal sludge and that the sludge emptied from simple pits is “fresh” sludge, which is not completely mineralized and which retains some significant pollutant load, in particular on the bacteriological level. Better faecal sludge management is therefore a big challenge.

The aims we wish to achieve for a better management of faecal sludge are, among others, the protection of the environment and public health. Treatment goals are reached through reduction of pathogens, stabilization of organic matter and nutrients, and safe reuse or disposal of treatment products [1].

To attain this goal, the overall pollution parameters of faecal sludge should be characterized. However, the sludge amount determination is also important.

The amount of faeces produced daily varies considerably depending on nutritional habits. Consumers of unprocessed foods with ahigh fiber content will produce a greater amount of faeces (by mass and volume) than consumers of highly processed and meat-based foods [2]. The frequency of faecal excretion averages one stool per person a day. However, it can vary from once a week to five times a day [3-4]. Achieving an accurate estimate would require intensive survey at the household level. Detailed demographic information is sometimes available, but not always the case. Another challenge is the rapid population growth in urban areas in low-income countries. Finally, estimating the volume of faecal sludge destined for treatment stations must also take into account the fact that septic tank trucks do not always pump all of the sludge contained in household sanitation systems [5].

The aim of this study is to promote better personal and environmental hygiene and sanitation in order to protect health, with protecting the environment, promoting health and facilitating access to environmental resources. This study is also a contribution for a reliable treatment plant establishment.

Material and Methods

Study Area

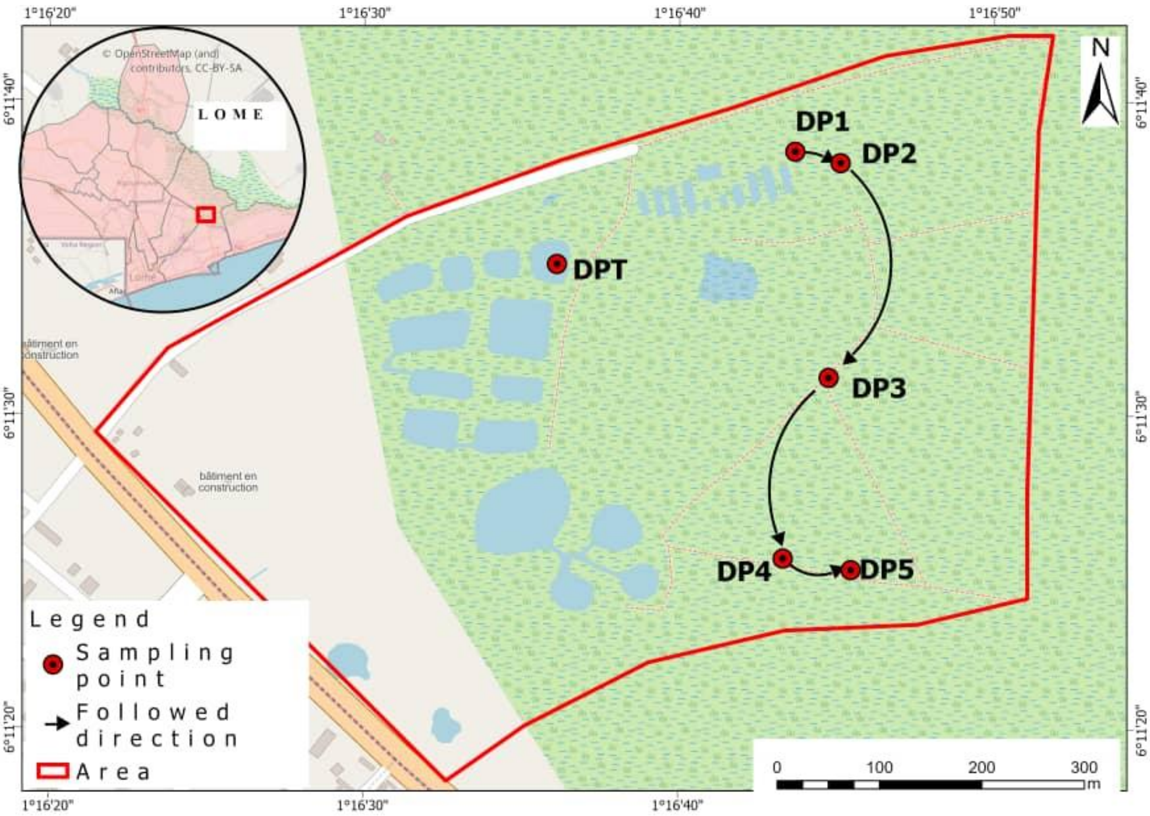

Figure 1: The study area where faecal sludge from Lome and its neighborhood is rejected

The main place for faecal sludge rejection in Lomé is located at Attiégou Koklovikopé (District of Bè-Kpota) (Figure 1). The study area is characterized by a total surface area of nineteen (19) hectares and the place is 1.355 km to river Zio to the West. As far as the climate is concerned, the South of Togo is characterized by a guinean subequatorial type climate with four alternating seasons: a long dry season (from November to mid-March), a long rainy season (from mid-March to mid-July), a small dry season (August to September) and a small rainy season covering the month of October. In general, the climate is dependent on two air masses: the harmattan (dry and hot) and the monsoon (hot and humid). The wind often blows in a west-east direction with a speed of 1.93 m/s. Evapotranspiration is 1540 mm/year and relative humidity varies between 70% (February) and 90% (June-July). The average temperature is around 27°C with variations of 6 to 9 °C between monthly minimums and maximums. In August, the temperature drops to 18 °C. Rainfall is on average between 80 and 950 mm per year. Nevertheless, the maritime influence softens the temperature and offers a relatively high humidity (> 75%) which compensates for the rainfall deficit [6-7]. The study area consists of a hydromorphic soil because its evolution is conditioned by the presence of excess water for a longer or shorter period of the year. It adjoins along the bank of the river Zio bed and specifically corresponds to a semi-peaty soil on fluvial alluvium because it is strongly colonized by a thick meadow with *paspalum vaginatum Sw* (Figure 2).

Figure 2: Meadow of paspalum vaginatum sw.

According to the stratigraphy of the coastal sedimentary basin of Togo (sedimentary series of Meso-Cenozoic age), the study area is of Oligocene-Miocene age because it consists of more or less sandy clays and limestone with nummulites [8].

Figure 3: View of the area where transport companies discharge the faecal sludge

Figure 3 shows the place where sludge is discharged each day. The liquid part of the sludge flows from this point (DP1) to the point DP5. According to the geographical situation of the deposit site, rainwater or any liquid will naturally flow from DP1 to river Zio.

Quantification of Faecal Sludge rejected in Study Area

The first step in designing faecal sludge (FS) treatment technologies that will meet defined treatment objectives is to quantify and characterize the FS to be treated. The quantities of FS generated and the typical FS characteristics are difficult to determine due to the variety of onsite sanitation technologies in use, such as pit latrines, public ablution blocks, septic tanks, aqua privies, and dry toilets. Due to the variability of FS volumes generated, it is important to make estimates based on the requirements specifically for each location and not to estimate values based on literature.

Two approaches that have been developed are the Sludge Production Method, and the Sludge Collection Method, depending on whether the goal is to determine total sludge production, or the expected sludge loading at a treatment plant. The Sludge Production Method for estimating FS quantities starts at the household level with an estimate of excreta production (i.e. faeces and urine), the volume of water used for cleansing and flushing and in the kitchen, and accumulation rates based on the type of onsite containment technology. The Sludge Collection Method starts with FS collection and transport companies (both legal and informal), and uses the current demand for services to make an estimate of the volume of FS.

Collecting the necessary data for an accurate assessment of faecal sludge production is a real challenge, especially in cases where no data is available. We have used to quantify the sludge amount deposited on study area. In this study, we have chosen the method of sludge collection from formal and informal companies that reject FS on the study area, because the majority of the faecal sludge collected are transported and delivered in the site of our study area. Data was collected from 2017 to 2019.

Characterization of Faecal Sludge

The sampling principles and methods described by the AFNOR standards on "Water quality" and Rodier on "water analysis" were used [9-10]. The effluent samples from faecal sludge deposited in the study area were resulted from (04) sampling campaigns (June 2018, December 2018, June 2019 and December 2019).

Thus, five (05) effluent sampling points (DP1 to DP5) from the faecal sludge and one (01) sample of water point serving as reference (DPT) were chosen for sampling according to the direction of flow of these effluents. Effluents from sludge flow via channels to river Zio. The geographic coordinates of the various sampling points were recorded using a “Garmin” type GPS. The faecal sludge effluent samples were taken in clean polyethylene plastic bottles with a capacity of 1.5 L. All the samples collected were taken to the laboratory in an icebox for analysis. Analysis parameters include solids concentration, chemical oxygen demand (COD), biochemical oxygen demand (BOD), nutrients, pathogens, and metals. These parameters are the same as those considered for domestic wastewater analysis, however, it needs to be emphasized that the characteristics of domestic wastewater and FS are very different.

Results and Discussions

Prior to a reliable treatment plant, quantification and physicochemical characterization of faecal sludge is necessary.

Volume of Faecal Sludge received at Depositing Site

This estimate of volume sludge is based on the quantification of the number of trips made by the sludge emptying trucks. We use the average volume of the transport vehicles which come in the area. The volume of sludge deposited on the site during three years 2017, 2018 and 2019 is recorded in tables 1, 2 and 3.

Table 1: Evolution of the Volume of Sludge during 2017

2017	vol_min (m^3)	vol_average (m^3)	vol_max (m^3)	vol_monthly (m^3)
jan.-17	1240	1736.50	2170	43412.40
feb.-17	1302	1853.80	2418	44491.20
march-17	1264.8	1691.47	2219.60	45669.60
apr.-17	1488	1838.55	2666	42286.60
may-17	1215.2	1924.86	2542	50046.40
june-17	1413.6	1871.62	2765.20	46790.40
july-17	1252.4	1878.12	2318.80	48831.20
aug-17	744	1954.60	2504.80	52774.20
sept.-17	1252.4	1880.82	2480	47020.40
oct.-17	396.8	1773.68	2529.60	46115.60
nov.-17	1426	1840.62	2430.40	46015.60
dec.-17	1636.8	2063.10	3558.80	49513.20
Annual Volume (m^3)				**562966.80**

Table 2: Evolution of the Volume of Sludge during 2018

2018	vol_min (m^3)	vol_average (m^3)	vol_max (m^3)	vol_monthly (m^3)
jan.-18	1242	1939.96	2401.20	50439
feb.-18	1131.60	2047.66	2755.80	49143.80
march-18	92460	1959.05	3118.80	48976.20
apr.-18	1021.20	1977	3022.20	45471
may-18	1559.40	2129.40	3036	48976.20
juin-18	1380	1957.88	2553	46989
juil.-18	1531.80	2040.28	2511.60	53047.20
aug-18	1545.60	2239.10	3726	55977.60
sept.-18	1628.40	2053.98	2677.20	51349.40
oct.-18	1311	1923.31	2318.40	51929.40
nov.-18	1642.20	2170.87	2815.20	54271.80
dec.-18	1863	2230.55	2953.20	53533.20
Annual Volume (m^3)				**610103.80**

Table 3: Evolution of the Volume of Sludge during 2019

2019	vol_min (m^3)	vol_average (m^3)	vol_max (m^3)	vol_ monthly (m^3)
jan.-19	1518	2054.54	2718.60	51363.60
feb.-19	1587	2184.43	3146.40	52426.20
march-19	1573.20	2090.17	2553	54344.40
apr.-19	1656	2144.76	2732.40	51474.20
may-19	1738.80	2141.22	2677.20	53530.40
juin-19	1697.40	2219.92	3201.60	48838.20
juil.-19	1669.80	2145.13	2649.60	57918.60
aug-19	1600.80	2115.12	2622	54993
sept.-19	1600.80	2008.73	2456.40	50218.20
oct.-19	1462.80	1933.54	2304.60	52205.60
nov.-19	1669.80	2026.39	2704.80	50659.80
dec.-19	1476.60	1980.02	2359.80	49500.60
Annual Volume (m^3)				**627472.80**

The registration campaigns began in 2017 and continued until December 2019. The surveys over the three years provided sufficient information on the volumes of faecal sludge received on the study area. Trucks come in, from Monday to Saturday every week, except Sundays and holidays. The assessment consisted of counting the trucks received daily on the study area, and according to their volume, we estimate the average daily and monthly volumes.

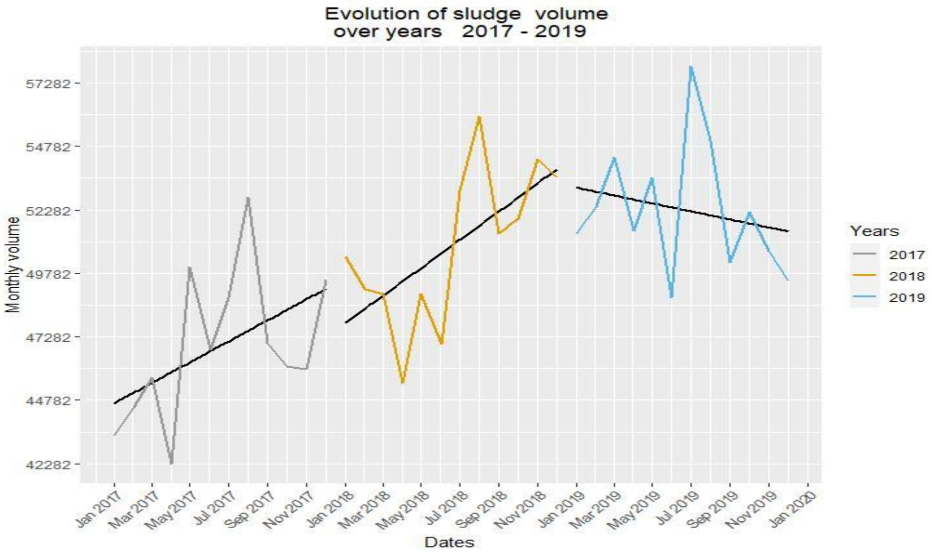

Figure 3: Annual Evolution of Faecal Sludge from 2017 to 2019

The analysis of the tables and graph shows that there is an increase of sludge deposited on the site over the year (Figure 3). However, a slight decrease can be observed for 2019. The increase of sludge quantity probably reflects economic situation because, more and more households have an interesting job, they could financially support the emptying cost of their pits once they are full. Due to economic growth and mentality changes, people build their houses integrating water latrines instead of traditional ones. From 2017 to 2018 the sludge amount received on the site increased about 47.137 m^3 and 17.369 m^3 from 2018 to 2019. This slight increase from 2018 to 2019 can be explained by the fact that the frequency of emptying at the household level is three to five years and that only public latrines which need regular emptying will then significantly supply the site.

Physico-chemical and Bacteriological Characteristics of Faecal Sludge

Prior to any reliable treatment process, the characterization of feacal sludge is necessary to acquire site-specific data. The data of characterization are classified in table 4.

Table 4: Data of Sludge Characterization from 4 Sample Points in Comparison to a Reference DPT (June 2019)

Parameters	Unity	DP1	DP2	DP3	DP4	DP5	DPT
Temperature	°C	34.1	31.7	31.4	31.5	30.5	31.5
pH	upH	7.47	7.73	7.62	7.60	7.55	7.53
Conductivity	µS/cm	6840	5930	5750	4100	3560	3440
eH	mV	-71.8	-61.6	-56.9	-54.1	-51.3	-46.2
Dissolved Oxygen	mgO_2/L	0.01	0.03	0.03	0.05	0.07	3.01
NH_4^+-N	mg/L	351	296	283	257	186	4,3
Total Kjeldahl Nitrogen, TKN	mgN/L	806	681	651	591	428	12,9
Total Phosphorus, TP	mgP/L	59.9	54.8	51.8	47.6	38.8	7.9
COD	mgO_2/L	4800	3200	2510	2100	1600	50.0
BOD_5	mgO_2/L	3908	2528	1900	1548	1168	41,5
COD/BOD	-	1.2	1.3	1.3	1.4	1.4	1.2
Removal	%	0	35.3	51.4	60.4	70.1	-
Total suspended solids (TSS)	mg/L	357	305	284	207	175	2.4
Oil and Grease (OG)	mg/L	32.9	21.9	18.6	16.4	11.0	0.3
Faecal coliforms	ufc/100ml	22500	17500	5100	250	110	37
E. Coli *(EC)*	ufc/100ml	15000	4500	4000	120	100	5

The evolution of COD and BOB5 is designed in figure 4.

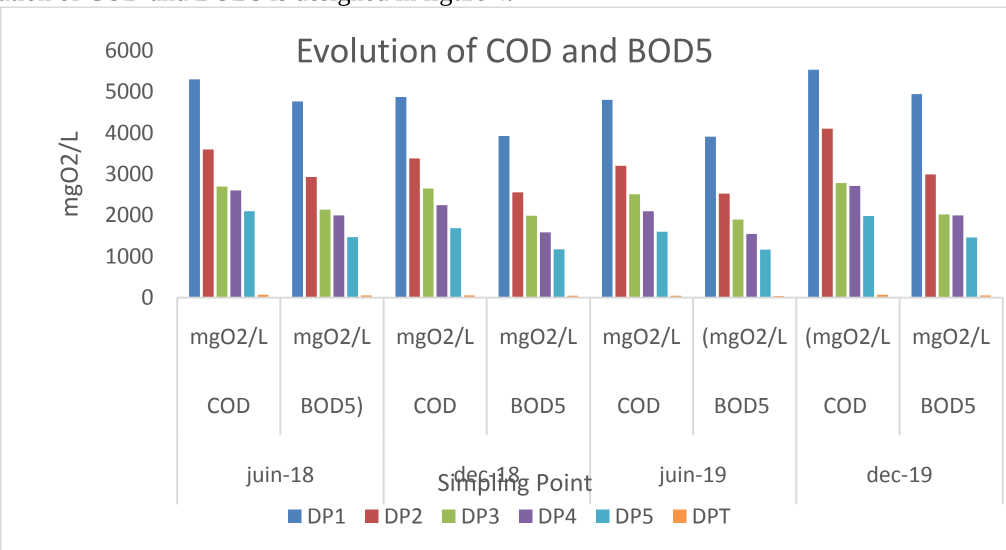

Figure 4: Variation of COD and BOD5 from DPT1 to DPT in June 2019

The sludge on the site is rejected without any real mechanism of treatment from human. However, there is a considerable decrease in the concentration of COD and BOD as one moves away from DP1 to DPT. That is possible because the study area can be considered as a bed planted of macrophytes or horizontal subsurface constructed wetlands. There are variety macrophytes in the area, but *Paspalum vaginatum* Sw are dominated because they are freely floating on the surface of the water, usually with submerged roots. The water flows through the wetland bed and comes into contact with the soil grains and plant parts, thus enabling a series of physical, biological, and chemical processes to take place, which contribute to the degradation and removal of various pollutants.

Natural digestion involving aerobic, anaerobic and vegetable assimilation of pollutants in sludge justify the significant decrease of COD and BOD.

From 2018 to 2019, the COD values obtained at the deposition point are respectively 5300 mgO_2/L (June 2018), 4870 mgO_2/L (Dec 2018), 4800 (June 2019), 5530 mgO_2/L (Dec 2019) for DP1 and at the last sampling point (DP5) 2100 mgO_2/L (June 2018), 1687 mgO_2/L (Dec 2018), 1600 (June 2019) and 1980 (Dec 2019).

From June to December 2018, removal yield of COD following DP1 to DP5 was about 68.17% and for the same period in 2019, following DP1 to DP5, the removal yield was about 58.75%.

This significant removal yield of COD is probably due to vegetable assimilation of pollutants. Indeed, different plants colonize the site. Among them *paspalum vaginatum Sw* is the most visible plants on the site. This plant is a perennial and glabrous grass with creeping stems (stolons) from which stem varies from 10 to 60 cm.

The concentrations of BOD5 at the same points vary in the same magnitude as COD values. The values obtained vary from 4763 mgO_2/L for DP1 (June 2018) to 1175 mgO_2/L (Dec 2018) for DP1 and vary from 3908 mgO_2/L for DP1 (June 2019) to 1465 mgO_2/L (Dec 2019) for DP5. From June to December 2018, removal yield of DBO5 following DP1 to DP5 was about 75.33% and for the same period in 2019 following DP1 to DP5 the removal yield was 62.51%. Compared to faecal sludge treatment station in Dakar where the BOD5 of the effluent is 870 mg O_2//L [11], one can conclude that the natural treatment process occurring in the present study site is in then significant. In the North American Data Base (NADB) literature containing data from over 100 sewage basins, compiled for the US-EPA it is reported that the efficiency of the purification of flow basins is high for COD and BOD (90%) and for bacterial pollution (99%) but significantly less for N and P (10-15 %) [12]. Vegetation itself functions as a temporary storage of nutrients, especially at the start of their growing season when large amounts of nutrients are taken up by the root system [13]. The removal yield in this case is not enough as recommended by US-EPA because the site is not really managed to attend good result. Natural processes such as aerobic, anaerobic digestion, vegetable assimilation and rainwater dilution are the main factors contributing to pollutants' removal. Therefore, to increase the yield, the management of the site should be done following a specific treatment.

Conclusion

This study was devoted to faecal sludge quantification and its characterization on the site of damping around Lomé. The quantity of FS was 562966.80 m^3, 610103.80 m^3, 627472.80 m^3 respectively for 2017, 2018 and 2019, well enough to be treated in a well-designed treatment plant. The characterization of the FS at different points of damping site shows that the COD value decreases in one direction (DP1 to DP5). The massive presence of the species *Paspalum vaginatum* Sw, which grows harmoniously on the occupied surfaces, would play a very important role in this purification process. It would be very interesting to focus on the role played by this species in the purification of wastewater and faecal sludge in order to propose a process for the treatment of faecal sludge. Data collected from this study are then important to design a treatment plant-based wetland model where *Paspalum vaginatum* Sw will play an important role.

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