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Performance Study of the Katiola Fecal Sludge Treatment Plant (Côte D'ivoire)

Kone Kinanpara[1,2]*, Ta Bi Tra Noel Alexandre[3], Yeo Ténéna Martial[1,2], Gnagne Théophile[3] and Bony Kotchi Yves[2]

[1]*Department of Environmental Sciences and Technologies, Department of Environment, University Jean Lorougnon Guédé, Post office box 150 Daloa, Côte d'Ivoire.*

[2]*Department of Biodiversity and Tropical Ecology, Department of Environment, University Jean Lorougnon Guédé, Post office box 150 Daloa, Côte d'Ivoire.*

[3]*Department of Geosciences and environment, Department of Environmental sciences and management, University Nangui Abrogoua, Abidjan, Post office box 801 Abidjan 02, Côte d'Ivoire.*

Corresponding Author: Kone Kinanpara, Department of Environmental Sciences and Technologies, Department of Environment, University Jean Lorougnon Guédé, Post office box 150 Daloa, Côte d'Ivoire or Department of Biodiversity and Tropical Ecology, Department of Environment, University Jean Lorougnon Guédé, Post office box 150 Daloa, Côte d'Ivoire.

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Abstract

In Côte d›Ivoire, as in many cities in sub-Saharan Africa, the issue of fecal sludge treatment remains a public health and environmental protection issue. In Katiola, a plant was set up to address this challenge. This study focused on its operation, with a particular focus on unsaturated flow drying beds, a simple technology adapted to local realities. The study was based on direct observations, surveys, and an analysis of operational data over several years. It was noted that the plant receives increasing volumes of sludge, but often still below its capacity. The unsaturated flow drying bed, although efficient in infiltration and drying, has limitations related to frequent clogging, requiring rest periods to maintain its efficiency. Despite these constraints, the Katiola plant plays an essential role in limiting illegal discharges. Its proper operation, however, depends on the availability of emptying operators and better local organization. This study thus highlights the need to strengthen technical and human resources for more efficient sludge management in the municipality of Katiola.

Keywords: Sludge, Unsaturated Flow Drying Bed, Treatment Plant, Katiola

1. Introduction

In many developing countries, wastewater management, particularly wastewater from on-site sanitation systems, remains a major issue. In sub-Saharan Africa, it is estimated that more than 70% of urban residents use non-collective systems such as septic tanks and latrines [1]. These systems produce fecal sludge, the poor management of which can lead to severe environmental pollution and represent a significant risk to public health [2]. Nearly 80% of wastewater is discharged into natural environments without prior treatment (WHO/UNICEF), thus exacerbating the degradation of water resources and soils [3]. To address these challenges, several African countries have undertaken the construction of fecal sludge treatment plants to ensure more sustainable management of this waste.

In Côte d'Ivoire, around twenty treatment plants have been built since 2011 with the support of partners and managed by the National Office of Sanitation and Drainage. The one in Katiola, the capital of the Hambol region, has not yet officially opened. It has an estimated treatment capacity of 50 m^3/day. Despite this capacity, little information exists on its actual performance, making a thorough technical assessment of its operation necessary. In the absence of regular monitoring, illegal emptying or non-compliant discharges persist in Katiola, compromising sustainable sanitation objectives. Preliminary observations reveal that the concentration of suspended solids in treated effluents can exceed 1000 mg/L, while the Ivorian standard, established by the National Agency for the Environment and Sustainable development, authorizes a maximum of 150 mg/L [4]. This observation suggests partial or uneven effectiveness of the treatment units installed.

To ensure the proper functioning of the Katiola plant in both technical and health aspects, monitoring of fecal sludge management was carried out to assess its capacity. It is within this framework that this study was initiated, with the general objective of evaluating the efficiency and impact of the fecal sludge treatment plant in the city of Katiola. Specifically, it involves quantifying the fecal sludge collected and treated by the plant and evaluating the operation of the

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unsaturated flow drying bed.

2. Methodology

The methodology considers the situation of the study area, the structure of the work, and the tools used to achieve the expected results. The surveys were conducted between February and April 2025.

2.1. Presentation of the Study Area

Located in the north-central part of Côte d'Ivoire in the Hambol region (figure 1), the city of Katiola (regional capital) is located on the Bouaké-Korhogo axis, more than 400 kilometers from Abidjan (the economic capital). The sub-prefecture is bordered to the north by Fronan, to the south by Bouaké, to the west by Botro, and to the east by Timbé.

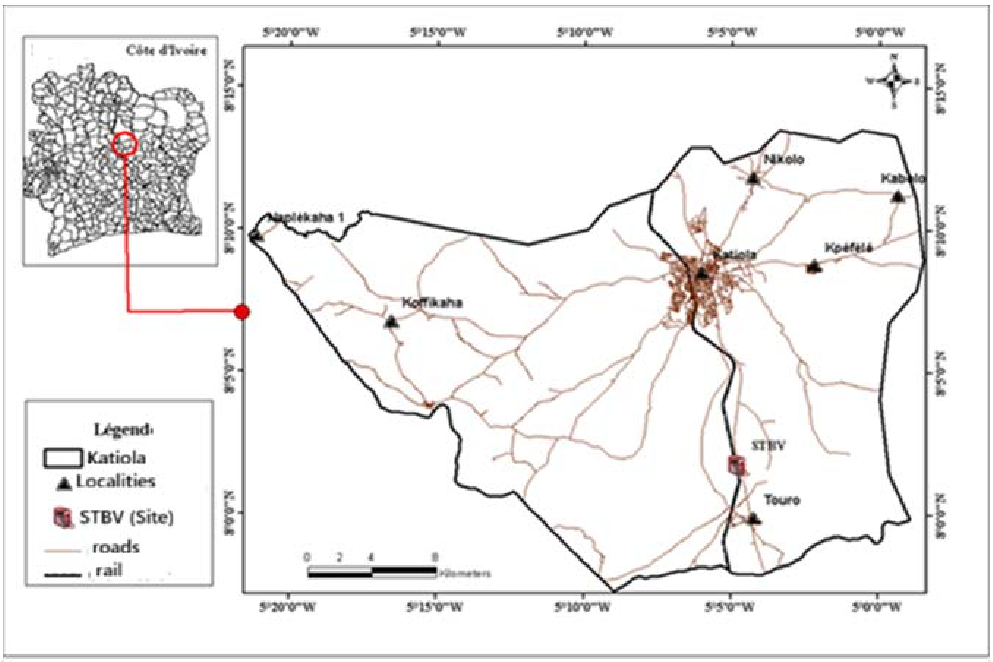

Figure 1 : location of study aera

2.2. Investigations

Visits were made to certain neighborhoods such as Dioulabougou, Pediakaha1, Mosque of the city. They allowed to observe the localities having septic tanks and fecal sludge treatment systems. The sludge used in this study comes mainly from the Lafigué gold mine located in the department of Dabakala and certain neighborhoods of Katiola. The methodology consisted of following the emptying trucks to the cleaning site. The questionnaire focused on the nature of the sanitation facility, the site where the collection is carried out (figure 2).

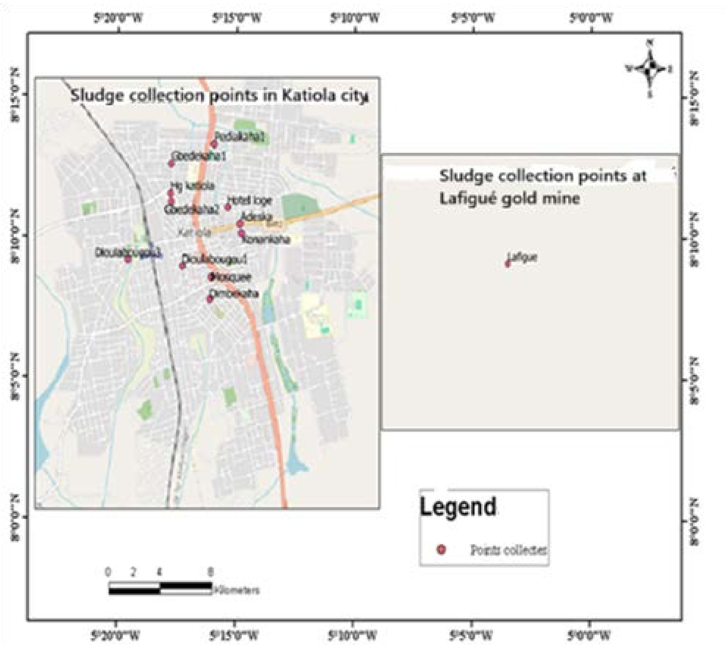

Figure 2 : Sluge collection points

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2.3. Description of the Fecal Sludge Treatment Plant

The fecal sludge treatment plant is located 12 kilometers from the city on the Katiola - Bouaké axis in the village of Touro. It is composed of two large treatment sub-units. The first consists of two series of unplanted drying beds (figure 3) and four drying areas for the sludge scraped from the beds. It has a 64 m2 square drying bed with 8 meters on each side and 50 centimeters deep. The second includes a lagoon system for treating the percolate from the drying beds. Pre-treatment structures consist of a screen system for retaining the coarse elements contained in the sludge. A one-way traffic lane allows the circulation of vacuum trucks in the station for sludge unloading. The service building provides a global view of the operations and movements of the vacuum trucks. The station is supplied with drinking water by a borehole powered by solar energy. The treatment consists of depositing the raw sludge directly onto unplanted drying beds through the pretreatment structures. The dried sludge is then removed and stored for approximately 3 months until it is disposed of for reuse in agriculture or landfill. The percolate from the beds is connected by a lagoon system for co-treatment with wastewater (figure 4). The plant has a treatment capacity of 50 m3/day.

Figure 3 : various sludge treatment works

Figure 4 : filtrate flow at the outlet of the drying bed

2.4. Description and Operation of Drying Bed

It is designed and sized like a conventional drying bed, except that the last layer of sand is replaced by paving stones laid without joint closure. It consists of a surface layer of paving stones 10 centimeters thick, a layer of gravel 30 centimeters thick with sizes 5-10 millimeters and a layer of coarse gravel 40 centimeters thick with sizes 10-40 millimeters.

The tanker truck dumps its entire contents onto the infiltration surface of one of the bed's compartments in an average of 15 minutes due to the pretreatment system. From then on, the compartment that just received the sludge is left to rest for 3 days. The next dumping takes place in another compartment, which will also be left to rest. On the third day, the compartment that initially received the sludge, which has since dried and been scraped, can once again receive the fecal sludge deposit. Through the succession of one day of unloading and three days of rest, the filter bed of the trap gradually clogs. To remedy this, it has been established that after 9 months of unloading, the trap must be left to rest for 1 month for almost total restoration of the porosity of the filter bed.

2.5. Treatment Plant Operation

Operating the plant requires the presence of qualified personnel to guide the sludge collectors to avoid unloading before the end of the rest days. They also ensure the scraping of the infiltration surface. Scraping must be performed to

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facilitate penetration by air diffusion into the porous mass through the infiltration surface. The volumes of sludge received were determined by the volume of each sludge collector at the inlet and outlet of the plant. Previous data were also analyzed and compared with current results.

3. Results

3.1. Origin and Quantity Collected of Fecal Sludge

Figure 5 shows the origin of fecal sludge during the period from January to April 2025. Household surveys were carried out on three trucks coming more in the Dabakala area and some in the districts of Katiola. Twelve districts were affected by this survey. Note that the majority of trucks come from the Lafigué gold mine with a quantity of 2250 m^3 of fecal sludge. On the other hand, trucks coming from the districts of Katiola (Dioulabougou, Konankaha1, Pediakaha1, Gbedekaha1, Katiola General Hospital, Gbédékaha 2, Mosque, Adeska, Loge Hotel, Dimbekaha, Lonankaha,) have a low quantity of fecal sludge ranging from 38 m^3 to 140 m^3.

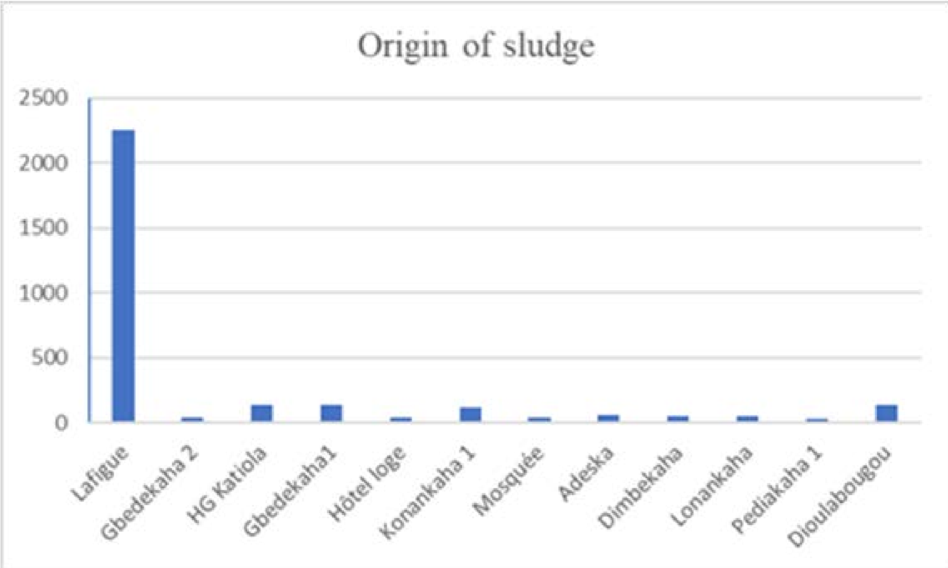

Figure 5: Origin of Fecal Sludge

3.2. Quantities of Sludge Entering the Station

Table I shows the average volumes of sludge received per day at the fecal sludge treatment plant since its commissioning. The quantities of sludge treated at the plant are lower than the nominal quantity of 50 m^3/day. In fact, the volumes of sludge treated from 2022 to 2023 were on average 4m^3/day. The minimum and maximum quantities treated during this period were respectively 0m^3/day and 60m^3/day. In 2024, the quantities of sludge treated were higher than those of 2022 and 2023, i.e. an average of 29m^3/day. It can be seen that in 2025, during the first month of the year, the quantities of sludge treated are higher than those of 2024. On average, 49m^3/day of sludge are received. This is lower than the nominal quantity of 50m^3/day. We then note that the quantities of sludge entering the treatment station increase from year to year. The average quantities received in relation to the nominal volume are represented by figure 6.

Years	Volume of sludge received (m^3/day)			
	Average	Minimum	Maximum	Standard deviation
2022	4	0	60	7
2023	5	0	50	7
2024	29	0	140	38
2025*	49	0	150	13

Table 1: Avera Quantity of Sludge Received at Katiola Treatment Station

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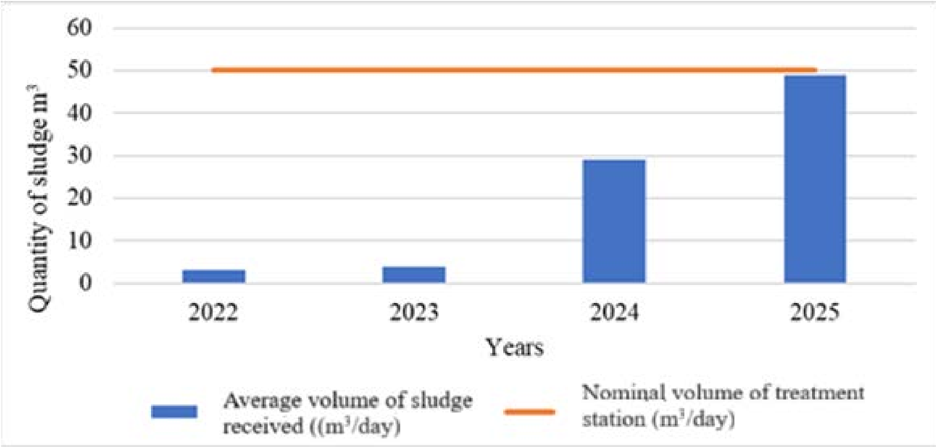

Figure 6: average quantities of sludge compared to the nominal volume

3.3. How the Drying Bed Works

The fecal sludge discharged for approximately 15 minutes by the tanker truck is distributed over the surface of the bed and infiltrates into the filter bed for 24 hours (figure 7). Generally, after 48 hours, drying is sufficient to carry out scraping to free the infiltration surface for oxygenation of the filter bed (Figure 8). The scraping time for one person varies from 20 to 40 minutes. The surface thus freed by scraping can be subjected to a new supply. The scraped sludge is exposed to the sun outside the drying bed.

Figure 7: feeding and infiltration of fecal sludge

Figure 8: Drying, Scraping, Transporting Sludge to the Drying Area

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4. Discussion

Analysis of sanitation facilities revealed that these are almost exclusively made up of individual septic tanks, not shared between several households. This predominance of autonomous sanitation systems is typical of urban contexts in developing countries, particularly in sub-Saharan Africa, where their low investment and maintenance costs make them more accessible to populations, confirm that these systems cover between 65 and 100% of sanitation needs in these areas [5-8]. In Katiola, this situation reflects a desire among households to ensure sanitary autonomy, but also a certain fragility of the collective sanitation system, which remains embryonic or even non-existent. Furthermore, the data collected on the fecal sludge treatment plant sources of sludge supply show a very clear concentration around the industrial site of the Lafigué gold mine. Indeed, more than 90% of the collections come from this site, while the residential areas of Katiola (Pédiakaha1, Hôtel Loge, Mosque sector, etc.) represent only a marginal fraction of the sludge received.

This imbalance is mainly explained by the absence of local mechanical emptying companies in the municipality. Households forced to use services from Bouaké face high costs, which considerably limits the frequency of emptying. However, the absence of regular emptying leads to major risks. As Dayal *et al*., pointed out, poorly maintained septic tanks eventually lose their retention capacity [9]. Solid sludge, when not extracted periodically (every 3 to 5 years), can migrate to leaching fields or infiltration wells, thus causing overflows and health problems (presence of wastewater pools, soil pollution, proliferation of pathogenic vectors). Following an annual awareness among the population on the impact of dumping fecal sludge in nature, there is an increase in the number of septic tankers who dump sludge at the treatment station. However, the quantity of sludge received is less than the nominal volume to be treated. As a result, we can still operate the plant.

On a technical level, the performance analysis of the fecal sludge treatment plant equipped with unplanted drying beds for which was carried out reveals a satisfactory relative efficiency. This process is based on a strategy of fractionating sludge inputs, making it possible to control the height of the deposited layers, avoid overloads and promote efficient evaporation. Unlike planted beds, where the sludge height can reach 30 to 40 cm before infiltration, the drying beds used in Katiola, ensure better distribution and accelerate sludge drying. These observations are supported by recent studies. Badza *et al.,* demonstrated that sludge depth plays a crucial role in drying time, and that good sizing makes it possible to limit treatment time [10]. In addition, Wang and Wang, through technical modeling, recommend a dry matter load of 73 to 122 kg/m² to optimize the performance of drying beds, considering climate variability [11]. In tropical contexts similar to that of Katiola, drying times can vary from 2 to 6 weeks, depending on weather conditions (sunshine, relative humidity, wind) and sludge characteristics (thickness, homogeneity, presence of coarse matter). Compared to planted drying beds, unsaturated flow drying bed have the advantage of greater simplicity of operation, lower maintenance costs, and increased efficiency in reducing sludge volume. However, it is recognized that planted beds offer better leachate purification, which could constitute an avenue for improvement for future phases of plant expansion [12-14].

5. Conclusion

This study, devoted to the performance evaluation of the Katiola fecal sludge treatment plant, has highlighted the current realities in terms of non-collective sanitation management in this locality. The results obtained reveal that sanitation systems in Katiola are largely dominated by individual devices, mainly non-shared septic tanks. This method of sanitation, although accessible in terms of cost, remains poorly regulated and suffers from a lack of infrastructure for mechanical emptying, thus limiting its environmental and health effectiveness. The analysis carried out showed that the unsaturated flow drying beds installed on the site offer acceptable performance, in particular thanks to a sludge input fractionation strategy. This approach makes it possible to control the load, limit drying times, and reduce the risk of clogging. However, although these performances are in line with recent literature, the plant remains underutilized due to the low mobilization of sludge from households, the majority of which do not have regular access to a local emptying service. The challenges identified in this work call for multi-sectoral solutions. We therefore recommend:

- strengthening the fecal sludge collection chain by facilitating the installation of local mechanical emptying service providers.
- raising public awareness of the need for periodic emptying to preserve the functionality of sanitation facilities and avoid environmental pollution.
- improving the performance of the fecal sludge treatment plant by considering the medium-term introduction of planted drying beds, which are more efficient for leachate treatment, and ensuring rigorous monitoring of drying parameters (time, load, thickness, climate).

Declaration of Interest, Funding and Acknowledgments

Declaration of Interest

The authors declare that there are no conflicts of interest that is relevant to the content of this article.

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