

# Uncovering the Challenges of Faecal Sludge Management in Benin's Urban Hubs: The Cases of Abomey-Calavi and Natitingou

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## Abstract

The issue of faecal sludge management in developing countries remains a significant challenge due to the indiscriminate discharge of sludge into the environment. This practice generates more environmental problems than it solves. This study aims to assess the management of household faecal sludge in the communes of Abomey-Calavi and Natitingou, Benin, in order to optimise the best storage conditions for subsequent more effective treatment. To this end, a sociological survey was conducted among households in Abomey-Calavi and Natitingou, as well as among manual emptiers. The results of our studies revealed that two types of latrines are used in households. 20.55% of households use traditional latrines, while 59.83% use ordinary latrines. 7.97% of households use both types of latrine. Moreover, the depth of the latrines varies from 2.5 m to 7 m in Abomey-Calavi and from 2.5 m to 8 m in Natitingou. Among households with a latrine, 28.26% empty their pit at least once, while 71.74% have never emptied it. The emptying cost varies between 35,000 FCFA and 90,000 FCFA. The mixing of faecal sludge with solid waste, including plastic materials, makes emptying difficult due to the obstruction of the vacuum pump. The results obtained will serve as a reliable database to facilitate decision-making in the context of faecal sludge management.

## Keywords

Management, Faecal Sludge, Valorization, Benin

## 1. Introduction

In African countries in general, urban areas have experienced very difficult management of population growth in recent decades, one of the greatest challenges facing humanity [1] [2]. This population growth has undoubtedly led to a high production of all kinds of waste, and that from households raises no less problems related to health and the environment. Among this household waste, faecal sludge is particularly distinguished, the management of which remains a poor relation of urban sanitation and a major challenge to be taken up [3]. Indeed, the storage of sludge, emptying, transport and evacuation of it carried out in a way that minimises health risks and respects the environment are very formidable problems [4] [5]. Yet the question of waste disposal, the problem of the availability of renewable and non-renewable natural resources, that of pollution and the issue of social exclusion are all factors that can jeopardise sustainable development in the case of an urban agglomeration [3] [6]. Indeed, waste must be used to the best of its potential: its valorisation is thus not only useful, but necessary [7]-[9]. It can then become a product that we can transform into a true secondary raw material [10]. Furthermore, several research studies have shown that poor management of faecal sludge and other types of waste is responsible for various scourges, including aesthetic and olfactory nuisance, the increasing detection of groundwater contamination has led to the development of the concept of aquifer vulnerability to pollution [3] [11] [12]. Benin, a West African country with a population of over ten million in 2013 [13], is no exception.

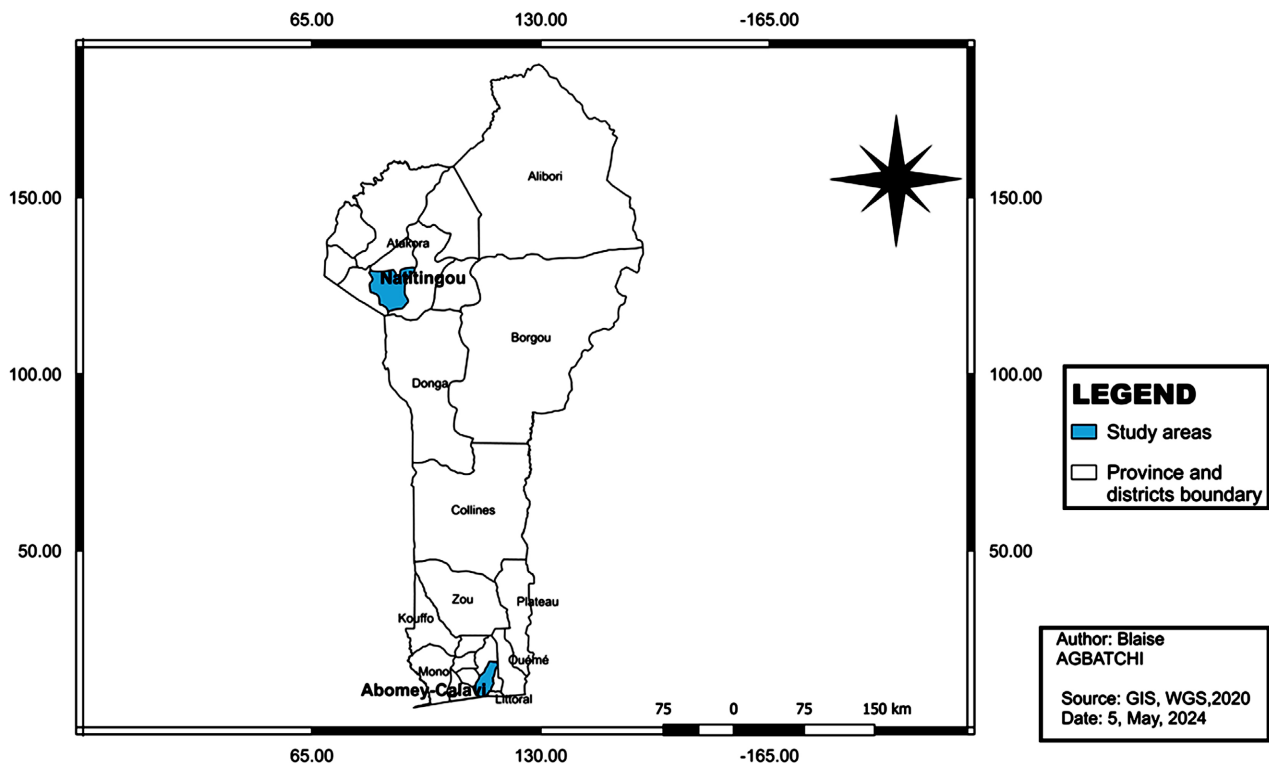
In Benin, according to the final results of the fourth General Population and Housing Census (RGPH4), 7000 people, including 4300 children, die each year from diarrhoea [14]. These deaths are 90% due to impure water and lack of sanitation and hygiene [14]. It is for this reason that the Beninese government, in its Action Plan (PAG) for the period 2021-2026 in the living environment sector, has put in place a new policy for modernising the management of faecal sludge and wastewater. This is already reflected in the construction of two large modern faecal sludge treatment plants: the first in Sèmè-Podji and the second in Abomey-Calavi [15] with different treatment techniques. These techniques are characterised by the implementation of filtering masses, with the aim of stabilising the organic matter and reducing the volume of the sludge in order to facilitate its transport [16]. The choice and design of these techniques are based on the characteristics of the faecal sludge in the commune and the objectives of the treatment and valorisation. It is therefore necessary to empty the pit regularly to avoid any malfunction of the treatment facilities downstream of the pits in order to avoid clogging of the filtering masses (in-situ soil, sand filters or other materials).

It is in this context that the present study aims to assess the management of faecal sludge in Benin, in order to optimise the best storage conditions for its subsequent more effective and profitable valorisation.

## 2. Methodology

### Study Area

In order to better comprehend the sludge management practices in Benin, a sociological survey is deemed necessary. To this end, two municipalities have been selected for investigation: Abomey-Calavi, situated in the south of the country, and the municipality of Natitingou, located in the north-western region of Benin (Figure 1).



**Figure 1.** Map of the study area.

The study area covers two different communes. The commune of Abomey-Calavi located in south part of Benin and the commune of Natitingou situated in the northern part of Benin.

Abomey-Calavi belongs to the Atlantic Department and is bordered to the north by the commune of Zè, to the south by the Atlantic Ocean, to the east by the communes of Sô-Ava and Cotonou, and to the west by the communes of Tori-Bossito and Ouidah. It covers an area of 539 km<sup>2</sup>, representing 16.67% of the total area of the Atlantic Department [17].

The population of Abomey-Calavi commune is estimated at 656,358 inhabitants, representing 47% of the population of the Atlantic Department, with an average density of 571 inhabitants per km<sup>2</sup> [13] [17]. The economic activities of the commune are agriculture, livestock farming, fishing, agro-food processing, crafts, commerce, transport, tourism and hotels [17]. Abomey-Calavi climate is characterized by rainy seasons and two dry seasons. The long rainy season starts

from April to July; and the short rainy season spans from October to November. Concerning the dry season, the short season lasts from August to September and the long is from December to March [18].

On the other hand, the commune of Natitingou covers an area of 3045 km<sup>2</sup>, or 12.8% of the total area of the department. Bordered to the north by the commune of Toucountouna, to the south and east by the commune of Kouandé, and to the west by the commune of Boukombé [19]. The population of the commune was 103,843 inhabitants in 2013 (RGPH4) [13]. Tourism, hotels, crafts, agriculture, animal production, fishing, commerce, processing and industry, and transport and communication are the main economic activities of the commune [19]. Natitingou has a Sudano-Guinean climate, characterised by two seasons. A rainy season lasting six (06) months from May to October, and a dry season covering the period from November to April.

### 3. Methods

#### 3.1. Data Collection

To collect the data, a semi-structured questionnaire was developed and inserted into the “Kobocollect” data collection tool, facilitating data collection from a mobile phone. The household surveys aimed to collect necessary information such as household size, the status of the household head (tenant or owner), the type of on-site sanitation system, duration of use, whether desludging had been carried out, the desludging method, frequency of desludging, cost of desludging and its accessibility. The semi-structured questionnaire developed for the desludging companies aimed to collect essential information on aspects such as the company name, the number and capacity of trucks, the treatment methods applied to the collected sludge, the cost of a desludging service, and the challenges related to the desludging activities. The surveyed households and desludgers were free to respond or abstain from any of the questions.

A total of 225 households and 22 desludgers were surveyed in Abomey-Calavi, and 101 households in Natitingou. The data collection was conducted from March 2022 to May 2023 considering the climate seasons in each region.

#### 3.2. Data Processing

The initial data collected were transferred in an Excel spreadsheet, where the responses to each question were grouped before proceeding to the data cleaning to better assess the quality of the collected data. We conducted a descriptive analysis directly in the “Kobocollect” tool, version 2022.2.3, and used the Excel 2026 spreadsheet to create the different graphs.

### 4. Results and Discussions

#### 4.1. Characteristics of Surveyed Households

**Figure 2** presents the status of the surveyed household heads. This figure shows that among the total households surveyed, 81% of the household heads are te-

nants and 19% are landlords in the case of the commune of Abomey-Calavi, compared to 24% tenants and 76% landlords in the commune of Natitingou (Figure 2). These contrasting results between the two communes could be explained by the significantly different living standards of the populations in these communes. It is clear that the living standard in the commune of Natitingou is still lower compared to Abomey-Calavi. The commune of Abomey-Calavi is facing a very rapid demographic growth. This is due to the proximity of the city of Cotonou, the economic capital of Benin, which can no longer accommodate its rapidly growing population [17] [20]. As a result, the population of Cotonou is settling in Abomey-Calavi, which is considered the main dormitory town for Cotonou’s workers [20].

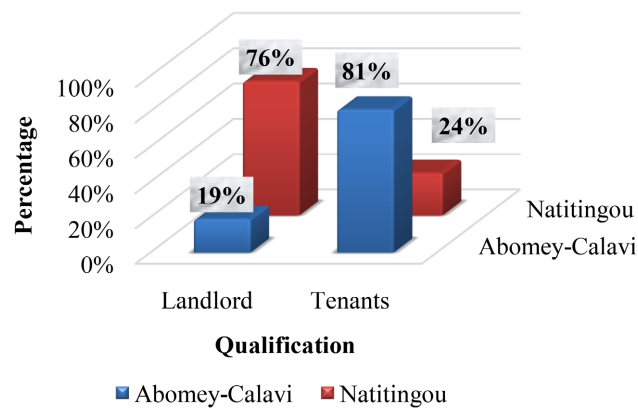


Figure 2. Qualification of heads of household.

In addition, 69.23% of the households have a stay of between 2 and 12 years on the plot, 26.15% between 12 and 17 years, while 4.62% have been living there for more than 17 years (Figure 3). This demonstrates the strong and renewed demographic growth of the commune of Abomey-Calavi, with a population growing exponentially from 60,786 inhabitants in 1979 to 656,358 inhabitants in 2013, with an annual intercensal growth rate of 6.7% between 2002 and 2013, compared to a growth rate of 9.43% between 1992 and 2002 [13] [17].

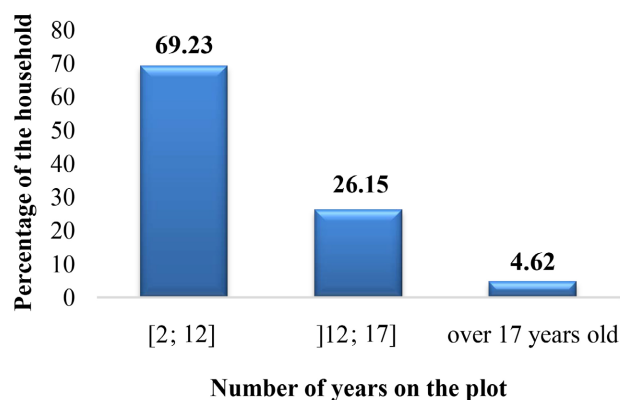
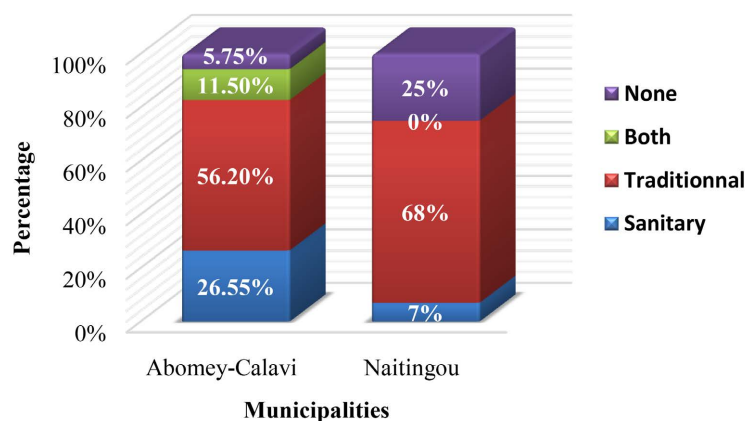


Figure 3. Length of stay on the plot.

## 4.2. Evaluation of Latrine Usage

**Figure 4** displays the different sanitation systems in the communes of Abomey-Calavi and Natitingou. The analysis of this figure reveals that two types of latrine are generally used in these communes. Sanitary latrines count for 26.55% in Abomey-Calavi, compared to 7% in Natitingou. 68% of surveyed households were in Natitingou, compared to 56.2% in Abomey-Calavi. It is also noted that 11.5% of households in Abomey-Calavi use both types of latrine simultaneously, which is not observed in Natitingou. This confirms the higher standard of living in Abomey-Calavi compared to Natitingou. However, the rate of use of traditional latrines remains the highest in both cases. The same observation was made by Defo (2015) in the city of Bafoussam (Cameroon), with 59% of use. Furthermore, 5.75% and 25% respectively in Abomey-Calavi and Natitingou do not have any autonomous sanitation system to date (**Figure 4**). Among the latter, some continue to practise open defecation, while others use either the nearest public sanitation system (school) or their neighbours latrines. These results are in line with the final results of the fourth general population and housing census (RGPH4) in Benin, which reveal that 86% of Beninese do not have access to improved sanitation facilities and 54% practise open defecation, which significantly increases the risks of contamination of the soil, water and food [13]. Remembering that water and air are two vital elements essential for human life and survival, it therefore seems necessary to think earlier about their preservation. Moreover, the absence of a sanitation system responsible for the spread of faeco-oral diseases is a major cause of several diseases, morbidity and mortality worldwide [21] [22].



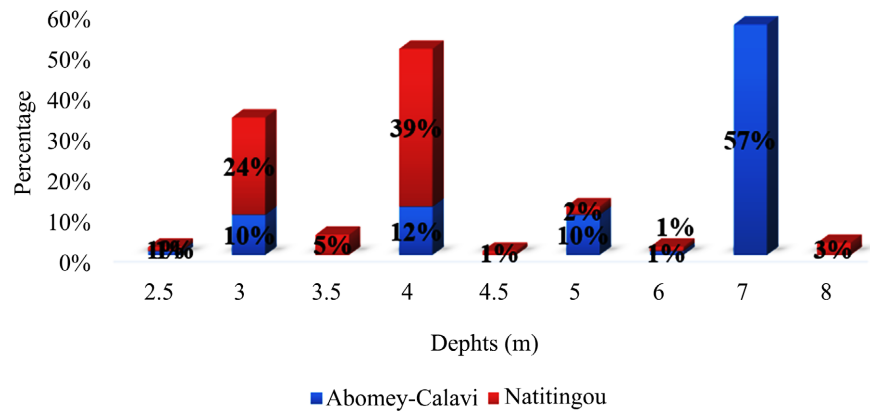
**Figure 4.** On-site sanitation systems in Benin.

## 4.3. Characteristics of Autonomous Sanitation Systems

During our household survey, we focused on two main parameters: the depth of the latrines and their duration of use. Depth is one of the most important hydrogeological parameters for evaluating the vulnerability of the groundwater table to pollution (DRASTIC method) [23]. It provides an indication of the distance the pollutant must travel before reaching the water table [23].

Analysis of **Figure 5** summarising the various depths of the recorded latrines

reveals that the latrines surveyed in the households are characterised by depths of 2.5 metres at 1% in both cities, 3 metres at 10% (Abomey-Calavi) and 24% (Natitingou), 3.5 metres at 5% (Natitingou), 4 metres at 12% (Abomey-Calavi) and 39% (Natitingou), 4.5 metres at 1% (Natitingou), 5 metres at 10% (Abomey-Calavi) and 2% (Natitingou), 6 metres at 1% in both cities, and 7 metres at 57% (Abomey-Calavi) and 8 metres at 3% (Natitingou).



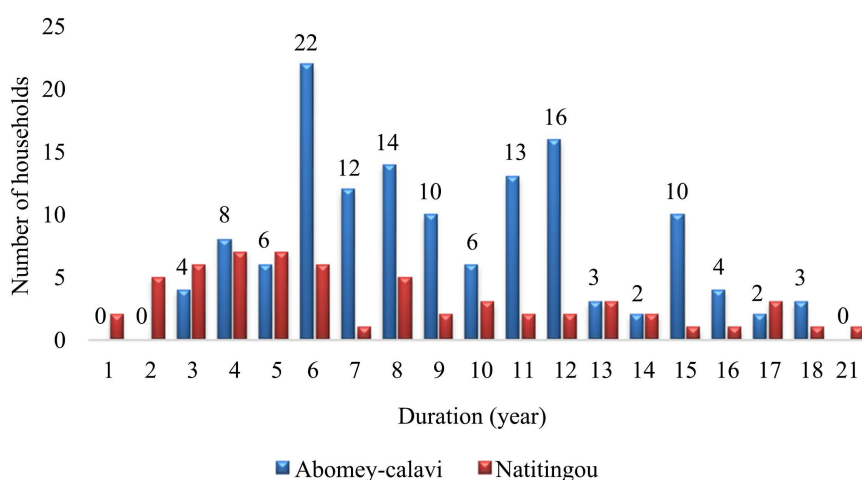
**Figure 5.** Depth of latrines.

These observed values are generally above the work of Gaston (2015) on the sizing of pits, whose total depths vary between 1.4 m and 2.20 m [24]. Moreover, these differences are justified by the absence of adequate regulations for the construction of septic tanks in Benin. The reasons given by households for the choice of pit depth are diverse. For some households, the choice of depth is based on the need for sand that can be used for backfill in the case of new construction. For others, it is more related to the proximity or not of the groundwater. For others, the choice is made based on financial means. However, studies by Poromna *et al.* (2022) in Lomé (Togo) and Mokili MBULUYO *et al.* in Congo have reported the vulnerability of the groundwater table due to poor management of sewage sludge [11] [23]. Although an excessively high depth could reduce exposure to health risks, this is not the case with regard to groundwater pollution, which is becoming a reliable and safe water source for all. It is therefore important to establish regulations to be taken into account during the construction of autonomous sanitation systems in order to protect the water table from pollution related to the infiltration of stored faecal sludge.

Regarding the duration of use of septic tanks and latrines, **Figure 6** presents the households according to their year of latrine use.

This figure suggests that the latrines have a usage duration ranging from 1 to 21 years without ever being emptied, and the majority are used for over 6 years. A multitude of questions remain regarding the quality of the sludge that will be collected from these latrines and the appropriate type of treatment. Indeed, the settleable organic matter in the pit undergoes biological transformation through anaerobic processes (liquefaction, acidogenesis, acetogenesis and methanogene-

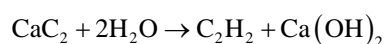
sis) during which numerous reduced compounds are dissolved in the liquid phase and therefore escape as malodorous volatile products (ammonia, hydrogen sulphide, methane) [25]. It is therefore evident to recognise the two main functions of septic tanks: the retention of solid matter through the hydraulic phenomena of sedimentation and flotation, and the hydrolysis (solubilisation), acid fermentation and methanisation (gasification) of the produced sludge due to the retention of solid matter [24]. In fact, a septic tank only reaches a state of biological equilibrium after approximately 2 years of operation, which is why its emptying is only recommended after at least two years, otherwise it never reaches its biological equilibrium [24] [26]. It can therefore be concluded that the septic tanks and latrines of the surveyed households are in a state of biological equilibrium.



**Figure 6.** Duration of latrine use in households.

#### 4.4. Modes of Use and Maintenance of On-Site Sanitation Systems

Concerning the different modes of use of latrines and septic tanks in households, our results revealed that various latrine treatment products are used by households to treat the sludge in the latrines. Among these products, we have cresol, ash, engine oil, chlorine, calcium carbide and charcoal. The purpose of using these products in general is either to disinfect the interior of the latrines (cresol and chlorine), to eliminate odors (ash, engine oil, charcoal) or to reduce the quantity of sludge in the latrines (calcium carbide). However, the specific use of chemical products such as cresol, calcium carbide and chlorine could have adverse short-term or long-term effects for both public health and the environment. It has been proven for years that calcium carbide in aqueous media releases acetylene, which is a flammable gas [27] according to the equation:



There is therefore a risk of fire in the event that the generated gas escapes from the pit. This could also explain the cracks in the walls and pits due to the gas pressure from expansion. Awareness-raising among the population is there-

fore necessary.

Other practices such as regular washing of latrines with bleach and other detergents are also observed in some households. Also, after defecating, households mostly use water and sometimes simple paper (notebook paper, cement bags, etc.) or toilet paper to clean themselves. The use of these cleaning materials is important to ensure good hygiene practices and avoid significant contamination by germs and other foreign and toxic substances. Furthermore, the latrine and septic tank emptiers mention the presence of a mixture of emptied sludge with other solid waste such as sachets, plastics, baby diapers, fabrics and others (**Photo 1**) in the pits. This constitutes one of the most common difficulties related to the latrine emptying activity, leading to obstruction of the suction system of the trucks. Moreover, this practice requires, during the treatment of the emptied sludge, a preliminary treatment to eliminate these solid wastes, which will undergo a separate treatment. As a result, the treatment stage becomes a long and tedious process.

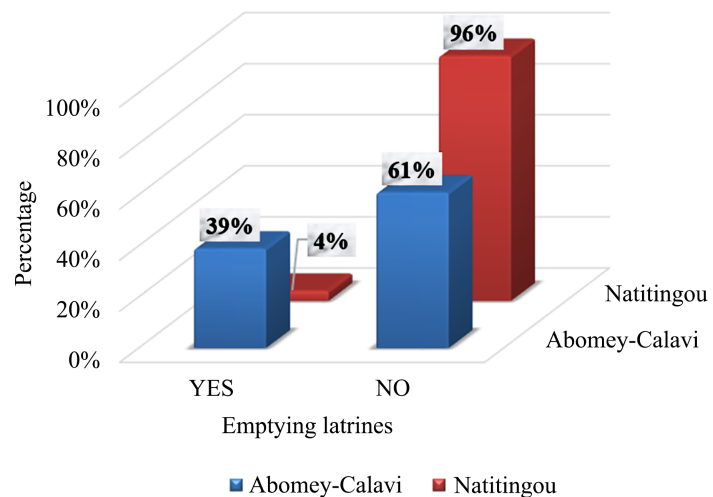


**Photo 1.** Overview of solid waste found in faecal sludge (Agbatchi©, 2023).

#### 4.5. Emptying On-Site Sewage Systems

Concerning the methods employed for the emptying of sanitation systems, only 4% and 39% of the surveyed households in Natitingou and Abomey-Calavi respectively reported having emptied their latrines utilising appropriate vacuum trucks in Abomey-Calavi and through manual emptying in Natitingou (**Figure 7**). These two modes of pit latrine emptying have been documented by Mbang and his collaborators in Yaounde (Cameroun) [28]. The choice of emptying method is justified by the availability of desludging services in Abomey-Calavi, while in Natitingou, a complete absence of vacuum trucks was noted. The households that had undertaken latrine emptying at least once were predominantly tenants residing in households with a population exceeding 17 individuals. Those who had emptied their latrines more than once reported that prior to the first emptying, the latrines had been in use for over 7 years. However, ac-

According to Bierlier, pit latrines should be regularly emptied at an ideal interval of 2 to 5 years [29]. Regrettably, this recommendation is far from being adopted in the study area, as emptying is only carried out once the pit is full.



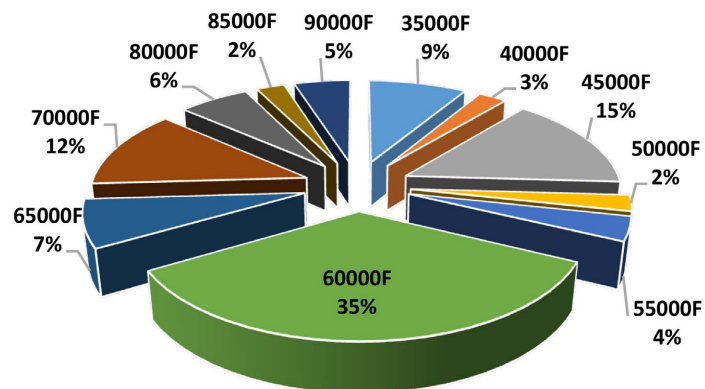
**Figure 7.** Emptying or no latrines.

It is noteworthy that after the initial emptying, the frequency of the emptying activity in the household is approximately 1 to 2 years. This frequency could be attributed to the fact that the latrines are not completely emptied, but rather only a reduction in the sludge volume within the latrine is achieved. Furthermore, 96% (Natitingou) and 61% (Abomey-Calavi) of the households affirmed never having emptied their latrines since their initial usage (Figure 7). For some of these households, the reason given is that the latrine is not yet full and there is any valorization of the matter.

The costs of latrine emptying have been confirmed through interviews with 22 desludging service providers. The variation in these emptying costs is contingent upon the quantity of sludge evacuated, the distance to the discharge station, any difficulties encountered during the process, and the type of pit. This would explain why the majority of households (66.66%) opt for the lowest cost (between 35,000 and 60,000 CFA francs), which leads to a reduction in the sludge quantity in the pits, as these costs do not cover the complete emptying of a pit. Furthermore, these costs are slightly higher than those mentioned by Defo (between 25,000 and 55,000 CFA francs) [30] and is in approximation with the results of Mbang (between  $20,000 \pm 6500$  FCFA and  $112,800 \pm 40,600$  FCFA) [28] (Figure 8).

The service providers have 15 to 25 years of experience. 61.54% of these enterprises possess a single truck, while 38.46% have two trucks. The truck capacities are either  $9 \text{ m}^3$  or  $12 \text{ m}^3$ , and they are sufficiently equipped. Although these enterprises have their headquarters, they do not have a specific station. They are generally located in the heart of the city of Abomey-Calavi or in Cotonou. Additionally, none of these enterprises undertake any treatment of the collected sludge. The collected sludge is typically discharged at two sites; one in Sèmè-Podji

and the second in Kanssoukpa (Abomey-Calavi). The treatment technique adopted for the commune of Sèmè-Podji is a non-planted drying bed (LSNP) with a capacity of 500 m<sup>3</sup>/day. The system in the commune of Abomey-Calavi is a planted drying bed (LSP) with reeds (*Echinochloa pyramidalis*) with a capacity of 600 m<sup>3</sup>/day, combined with a lagoon system to ensure optimal treatment efficiency. Furthermore, other NGOs negotiate the purchase of this sludge for other purposes (composting, etc.).



**Figure 8.** Latrine emptying costs.

## 5. Conclusion

In the findings above, it is clear that the faecal sludge management sector in Benin does not have any regulations related to the depth and volume of pits or the duration of sludge storage in septic tanks. Some communes in Benin do not have any enterprises for emptying latrines and septic tanks, nor do they have any faecal sludge treatment facilities. The excessively high cost of faecal sludge evacuation in households in the commune of Abomey-Calavi is a significant reason for the long-term storage of faecal sludge in pits on the one hand and for incomplete emptying on the other. It is therefore necessary and urgent to consider regulations for the valorization of faecal sludge in Benin. The results of this survey provide a reliable database to assist policymakers and experts in finding appropriate solutions for the valorization of faecal sludge.

## Author's Contribution

Blaise Agbatchi analysed and wrote the manuscript. Gouvidé Jean Gbaguidi processed the data. Nikita TOPANOU designed the study, validated the methods applied and reviewed the manuscript. Fidèle Paul Tchobo and Jacques Fatombi reviewed the manuscript and accessed it. All authors had full access to all the data in the study, had the final responsibility for the decision to submit for publication, and approved the final version of this article to be published.

## Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the University of Ab-

omey-Calavi. All methods were carried out in accordance with relevant guidelines and regulations and all experimental protocols were approved by the Ethics Committee. Informed Consent was obtained from all subjects and/or their legal guardian(s).

## Conflicts of Interest

The authors declare no competing interests.

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