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Faecal Sludge Management in the Residential Cores of Akure, Nigeria

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Abstract

Safe management of faecal sludge (FS) is momentous to the achievement of adequate and equitable sanitation for all by 2030. This seems difficult in urban slums where unplanned housing quarters with narrow roads, limited building backyards and airspaces negates the act of seal and abandon of on-site sanitation facilities when filled up with FS. Thus, this paper appraises faecal sludge management (FSM) in the core of Akure with the view to suggesting effective FSM systems that actively address the needs of the poor. Data utilised in this paper were collected from households using 400 sets of questionnaires. In addition, emptying service providers and relevant institutions were interviewed. Findings reveal that pit and septic tank were the two types of FS storage facility in the study locale. Manual emptying of FS that involved the use of a spade, shovel to scoop out FS was dominant. The bucket was prominent in the transport of FS to new pits dug close to old pits, which was the major means of FS disposal. Empirical estimates reveal that improvement in methods of emptying FS is the most important in improving FS management in this locale. This paper has shown that faecal sludge management in the study area was inadequate, unhygienic, unsystematic, unsafe, and perilous to environmental and public health. Therefore, recommends the establishment of a regulatory framework, adopt and adapt twin pit pour flush system, and improve FSM using mobile transfer stations.

Keywords

Faecal Sludge, Faecal Sludge Management, Onsite Sanitation Technologies, City Cores, Nigeria

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1. Introduction

Faecal sludge (FS) is the content in onsite sanitation (OSS) technologies. Strande [49] described it as fresh or partly digested slurry or semisolid substance with a high concentration of pathogen, results from the storage, collection or treatment of mixture of excreta and black water, with or without grey water. A well-constructed and maintained OSS facility is momentous to the separation of human contact from human faeces, and promotion of safe public health and environment [30]. It is an indubitable truism that, an effective and efficient FS management system should consider handling of FS until safe disposal stage because when FS is not well managed, it threatens human health and dignity [17]. Considering this fact, faecal sludge management (FSM) refers to the storage, collection, conveyance, treatment and safe disposal or productive reuse of faecal sludge [33]. It is indisputable that onsite sanitation technologies are dominant means of storing FS in many emerging cities of sub-Saharan Africa (where Nigeria lies) especially in unplanned and informal settlements [30]. Buttressing this, [6] affirmatively stressed that developing countries adopt OSS technologies as a way to meet sanitation targets in international treaties. Recent estimates by [51], shows that 2.8 billion of the global population use OSS technologies for their sanitary needs, which is expected to reach 5 billion in 2050 [49]. Furthermore, [50] stressed that the knowledge among city administrators that building sewerage in cities of developing countries is becoming

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prohibitively expensive led to the growing acceptance of cheaper and effective OSS technologies. Frankly speaking, OSS technologies are provided as panacea to the sanitation debacle in urban settings of developing countries. Amplifying this view, [45] noted that 65-100% of urban population in sub-Saharan Africa use OSS technologies for their sanitary needs. This represents an increase in the number of users compared to 2000 estimate. This increase in the number of users is expected to continue because it is most affordable to majority of urban dwellers in these countries [29]. Considering the increase, a growing concern among stakeholders is how FS in OSS facilities are adequately managed especially in urban slums with dense population, and that the practice of fill and seal of pit and moving of superstructure to newly dug pit is less feasible due to limited backyard and air spaces [50]. Amplifying this, [22] posited that improper FS management constitute huge sanitary and environmental concerns in urban slums because faecal oral routes enhance diseases transmission among people. Despite the huge success and progress made in the access to improved sanitation through OSS systems, literature admits that the faecal sludge management in developing countries is acute, inadequate and perilous to public health and the environment [4]. In this connection, recent study showed that only 37% of FS was safely managed in 12 reported cities across Latin America, Africa, South Asia, and East Asia [40, 51, 56]. For decades, OSS technologies is the crème de la crème of basic sanitation to urban dwellers in Africa, Asia and significant proportion of Latin population, but FS management situation in these urban areas is pernicious [20, 48]. Preponderance of FS sludge are generated and disposed of haphazardly into open spaces where it contaminates environmental media and predisposes urban dwellers to diseases [21] Particularly in sub-Saharan Africa, FS in pit latrines and septic tanks has management challenges [47].

In 2018, 55% of the world's population lives in urban areas, a proportion expected to increase to 68% by 2050, and it is expected that 90% of future urbanisation will occur in Asia and Africa [54]. In this connection, WHO and UNICEF [57] show that 50% of Nigerian population are urban residents. With a 3.2% urban growth rate, the urban population may double in the next two decades [3]. Also, WHO and UNICEF [57] indicate that 64% of Nigeria urban population use septic tank, latrines and their derivatives. Paradoxically, in order to meet the SDG goal 6.2, it is expected that 100% of Nigerians will gain access to basic sanitation by 2030, through onsite sanitation technologies [14]. These indices indicate that, as Nigeria population grows exponentially due to increase in rural-urban migration and natural population; existing onsite sanitation facilities in urban slums become stressed. This implies that larger number of OSS facilities would be provided to meet the sanitary requirement of the populace, which translate to the generation of larger quantity of faecal sludge. This situation according to Halcrow *et al* [16] calls for pragmatic steps towards improvement in FS management. We have been cautioned to depart from business as usual path, in order to improve access to adequate and equitable sanitation for all. It is the express belief of the researchers that provision of latrines for urban poor without efficient FSM systems will not lead to significant improvement in the number of users that would have access to safely managed sanitation in Nigeria. Thus, faecal sludge management should be in the mainstream of sanitation policies and strategies that aimed to achieving the sanitation targets in sustainable development goals in Nigeria. Dishearteningly, the 2017 estimate indicates that less than one percent of the urban population emptied and treated faecal sludge [57]. Quite pathetic that 25% of urban population disposed of FS in situ. However, the good news is that 30% of urban population safely managed their FS [57]. Therefore, research effort that would document evidence based recommendations that could improve the modalities of FSM in the urban panorama of Nigeria may likely be an asset to city administrators as they tackle this sanitation debacle headlong.

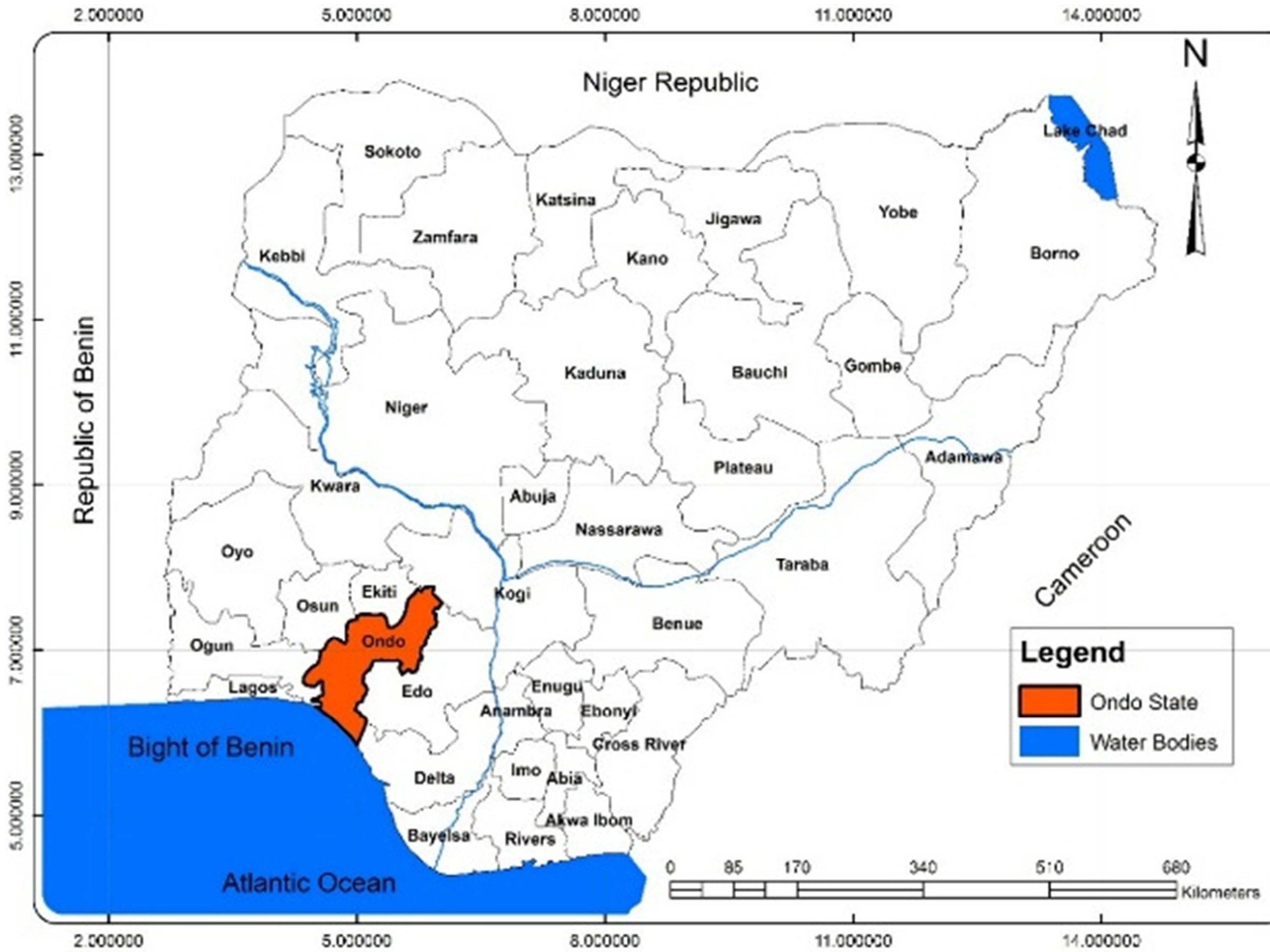
Cities are heterogeneous especially in developing countries with at least four different urban frameworks [25, 41]. One of them is the urban slum or informal settlement at the cores of ancient cities. As pointed out by [41], these informal settlements at the cores of cities in developing countries are characterised by unplanned and irregular layouts, narrow roads and unguided construction of toilet facilities. These attributes warrant improper management of FS. For instance, in the core of Akure, many FS storage facilities have no access points for safe emptying practices. This spatial configuration as posited by [24] hinders effective mechanical emptying services. FS transport and disposal constitute principal environmental concerns. Disposal occurs most onsite, and leaking of FS during haulage remains 'lice in the skin' of FS management in these informal settlements. Statutorily, FS management responsibility falls on the local government, but Akure South Local Government is limited in capacity to manage FS. On this note, this paper investigates FS management in Nigeria urban slums using the residential cores of Akure as a reference. Through this, the paper provides empirical answers to the following questions: what are the types of FS storage facility in the core of Akure, how do households empty, transport, and dispose FS in the study locale, and lastly, do identified variables such as location of FS storage facility, distance of FS storage facility from abutting access road among others influence FSM in the residential cores of Akure, Nigeria?

2. Conceptual Considerations

This paper adopts the Community Led Urban Environmental Sanitation (CLUES) developed by [25]. This is because the paper focuses on unplanned and informal urban cores. CLUES is the refined Household Centered Environmental Sanitation (HCES) sanitation planning innovation [52]. Nkansah [31] noted that some principles and guidelines of HCES lack capacity and content to be effective in FS management especially in unplanned informal settlements. Similarly, [52] posited that CLUES presents simplified guidelines based on Bellagio principles for sustainable sanitation.

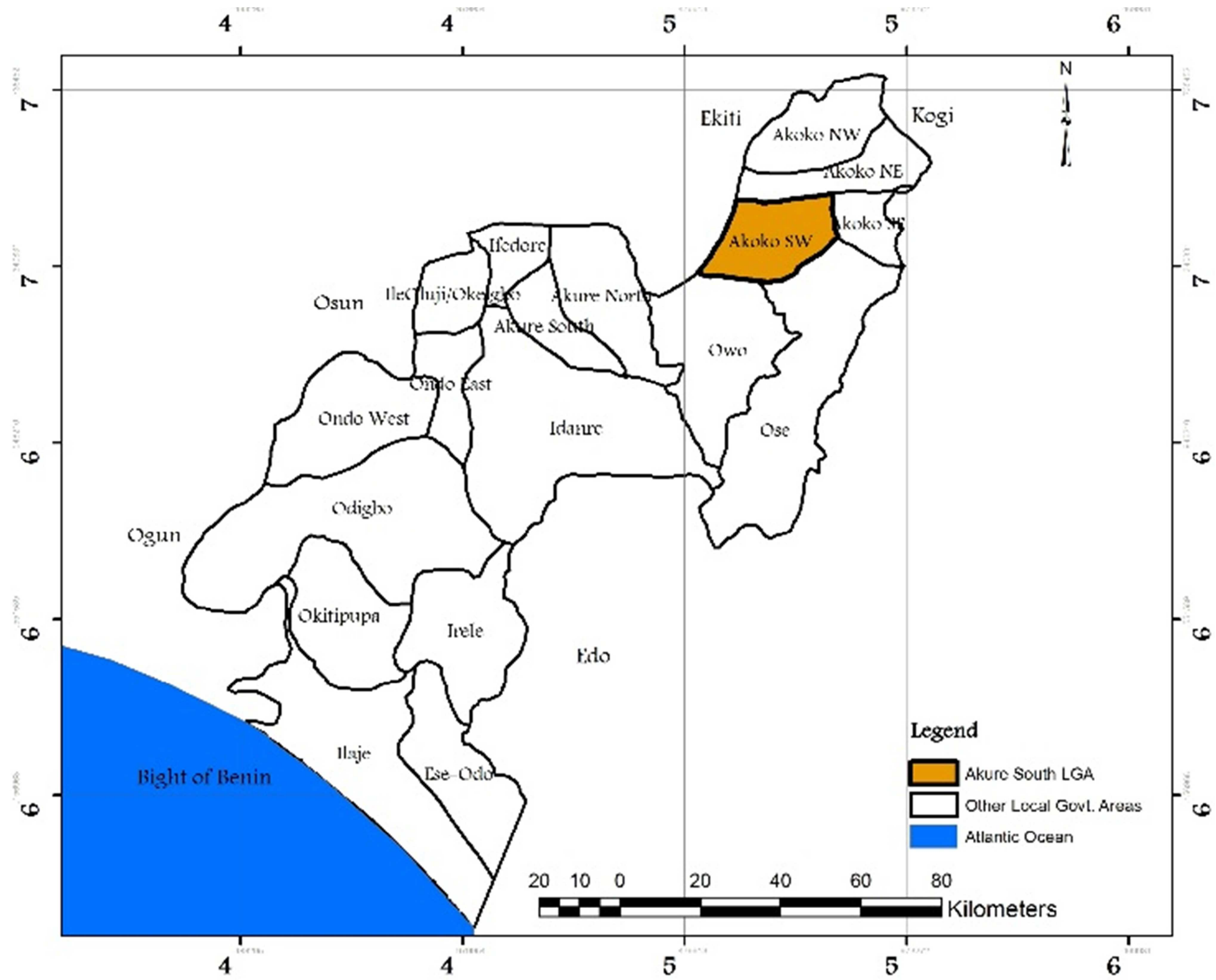
Households are at the heart of HCES but households are concerned about basic sanitation at household domain, cleaner immediate environment and the nieghbourhood without recourse to adequate citywide sanitation [31]. Amplifying this, [9] noted that HCES aims to solve sanitation issues at source where they are generated, and [23] asserted that hygiene and sanitation problems emanate from households. When viewed from FSM perspective, households are more concerned about the emptying and removal of FS from their immediate surroundings without capacity to ensure that those FS reach appropriate treatment plant and disposal sites.

The transportation and disposal of FS occur at the city domain; therefore, effective management of FS requires strong regulations and institutional framework. This is what CLUES propagates, with the intention that enabling environment, which will yield effective and efficient FSM systems, would be attained. Overtime, CLUES has replaced the HCES as demand led sanitation planning approach with multidisciplinary initiatives to tackle urban sanitation debacle including FSM. CLUES advocates for the participation of relevant stakeholders at initial stage, and places community at the centre of planning and implementation of urban sanitation solutions [52].



Source: Ondo State Ministry of Physical Planning and Urban Development

Figure 1. Ondo State in the National setting.

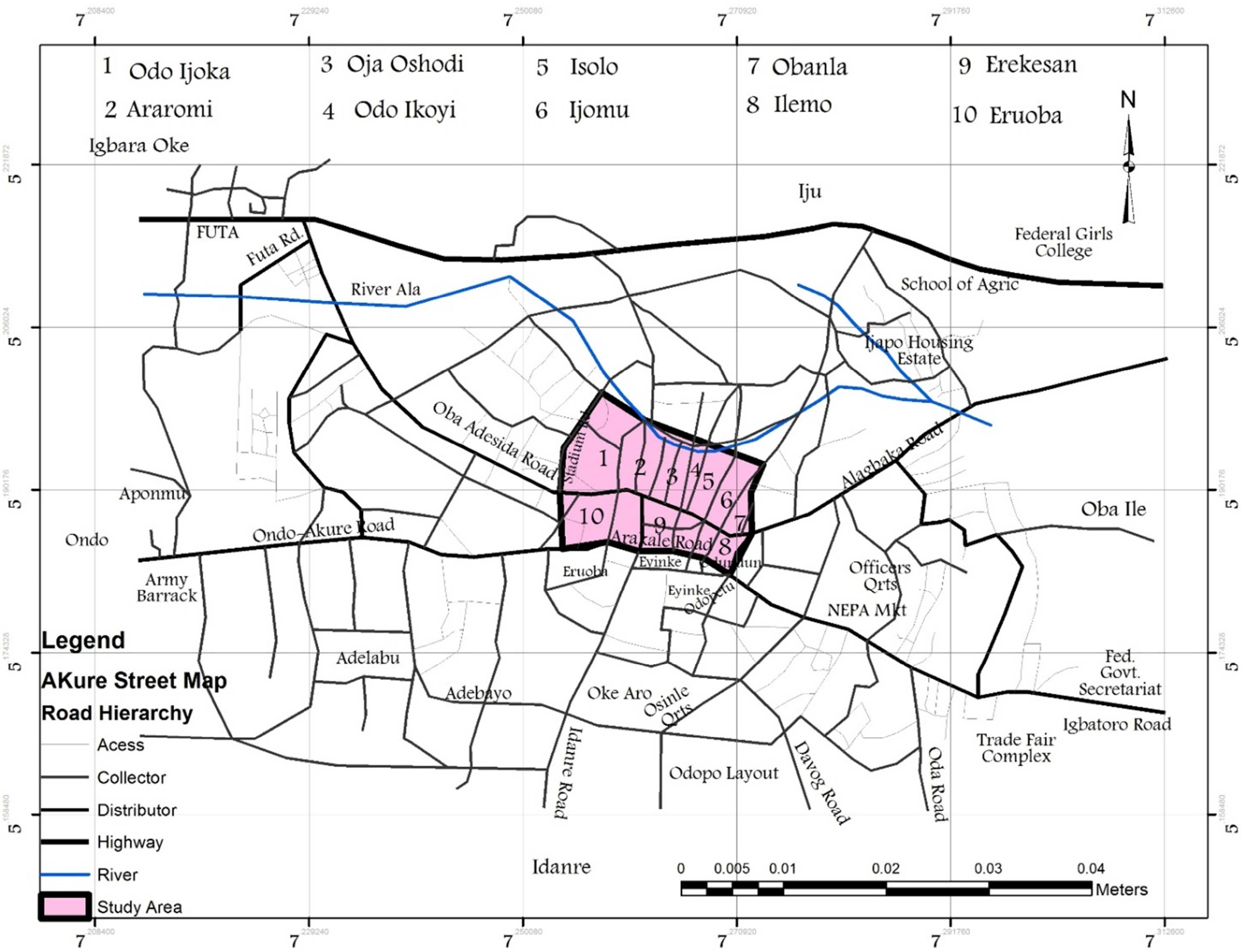


Source: Ondo State Ministry of Physical Planning and Urban Development

Figure 2. Akure South LGA in its Regional setting..

In the application of this concept to FSM in the city of Akure, Nigeria, the seven key steps are critical in the planning and implementation of sanitation interventions. This concept was tested based on its guidelines. An expert in urban sanitation led the process in 10 urban residential cores of Akure. This planning process began with sensitization of the residents particularly on FSM challenges that emanate from their sanitation practices and ignition of sanitation promotion among the people. It involves also the identification of local champions that could drive the goal of the programme among his people. The second step involves creating community mobilization team that are the Landlord Association, which became the users' committee representative. It involves also the identification of the appropriate stakeholders and demarcation of the geographic boundary using google maps.

A situational analysis was carried out through the instrumentality of questionnaire to collect data about FSM practices from 400 households (step three). Step four involves interactions with users committee through interview guide. This helps to prioritise and validate communities FSM needs and preferences as well as demystifies sanitation problems in the study area. This is followed by identification of preferred FSM systems that are affordable and feasible to spur improved effective FS management (step 5). The 6th step involves the preparation of local action plans by stakeholders. This is expected to translate to working documents that could instigate improved FS management. In the last step, government and the private sectors are occassioned to implement technical solutions that will yield improvement in the management of FS. Any urban solution will rely on the information gotten in step three [25]. By this fact, study that will reveal pragmatic situations of FSM worth exploring. This is to promote the need for improved FSM systems especially in unplanned and informal city cores in Nigeria.



Source: Adapted from [58] (Modified by the Author)

Figure 3. The Core of Akure (study area) within the Street Map of Akure

3. Materials and Methods

3.1. Research Locale

This research was carried out in the residential core of Akure, the administrative and commercial capital of Ondo State, Nigeria. Specifically, the research was carried out in ten residential neighbourhoods in the core of Akure. As illustrated in Figure 3, the ten residential neighbourhoods are Odo Ijoka (1), Araromi (2), Oja Oshodi (3), Odo Ikoyi (4), Isolo (5), Ijomu (6), Obanla (7), Ilemo (8), Erekesan (9), and Eruoba (10). Akure has total areal extent of 340 km^2 [32], and locates between Latitudes 60 95'N and 7 15'N of the equator and Longitudes 5 15'E and 5 40'E of the Greenwich Meridian [27]. Afe [1] noted that Akure became the capital of Ondo State in 1976. It is also the headquarters of Akure South LGA, with 11 political wards, which is further divided into 653 polling stations. The climate is hot and humid, influenced by rain-bearing southwest monsoon winds from the ocean and dry northwest winds from the Sahara Desert [44]. It has ferruginous tropical soils with two rainy seasons. Whilst, the average annual temperature is 26.7 °C, the average annual rainfall is 2378 mm [8]. Akure has mean annual relative humidity of about 77.1% [10]. It has rainforest vegetation, which is evergreen. The vegetation consists of moist lowland forest [36]. Rotowa et al [44] posited that Akure has three residential zones, which are the core, transition and the periphery. The core is a typical urban slum settlement with low compliance with urban planning regulations and basic sanitation [44]. Pit latrine is the prominent type of latrine with indiscriminate disposal of wastewater into open drains a common practice [37]. The rivers that drain the core has been converted to natural sewers that transport human faeces and solid wastes [38]. Generally, environmental cleaning is poor and open defecation is high [43]. The residential environment is typically characterised with blocked drainages and scattered human and animal faeces. The population is dense and the overall sanitation is adjudged poor [2]. The geographic location of the study area is presented in Figures 1, 2, and 3.

3.2. The Database

Literature posits that FS management in unplanned city cores calls for great concerns [41]. This study began with a reconnaissance survey to the residential cores of Akure to ascertain the sanitation peculiarities in regards to FS management. This preliminary visit confirmed that the sanitation debacle in these residential cores warrant exploratory investigation. The paper adopts quantitative research method that focused on data collection about FSM practices through the instrumentality of the questionnaire and interview. This was supported by transect walk used to observe the physical conditions of FS storage facilities.

Data were obtained from the residents of randomly selected 10 housing quarters in the core of Akure and emptying service providers. The last Nigeria population census conducted in 2006 did not present the population figures at settlement level; thus, this study relied on household population for the administration of questionnaires. To achieve the household population, this study conducted building demographic survey to extrapolate the number of buildings in the study area. Using 2019 Google Earth imagery of the study area, which was verified through groundthruthing and digitised in ArcMap version 10.2, the building population was counted as 2342 buildings. Given that, [60] estimated an average household size in Ondo State as five persons per family (5ppf) and five households per building (5hpb); thus, the estimated household population of the study was computed as 11710 households (2342 buildings x 5hpb = 11710 hhds).

A sample size of 400 households amounting to 3.4% of the household population were randomly selected across the study area for questionnaire administration. This sample size is plausible considering the homogeneity of sanitation concerns of the housing quarters [44]. In addition, [35] used smaller sample size of 116 households on a related study to obtained good results in the study area. The simple random sampling technique with replacement was used to pick respondents in residential buildings for the field survey. Purposive sampling technique was used to select emptying service providers interviewed. Data codification and analysis were done with IBM statistical packages for social scientists (SPSS) version 26 and Microsoft Excel 2013. Data were analysed with appropriate test of measures and presented in Tables.

This study utilized 38 variables, with seven out of the 38 variables selected for multivariate analysis. The mean score of FSM variables summed up for each participant was gotten through data transformation. This mean score was used as the outcome variable, which was a parsimonious representation of FSM index of the study locale. Six explanatory variables were identified to establish their influence on FSM in the study area. These six predictors were emptying cost (EMPCOST), method of disposal (METODIS), method of emptying (EMTYMETO), type of storage facility (TYSTOFA), location of storage facility (LOSTOFA), and distance of storage facility from abutting access road (DISTOFA). For clarity, the specification and justification for the choice of the explanatory variables were discussed and presented in Table 1.

Table 1. Definition of FSM variables.

Variable Code	Specification of variable code	Mean*	SD
FESLUMA	Feacal sludge management index	.0644	.16823
EMPCOST	Emptying cost of faecal sludge in Naira	.8746	.37137
METODIS	Where faecal sludge is disposed	.2807	.11854
EMTYMETO	Methods of emptying FS	.1003	.22471
TYSTOFA	Types of storage facility	1.20^{+}	.401
LOSTOFA	Location of storage facility	.2263	.13653
DISTOFA	Distance of storage facility from abutting access road	1.1969	.18861

Source: Authors Field Survey, 2019

$^{+}$ Mean score and SD of untransformed data

* Mean scores and SD of log (Ln) transformed data

FESLUMA is the performance of faecal sludge management through storage, collection, haulage, and disposal. It is the variable of primary interest used to measure FS management on a scale ranging from 1 – 100 percent. EMPCOST measures the amount of money involved in the emptying process of FS. This influences all stages of FSM, which translates to the extent of safety involved in FS management. METODIS describes the place of disposal, which includes bury on plot, discharge to open field, dumpsite, gutter/culvert, and bury on open field such as bushes. This variable is relevant to effective and efficient FSM systems because where FS is being disposed of determines how safe FS is being managed. Often times, FS is disposed into open environment when there is no FS treatment plant. This indicates a change in hatching sites of pathogens from household to community domain, which predisposes communal health to diseases. EMTYMETO describes the methods of emptying FS. This variable measures the number of households that empty FS by hand using shovel/similar or mechanically using small machine or vacuum truck. Given the peculiarities of city cores, FS emptying is a principal component of FSM. This is because when FS emptying is deficient, FS threatens the environment, human health and dignity. TYSTOFA identifies the types of FS storage facility, which are pits and septic tanks in this context. Literature has established the importance of well-constructed and maintained storage facility in the effective FSM system [30]. It is believed that OSS technologies can provide similar benefits and convenience to convectional sewerage and cistern flush systems [39]. It is said that when OSS facilities hygienically stored FS, FS is regarded as safely managed [56]. LOSTOFA describes the location of the FS storage facility. Location and accessibility challenges of FS management is well established in the literature [31]. Aside financial incapability of urban poor, inaccessibility of mechanical emptying vehicles because of the location of FS storage facilities and spatial composition of city cores in sub-Saharan Africa pose FS management challenges [47]. DISTOFA measures the straight-line distance from the point of access to pits and septic tanks to the nearest abutting access road in metres. This research opines that the farther the access road from the point of access to FS storage facilities, the higher the likelihood of poor FSM. The choice of this variable is to establish the need to rehabilitate access roads as it influences FSM in the study area.

4. Results and Discussion of Findings

This paper covers the stages of FS management value chain in the core of Akure. It examines the influence of some variables on FS management in the study area. Fundamentally, the value chain of FSM consists of five interrelated stages id est. containment, emptying, transportation, treatment, disposal or enduse. In the study locale, four stages were explicitly conspicuous, videlicet: storage, emptying, transportation and disposal.

4.1. Faecal Sludge Storage Facilities from the Core of Akure

As illustrated in Table 2, two types of FS storage facility were conspicuous, which were pit and septic tank containment system, but the pit was dominantly visible. At least 70 in every 100 (N=400) FS storage facilities covered in the study area were located within the compound. The mean distance of 17m (N=400) was observed between FS storage facilities and the abutting access road. Whilst, some were just at 6m away from the road, some were at 50m away from access roads. The emptying and transportation challenges encountered by vacuum trucks were attributed to the unplanned spatial configuration of the study area, which manifested in inappropriate locations of FS storage facilities.

The mean age of FS storage facilities was discovered to be 12 years (N=368). Given that the maximum emptying cycle was 5 years, this partly explained the high emptying occurrence discovered in the survey. About 97.5% (N=320) of the pit and all septic tanks assessed had one hole and one chamber respectively. The presence of twin-pit latrine system was presumably invisible in the core of Akure. A marginal departure from what obtainable a priori was the recent introduction of two pits to perform the functions of the septic tank and soak away rather than two pit toilet that when one is working, the other one is resting. The twin pit system had been established as a sustainable alternative to conventional pit latrines in Asia and some parts of Africa for its efficiency in promoting compost FS and reduction in empty frequency [19].

Most of the pits were at the depth of 3m (n=51), while 12ft by 6ft by 4.5ft was the largest observed size of septic tank. The prominent depth of pits encourages the climbing inside of emptiers during emptying exercise. For the safety of emptiers, the pit should not have depth more than 1.5m, which permits adequate ventilation in the pits. Further, 22% (N=400) of the facilities examined had an outlet connection; either connected to open ground or gutter/culvert. The presence of outlet opening of toilet facilities produced filthy, sometimes stagnant grey water, which navigate through the surface of the study locale thereby creating an uncomfortably mud dank surface. As adumbrated by [46], such practice creates a definite route for disease transmission, which predisposes urban core residents to ill health.

Only 30.6% (N=392) of facilities assessed were watertight. Baseless pits and leaky septic tanks coupled with degradation through microbial activities limit the accumulation rate of FS in pit sanitation technology [53]. Depending on the characteristics of the soil around the pit and the horizontal distance between the facility and environmental media that can be contaminated, such as water, it might be a source of public health risk. The most found solid wastes in the pits were Hygienic materials (88%, N=400), which were negligible in septic tanks due to the clogging of pipes. Solid waste contributes only 0.2% of the volume of FS in pit latrines in urban slums as posited by [51].

The majority of respondents (62%) admitted that untrained masons that were illiterate with incompetent technical skills were the constructors of FS storage facilities. This predisposed local unskilled emptiers to calamity. As supported by [46], the untrained local masons or informal workers might lack technical competence, which limits the future chance of emptying of FS.

Interview responses from the Ministry of Physical Planning and Urban Development indicated that no standard guideline was available for the construction of pit latrines, but a well-detailed septic tank drawing with specifications was required for the application of building approvals. At the household domain, the variability in the construction type and quality indicated that no specific standard exists for construction of pit latrines in the study area.

This was comparable to the submission of [59] that standardised construction guidelines do not exist for sanitation technologies in the informal settlements of Lusaka. This study asserted that there was no standard technique and guideline for construction of FS storage facilities in the core of Akure. A paradigm shift in FSM is required at both household and institutional domains to spur improved management of faecal sludge in the core of Akure. Figures 4 to 7 show faecal storage facility types in the study area.

Source: Authors Field Survey, 2019

Figure 4. A typical Pit Storage Facility in Obanla.

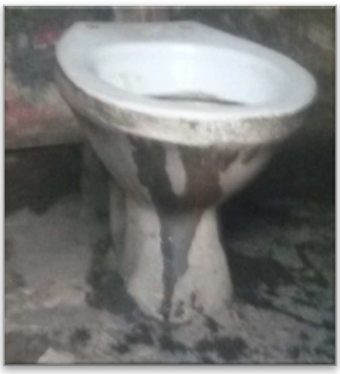


Figure 5. Water Closet Users Interface in Araromi.

Source: Authors Field Survey, 2019

Figure 6. A typical Septic Tank in Araromi.

Source: Authors Field Survey, 2019

Figure 7. A typical Pit Latrine Structure in Isolo.

Table 2. Types of FS storage facility.

Facility	Frequency	Percent	Mean	Std. Deviation
Pit	320	80.0		
Septic Tank	80	20.0		
Total	400	100.0	1.20	.401

Source: Authors Field Survey, 2019

4.2. Emptying of Faecal Sludge from the Core of Akure

This study found out that the majority of respondents (84%) had emptied their pit or septic tank when filled up in the core of Akure, while only 16% of respondents avowed that their FS storage facilities had not filled up. Due to the high population density [37] and high housing overcrowding index [11] that characterised the study area, the practices of covering of old pits and relocating superstructure to new dug pit latrine were not common. This could partially justify the reason for the high incidence of FS emptying in the study area.

Table 3 revealed that FS emptying occurred by both manual and mechanical methods but manual emptying predominates. Given the peculiarities of the study area, these findings were not surprising. Semiyaga [46] posited that manual emptying characterised urban slum because of inaccessibility of vacuum trucks due to narrow roads and no access points to FS storage facilities. This manual emptying is a principal cause of environmental pollution and degradation because emptied FS were buried in places that it could contaminate water resource and the environment.

On spot field experience of manual emptying exercise (Figure 8) in the core of Akure showed that manual emptying process began with creating access to the pit or septic tank. Whilst in a pit, the manual emptiers removed the slab to create access to the pit; they remove the lid on the access points to gain access to septic tank. This was followed by pouring of chemical substance locally called “private killer” into the pit or septic tank to kill maggots and other insects, and to reduce the stench odour produced by faecal sludge.

Similarly, the chemical substance changed the texture of faecal sludge to sand like structure that reduced the viscosity of faecal sludge and made it solidified. This was followed by scooping out expeditiously the top layer FS. Then, a gradual climbing inside of the pit or the septic tank followed as the volume of FS gradually reduced. Interactions with emptiers revealed that the number of people involved in manual emptying ranged from a minimum of two persons to three persons per pit or septic tank. The time taken to empty a pit depended on the size of the pit, volume of FS, and number of people involved in emptying exercise; but 3 hours was the mode. The equipment involved in manual emptying in the study area ranged from a shovel, a spade to the bucket.

Table 3. Method of emptying faecal sludge.

Method of Emptying	Fr.	Percent	Mean	Std. Dev.
Manually, using shovel, spade or similar	280	83.3		
Mechanically, using vacuum and hose	56	16.7		
Total	336	100.0	1.50	1.120

Source: Author's Field Survey, 2019

4.2.1. Faecal Sludge Emptying Frequency

This study further examined the emptying frequency of FS in the core of Akure. As indicated in Table 4, eight respondents (N=336) asserted that emptying of their facilities occurred yearly, which was common in buildings with high number of households sharing faecal containment system. All eight respondents were residents of buildings with pit latrines. About 328 respondents (N=336) admitted emptying of FS containment facility occurred every few years. Aside the few respondents that emptied once a year, the emptying frequency among respondents ranged from two years to five years. Given that, high average household size and number of households per building characteristically typified the study area, it is quite plausible that the emptying trend occurs. Especially, when pit latrines dominate. This positively relates to what happens in many African cities where pit latrines are dominant.

Few respondents (22%) attested to the variability of emptying frequency occasioned by seasonal changes. As agreed by a discussant at the interchange between Ijomu and Obanla "*during rainy season our pit has a lot of water, which made the excreta to float, to avoid over floating, we always emptied the top layers*". In addition, a manual emptier (Patrick Okete) in the study area stated that demand for emptying was higher in the rainy season due to rainwater that entered pit latrines.

This positively relates to the findings of [7] that higher number of emptying trips occur in the rainy season in Accra, possibly because of poor septic tank construction allowing the ingress of surface water runoff to rapidly fill the tanks. Notably, no respondent asserted that septic tank has been emptied once every year. This was because the size of septic tank was always large which translates to the large volume that characterised septic tanks. Findings on emptying frequency would be a veritable tool to plan for schedule emptying at both household and service provider domains.

Table 4. Emptying frequency of FS storage facility.

Emptying interval	Frequency	Percentage	Mean	Std. Dev.
Yearly	8	2.4		
Every few years	328	97.6		
Total	336	100.0	3.98	.153

Source: Author's Field Survey, 2019

4.2.2. Faecal Sludge Emptying Services

This study further anatomised the FS emptying services in the core of Akure. As indicated in Table 5, the informal emptying service was dominant in the core of Akure. The informal emptying service providers were socially stigmatised due to the nature of the services provided. They have no association that could give them an identity and propagate their voices when required. Similarly, it was established that there were no formal registration with any entity and non-payment of dues to any government agency whatsoever.

The crude method of burying FS in a new shallow dug pit near the old pit after emptying was dominantly visible among manual emptiers. They emptied without recourse to personal protective equipment (PPE) such as gloves, face shields, gowns (raincoat), and shoe covers (rain boot). Such practice predisposes manual emptiers to faecal related diseases. As reported by [55], the face shields of manual emptiers in South Africa revealed the presence of helminthic egg species, which cause diseases. These findings accentuated the fact that manual emptiers were characterised with indecent working conditions, which increased the risk of exposure to diseases.

At the time of this survey, the mechanical emptying service was completely informal. For the record, only two recognised governments controlled institutions were involved in mechanical emptying service. These were Ondo State Waste Management Authority, and Sanitation Department of Akure South Local Government Council. Interview responses from the manager of Z. L. Alliance showed that their company was strategizing on how to manage liquid wastes in Akure including faecal sludge. Interview responses from the manager of Igbatoro dumpsite (official dumpsite of Akure city) revealed that indiscriminate dumping of FS into open field within Igbatoro dumpsite defined the mechanical emptying service. Figures 8 and 9 show the types of FS emptying services.

Table 5. Faecal sludge emptying services.

Emptying service provider	Fr.	Percent	Mean	Std. Dev.
Informal Private Provider	280	83.3		
Formal Private Provider	56	16.7		
Total	336	100.0	1.50	1.120

Source: Author's Field Survey, 2019

4.3. Transportation of Faecal Sludge from the Core of Akure

As depicted in Table 6, the dominant means of transporting FS in the core of Akure was comparable to predominant ones that characterised the Neolithic era. This was not surprising, manual method of emptying dominated the sanitation landscape of the study area. Consequently, bucket was used to transfer FS from storing facility to place of disposal. Suffice to say that manual transport of FS was the principal method in the study area. Interestingly, significant proportion of respondents (16.7%) use vacuum truck to transport FS from containment facilities to the place of disposal.

Beyond deductive expectations, improved means of transportation was visible in the study area. This could be traced to the recent urban renewal exercise that took place in part of the study area. This measure has widened some narrow roads thereby made them suitable for the passage of vacuum trucks. For instance, the rehabilitated road between *Odo Eran* and *Iso Olisu* areas of the study locale permits the passage of vacuum truck that now evacuate both human and animal faecal sludge from this area. Quite pathetic to lament with nostalgia that this area was unhealthy for human habitation before the road rehabilitation, because of the deposit of animal and human excrement into open dug loathsome pit, which constitute a nuisance to human sight, public health and the environment.

It is apposite to say that, the knowledge on the existing types of FS transportation infrastructure would be consequential to planning for improved FSM. When combined with other extraneous elements, the right transport facility that could induce efficient spill management, reduce travel time, and cater for workers' health and safety might be unveiled for the local context.

Source: Authors Field Survey, 2019

Figure 8. Manual emptying of FS in Obanla.

Source: Authors Field Survey, 2019

Figure 9. A typical mechanical emptying vehicle in Akure.

Table 6. Means of transporting faecal sludge in the core of Akure.

Method of Transportation	Fr.	%	Mean	Std. Dev.
Carried with Bucket	280	83.3		
Exhauster truck	56	16.7		
Total	336	100.0	1.67	1.493

Source: Authors Field Survey, 2019

4.4. Disposal of Faecal Sludge from the Core of Akure

As empirically depicted in Table 7, a majority of respondents (81%) admitted that emptiers buried FS in a new dug shallow-pit around the old pit. Such practice could contaminate water resource that is within risk exposing horizontal distance of 30m with high water table level. There was a single disposal site where exhausted truck dumped faecal sludge. This dump site was located outside the study area but within the boundary of the city. No discharge fee, since the two mechanical emptying service providers were government controlled institutions.

There was presence of gravitational disposal method. This is a method where faecal sludge is disposed into gutter/culvert to flow with storm water in torrential rainfall. Although, this method was unpopular among respondents, 2.4% of respondents affirmed that FS was disposed of directly into the gutter along their street. It is imperative to note that this study could not confirmed the authenticity of the claim, since both manual and mechanical service providers interviewed gave a differing response on the subject matter. Figure 10 shows a typical method of FS disposal in the study area.

Figure 10. Typical disposal method in the study area.

Table 7. Place of disposal of FS.

Place of Disposal	Fr.	Percent	Mean	Std. Dev.
Do not Know	40	11.9		
Buried on Plot	272	81.0		
Discharged to Dumpsite	16	4.8		
Discharged to Gutter/Culvert	8	2.4		
Total	336	100.0	1.98	.512

Source: Author's Field Survey, 2019

4.5. Regression Analysis of Faecal Sludge Management

This study further examined some variables that influenced faecal sludge management in the study locale. The double log function of the multiple regression model was deployed to take the natural logarithm of both outcome and explanatory variables except the one in dichotomous scale before subjecting them to multiple regression analysis [13]. The choice of double logistic model over other functional lies in its ability to give high explanatory powers of R^2 as posited by [2]. In addition is the ability to reduce variability of the dataset and increase the likelihood of approximate normality. Besides, it has the ability to reduce heteroscedasticity, that is, the variance of residual uniformly distributed over model parameter estimates [34]. And the potentiality of presenting regression coefficients directly as elasticity estimates [13]. Especially, over the semi-logs function, the double function does not need to un-transform regression coefficients before interpretation. The predictors were entered into the model orderly using the forced entry option based on theoretical importance and the pragmatic experience of the researcher on FSM in the study locale as supported by [15]. The double log functional form is expressed as

$$\ln(Y) = \beta o + \sum_{i=1}^{n} \beta 1 \ln Xi \quad (1)$$

Where ln is the natural logarithm, 'Y' is the outcome variable, 'βo' is constant, 'βi'…...'βn' are regression coefficients, 'Xi'…...'Xn' are explanatory variables. When the variables utilised in this empirical estimation are entered to equation 1, the model is interpreted as

$$\text{Ln (FESLUMA)} = \beta o + \beta_1 \ln \text{(EMPCOST)} + \beta_2 \ln \text{(METODIS)} + \beta_3 \ln \text{(EMTYMETO)} + \beta_4 \text{(TYSTOFA)} + \beta_5 \ln \text{(LOSTOFA)} + \beta_6 \ln \text{(DISTOFA)} \quad (2)$$

A careful examination of multicollinearity among the predictors was conducted using the correlation matrix table. The 'rule of the thumb' here is that there should not be correlation coefficient in excess of 0.8 between predictors [18]. However, [15] suggested that the correlation coefficient between predictors should not exceed 0.9. In this study, there was no issue of multicollinearity, as the highest correlation coefficient between the predictors was 0.629 (Table 8). Table 9 shows that the combined effect (R^2) of the predictors was 0.948. This implies that the predictors accounted for 94.8% of the variation in FSM in the core of Akure. This also signifies that there were confounding variables not covered in this model. This opens a window for further research on the subject of discourse. Table 10 shows that $F = 991.517,\ p < 0.001$, which implies that this linear model predicted FSM in the study area significantly.

Table 8. Zero – order correlation matrix.

	Y	X_1	X_2	X_3	X_4	X_5	X_6
Ln FESLUMA (Y)	1.00	.525	-.399	.952	.852	.395	-.049
Ln EMPCOST (X_1)		1.00	-.332	.591	.554	.221	.031
Ln METODIS (X_2)			1.00	-.546	-.383	-.175	-.271
Ln EMTYMETO (X_3)				1.00	.629	.339	.061
TYSTOFA (X_4)					1.00	.339	-.024
Ln LOSTOFA (X_5)						1.00	.090
Ln DISTOFA (X_6)							1.00

Dependent Variable: Ln FESLUMA
Predictors: Ln DISTOFA, TYSTOFA, Ln DISTOFA Ln METODIS, Ln EMPCOST, Ln EMTYMETO
Source: Authors Field Survey, 2019

Table 9. Model Summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.973a	.948	.947	.07997

a. Predictors: (Constant), Ln DISTOFA, TYSTOFA, Ln DISTOFA Ln METODIS, Ln EMPCOST, Ln EMTYMETO
Source: Authors Field Survey, 2019

Table 10. ANOVA[a].

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	38.046	6	6.341	991.517	.000[b]
	Residual	2.104	329	.006		
	Total	40.150	335			

a. Dependent Variable: Ln FESLUMA
b. Predictors: (Constant), Ln DISTOFA, TYSTOFA, Ln DISTOFA Ln METODIS, Ln EMPCOST, Ln EMTYMETO
Source: Authors Field Survey, 2019

It is crucial to assert that the unit of measurement for both outcome and predictor variables was a percentage as used by [34]. It is momentous to note that the standardised Beta coefficients were reported and discussed in Table 11, which reveals that the most important variable that influences FSM in the core of Akure was the method of emptying (EMTYMETO). It has a positive and a significant coefficient estimate of *.914*, $p < 0.01$. This implied that a 100% qualitative improvement in the method of emptying FS would lead to 91.4% improvement in FSM.

It could be inferred that as the means of emptying FS improves, FSM will improve significantly. This conformed to deductive expectations, that a qualitative change in means of emptying would indicate a change from unsafe and unhygienic manual emptying to safe and hygienic mechanical emptying method, which uses suction equipment and produces efficient spill management. This also protects sanitation workers' health and safety since it prohibits the act of climbing inside storage facilities, and ensures workers do not have direct contact with faecal sludge.

In the same vein, such improvement would include a change from the crude method of using shovel, spade and bucket to scoop out FS from containment facilities to technical manual inclined options such as Gulper, Dung Beetle, and Vacutug. These manually operated mechanical systems would easily access the inaccessible locations of containment facilities in the study locale. As submitted by [28], such improvement could be achieved through the imposition of restrictions on unsafe manual emptying by local governments, provision of incentives such as training, capacity building, and licensing of the informal sector.

Another variable unveiled through the model that had an important influence on FSM in the core of Akure was method of FS disposal (METODIS). The coefficient estimate of .130, $p < 0.01$ was significant and positive. This signified that 100% improvement in the means of disposing FS would lead to 13% improvement in FSM in the study area. It need be adduced that a qualitative unit change in the method of FS disposal, FSM will improve. These findings were consistent with *a prior* expectation, since the crude method of burying FS close to the source of generation and indiscriminate disposal of FS on open fields characterised the sanitation panorama of the study area.

Specifically, burial of FS on-site might increase the risk of exposure of surrounding water sources to contamination [12]. Boot and Scott [7] proffered an example of improvement in FS disposal that could lead to a corresponding improvement in FSM. They submitted that transfer stations could be used to safely dispose of FS in Accra, Ghana. Similarly, [5] posited that entrenchment of Ventilated Improved Pit latrine sludge in urban agriculture was an appropriate option for safe disposal of FS in eThekwini Municipal, Durban, South Africa. *Sensu stricto*, an adoption of other options that prohibit dumping of FS into the open environment would be a similitude of qualitative improvement in FSM.

Further, the influence of emptying cost (EMPCOST) on FSM was negative and significant with coefficient estimates of -*.075*, $p < 0.01$. The EMPCOST elasticity estimate implied that 100% reduction in the emptying cost would lead to 7.5% improvement in FSM in the core of Akure. It could be inferred that reduction in emptying cost would lead to improvement in FSM, but at less than proportional rate.

One plausible explanation is that the majority of respondents did not view emptying cost as important motivator of their choice of emptying method, by extension, transporting and disposing methods of FS. Therefore, substantial reduction in emptying cost would not induce significant improvement in FSM. As stated by a respondent "*I cannot say the cost of emptying was high, because I could not do the job".* This is amplified by 52.4% of respondents who disclosed that emptying cost was cheaper.

This finding differs from [5], who posited that cost of emptying played influential role in the selection of emptying method in eThekwini Municipal, Durban, South Africa. If correctly interpreted, this implies that, any intervention that will focus on improvement in FSM in the core of Akure should lay less emphasis on cost of emptying. Empirical analysis revealed that residents were likely to pay for improved FSM at reasonable price resembling present cost of emptying.

As amplified by [31], the design and maintenance of pits are location specific. The influence of location of the FS storage facility (LOSTOFA) on FSM was positive and significant with the coefficient estimate of *.077*, $p < 0.01$. This implied that 100% improvement in the location of containment facility would induce 7.7% improvement in FSM in the study locale. The deduction is that a qualitative improvement in the manner of siting the pit latrines and septic tanks will lead to improvement in the management of FS. This improvement could result from taking cognisance of FS emptying when determining the location of containment facility. The locus of containment facilities should enhance easy emptying.

Similarly, the influence of types of storage facility (TYSTOFA) on FSM was significant and positive with the coefficient estimate of *.159*, $P < .01$. This connotes that 100% qualitative improvement in the types of FS storage facility would induce 15.9% improvement in FSM in the study locale. This was consistent with deductive expectations, that a qualitative improvement in types of FS facility would manifest in adoption of standard septic tanks or the adaption of single pit technology to lined twin-pit system that safely contain human excreta. This study agreed with the submission of [42] that ecological sanitation toilets with storage facilities that compost sludge into harmless substance should be introduced and tested to improve management of faecal waste in Akure.

Finally, the effect of distance of FS storage facilities from abutting access road (DISTOFA) on FSM was negative and significant with a coefficient estimate of *-.070, P <.01*. The DISTOFA elasticity estimate implies that 100% reduction in distance between storage facilities and abutting access road would lead to 7% improvement in FSM in the core of Akure. It could be inferred that as distance between the FS storage facility and its abutting access road reduces FSM improves. As expected, the reduction in distance between the location of FS storage facility and access road will improve accessibility of those facilities, judging from this study. Inaccessibility of FS containment facilities by mechanical emptiers had been a fundamental problem of safe and hygienic emptying, haulage, and disposal in urban cores [31].

Table 11. Regression Coefficients[a].

Model	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1 (Constant)	.564	.143		3.934	.000
Ln ECOST	-.068	.014	-.075	-4.728	.000
Ln MEDODIS	.165	.020	.130	8.208	.000
Ln MEDEMPTY	.611	.017	.914	35.133	.000
FACTYPE	.147	.022	.159	6.809	.000
Ln FALOCATE	.082	.014	.077	5.692	.000
Ln FACIDIS	-.054	.010	-.070	-5.273	.000

a. Dependent Variable: Ln FESLUMA
Source: Author's Field Survey, 2019

For verity, FSM index model was calibrated with mean values of the significant predictors, and the empirical FSM index of Akure city core was correctly predicted as:

FSM Index $= 0.564 + 0.130(0.2807) + 0.914\ (0.1003) + 0.159\ (1.200) + 0.077\ (0.2263) - 0.075\ (0.8746) - 0.070\ (1.1969)$

FSM Index $= 0.7510$

Without predictors, FSM index: 0.564 = 56.4%

With predictors, FSM index: 0.7116 = 75.2%

The percentage improvement in FSM index = 18.7%

This implies that a unit qualitative improvement in these predictors will yield at least 18.7% of an improvement in FS management in the study area. It is quite impossible that when a majority of residents adopt the mechanical emptying method and FS undergo appropriate treatment before disposal into the environment, FSM will not improve. It is also plausible that when residents adopt twin pit systems and/or standard septic tanks, and locate storage facilities in places that will enhance hygienic emptying, FS management will improve.

5. Conclusion and Recommendations

This paper has appraised FS management in the residential cores of Akure. Results obtained unravel that pit and septic are the dominant FS storage facilities in the study area. This is expected; several authors in this line of study have shown that OSS technologies dominate residential cores (slums) of cities in developing nations. Equally, this study quadrate with deductive expectations that FS management in urban slums is inadequate, unhygienic and unsafe for human health and the environment. Quite interesting that improvement in methods of emptying FS, place of disposal, and adoption of improved toilets will significantly improve FS management in the residential cores of Akure. Some results obtained in this paper have policy implications for FS management in Akure, Nigeria.

Having meticulously perused through documents on water and sanitation at the two tiers of Ondo State Government available to this study; this paper was of the opinion that the legislation on urban sanitation, which significantly covers FSM, should be promulgated at the state level. Ondo State House of Assembly should perform her statutory role by passing a bill on urban sanitation just as she did for the urban water sector in 2017. Given that the majority of respondents were urban poor who reside in unplanned residential cores, which spatial configuration hinders the effectiveness of mechanical emptying of FS, it may be inappropriate policy on the part of government to enforce the utilisation of standard septic tanks with two champers and a soak pit. On this note, this paper recommends the adaptation and adoption of the twin pit latrine system, which permits the resting of one toilet when the other is in use. This technology will undoubtedly reduce emptying frequency, enhance compost of FS that make it less hazardous, and overall, improve FS management. Quite pathetic, incompetent local masons construct OSS technologies that predispose manual emptiers to calamity. This signpost the need to give more attention to vocational education and training that can enhance the technical skills of these local masons. Policies and strategies on urban sanitation should cover the roles of these local masons in FS management in this locale.

The findings of this study reiterate the need to establish FS treatment plant in Akure at a strategic location after completing a comprehensive Environmental Impact Assessment of the facility. The FS treatment plant is capital intensive, which could be established through government funding or privatisation. This paper suggests the establishment of the FS treatment plant by Ondo State government. Similarly, advocates for privatisation of the management of the treatment plant to enable its long-term continuity and functionality. This would ensure mandatory costing of FS discharge at treatment point since private sector operates on profit making basis. A lesson learnt in Dakar, Senegal showed that when FSTP is managed by a public utility, it experienced steady and relentless deterioration.

Most importantly, this paper has shown that improving method of emptying is the principal factor that will improve FSM in the study area. In this view, there is a need to pilot manually operated mechanical systems such as gulpers, dung beetles, Vacutugs to empty FS, and transport the FS through their tankers to a mobile transfer station positioned in a strategic location around the study location. Then, transport the FS using vacuum truck to a treatment plant before disposing treated residue to a designated site. In this regard, public private partnership (PPP) models have proven successful in sanitation literature, such as a National Sanitation office of Senegal (ONAS) model in Dakar Senegal. This paper recommends similar PPP arrangement to improve FSM in the residential cores of Akure specificity and cores of cities with similar attributes to Akure in developing countries.

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Authors Contributions

This study was designed by the authors, written by Ayadi but edited by Rotowa. Both authors reviewed the manuscript, read and approved the final manuscript.

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The authors have declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

[1] Afe, E. A. (2012). A historical survey of socio-political administration in Akure region up to the contemporary period. *European Scientific Journal, 8* (18), 1857 – 7881.

[2] Akinbamijo, O. B. (2019). *Beloved, we are Debtors: A treatise on environmental management.* (Inaugural Lecture Series 115), Federal University of Technology Akure, Nigeria.

[3] Aliya, A. A., & Amadu, L. (2017). Urbanisation, Cities, and Health: The challenge to Nigeria- a review. *Annals of African Medicine, 16* (4), 149-158.

[4] Appiah-Effah, E., Nyarko, K. B., Gyasi, S. F., & Awuah, E. (2014). Faecal sludge management in low income areas: a case study of three districts in the Ashanti region of Ghana. *Journal of Water, Sanitation and Hygiene for Development, 4* (2), 189-199.

[5] Bakare, B. F. (2011). *Scientific and management support for ventilated improved pit latrines (vip) sludge content.* (Doctoral thesis, University Of KwaZulu-Natal, Durban). Retrieved from http://prg.ukzn.ac.za/docs/default-source/dissertation/5-04-mb.pdf?sfvrsn=0

[6] Boot, N. (2007). *Pit emptying systems- A technical brief.* Warwickshire, Uk: Practical Action.

[7] Boot, N. D., & Scott, R. E. (2009). Faecal sludge in Accra, Ghana: problems of urban provision. *IWA Publishing Water Science & Technology—WST, 60* (3), 623 - 631.

[8] Climate Data. (2019). *Climate Akure.* Retrieved from https://en.climate-data.org /africa/nigeria/edo/akure-385339/#climate-graph

[9] EAWAG. (2005). *Household-Centred Environmental Sanitation: Implementing the Bellagio Principles in Urban Environmental Sanitation (Provisional 254 Guideline for Decision-makers).* Duebendorf, Switzerland: EAWAG-Swiss Federal Institute of Aquatic Science and Technology (SANDEC).

[10] Eke, E. E., Oyinloye, M. A., & Olamiju, I. O. (2017). Analysis of urban expansion of Akure, Ondo State. *International Letters of Social and Humanistic Sciences, 75*, 41-55.

[11] Enisan, G. (2019). Assessment of housing needs in the core area of Akure, Nigeria. *International Journal of Environmental Monitoring and Analysis, 7* (4), 75-84.

[12] eThekwini Municipality Water and Sanitation Unit. (2004). *Pit latrine evacuation study report.* Durban: eThekwini Municipality Water and Sanitation Unit.

[13] Fasakin, J. O. (2002). Daily cost considerations in the operations of commercial motorcycles in Nigeria: A locational analysis for Akure township. *Transportation Research Part A, 36*, 189-202.

[14] Federal Ministry of Water Resources. (2017). *Making Nigeria open defecation free by 2025. A national roadmap.* Abuja: Federal Ministry of Water Resources.

[15] Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). London: SAGE Publications Ltd.

[16] Halcrow, G., Yetsho, T., Nguyen, N., & Tshering, G. (2014). Developing behaviour change communication for improving faecal sludge management in Bhutan. *Journal of Water, Sanitation and Hygiene for Development, 4* (1), 164-170.

[17] Harada, H., Strande, L., & Fujii, S. (2015). *Challenges and opportunities of faecal sludge management for golbal sanitation.*. Dubendorf: EAWAG/SANDEC.

[18] Hauser, D. P. (1974). Some problems in the use of stepwise regression techniques in geographical research. *The Canadian Geographer, 18* (2), 148-158.

[19] Hussain, F., Clasen, T., Akter, S., Bawel, V., Luby, S., Leontsini, E.,... Winch, P. J. (2017). Advantages and limitations for users of double pit pour-flush latrines: a qualitative study in rural Bangladesh. *BMC Public Health, 17* (515), 1-9.

[20] Ingallinella, A. M., Sanguinetti, G., Koottatep, T., Montangero, A., & Strauss, M. (2002). The challenge of faecal sludge management in urban areas – strategies, regulations and treatment options. *Water Science and Technology, 46* (10), 285-294.

[21] Katukiza, A. Y., Ronteltap, M., Niwagaba, C. B., Foppen, J. W., Kansiime, F., & Lens, P. N. (2012). Sustainable sanitation technology options for urban slums. *Biotechnology advances, 30* (5), 964–978.

[22] Kengne, I. M., Soh-Kengne, E., Amougou, A. K., Bemmo, N., Dodane, P. H., & Koné, D. (2011). Vertical-flow constructed wetlands as an emerging solution for faecal sludge dewatering in developing countries. *Journal of Water, Sanitation and Hygiene for Development, 1* (1), 13-19.

[23] Kolsky, P. (2004). *A statement issued at ''Creating Demand for Sanitation, Promoting Hygiene, Housing the Poor among Issues Addressed in Several Interactive Sessions'' of the UN. ENV/DEV/768, 23, April, 2004.* Retrieved from http://www.unis.unvienna.org/unis/pressrels/2004/envdev768.html

[24] Kone, D., & Chowdhry, S. (2012). *Business Analysis of Fecal Sludge Management: Emptying and Transportation Services in Africa and Asia.* Seattle, WA, USA: Bill & Melinda Gates Foundation.

[25] Lüthi, C., Morel, A., Tilley, E., & Ulrich, L. (2011). *Community Led Urban Sanitation Planning: CLUES. Complete guidelines for decision maker with 30 tools.* Zurich: Eawag-Sandec/WSSC/UN-HABITAT.

[26] Lüthi, C., Panesar, A., Schutze, T., Norstrom, A., McConville, J., Parkinson, J.,... Ingle, R. (2011). *Sustainable sanitation in cities. A framework for action.* Rijswijk: Papiroz Publisher House.

[27] Macmillian Nigeria. (2006). *Secondary Atlas.* Lagos: Macmillian.

[28] Mikhael, G., Robbins, D. M., Ramsay, J. E., & Mbeguere, M. (2014). Methods and means for collection and transport faecal sludge. In L. Strande, M. Ronteltap, & D. Brdjanovic, *Faecal sludge management. Systems approach for implementation and operation* (pp. 67-96). London: IWA Publishing.

[29] Morella, E., Foster, V., & Banerjee, G. S. (2008). *Climbing the Ladder: The State of Sanitation in Sub- Saharan Africa.* Washington DC, USA: The World Bank.

[30] Nakagiri, A., Niwagaba, C. B., Nyenje, P. M., Kulabako, R. N., Tumuhairwe, J. B., & Kansiime, F. (2016). Are pit latrines in urban areas of Sub-Saharan Africa performing? A review of usage, filling, insects and odour nuisances. *BMC Public Health, 16* (120), 1-16. doi: https://doi.org/10.1186/s12889-016-2772-z

[31] Nkansah, A. (2009). *Management of faecal sludge in the urban areas of low-income countries: a case of Tamale, Ghana.* (PhD Thesis, Loughborough University, London, UK). Retrieved from https://core.ac.uk/download/pdf/2741546.pdf

[32] Ojo, J. S., Olorunfemi, M. O., Bayode, S., Akintorinwa, O., Omosuyi, G. O., & Akinluyi, F. O. (2014). Constraint map for landfill site selection in Akure metropolis, southwestern Nigeria. *Ife Journal of Science, 16* (2), 405-416.

[33] Okoye, A. C. (2016). *For safe human waste disposal in Nigeria*. Retrieved 10 5, 2018, from Sunnewsonline: https://www.sunnewsonline.com/for-safe-human-waste-disposal-in-nigeria/

[34] Olajuyigbe, A. E., & Fasakin, J. O. (2010). Citizens' willingness to pay for improved sustainable water supply in a medium-sized city in South Western Nigeria. *Current Research Journal of Social Sciences, 2* (2), 41-50.

[35] Olajuyigbe, A. E., Olamiju, I. O., & Ola-Omole, M. C. (2017). Vulnerability of hand dug wells in the core area of Akure, Nigeria. *Urban Water Journal, 14* (8), 797-803.

[36] Ondo State Department of Research and Statistics. (2010). *Facts and figures on ondo state.* Akure: Department of Research and Statistics, Ministry of Economic Planning and Budget.

[37] Owoeye, J. O. (2013). A study on environmental habitability of core residential neighbourhood in Akure, Nigeria. *American Journal of Research Communication, 1* (2), 140-153.

[38] Owoeye, J. O., & Omole, F. K. (2012). Built environment decay and health situation of slum dwellers in residential core of Akure, Nigeria. *American Journal of Human Ecology, 1* (2), 33-39.

[39] Paterson, C., Mara, D. D., & Curtis, T. (2007). Pro-poor sanitation technologies. *Geoforum, 38*, 901-907.

[40] Peal, A., Evans, B., Blackett, I., Hawkins, P., & Heymans, C. (2014). Fecal sludge management: A comparative analysis of 12 cities. *Journal of Water, Sanitation, and Hygiene for Development, 4*, 563.

[41] Reymond, P., Renggli, S., & Lüthi, C. (2016). Towards sustainable sanitation in an urbanising world. In M. Ergen, *Sustainable Urbanization* (pp. 115-134). London: IntechOpen. doi: 10.5772/63726

[42] Rotowa, O. O. (2014). *Spatio environmental management of faecal waste in residential zones of Akure, Nigeria.* (Unpublished doctoral thesis), Federal University of Technology Akure, Nigeria.

[43] Rotowa, O. O., & Olamiju, I. O. (2019). An appraisal of water, sanitation and poverty in cities of developing nations: the Akure example. In O. B. Akinbamijo, E. Okoko, & O. O. Popoola (Eds.), *The Just City: Poverty, Deprivation and Alleviation Strategies* (pp. 615-630). Akure: Federal University of Technology, Akure.

[44] Rotowa, O., Olujimi, J., Omole, F., & Olajuyigbe, A. (2015). Socioeconomic factors affectibg households sanitation preferences in Akure, Nigeria. *European International Journal of Science and Technology, 4* (5), 183-194.

[45] Schoebitz, L., Bischoff, B., Christian, R. L., Charles, B. N., Siber, R., & Strande, L. (2017). GIS Analysis and Optimisation of Faecal Sludge Logistics at City-Wide Scale in Kampala, Uganda. *Sustainability, 9* (194), 1-16.

[46] Semiyaga, S. (2017). *Dewatering as a Critical Step in Urban Slum-Based Faecal Sludge Management.* (Doctoral thesis, Makerere University, Kampala, Uganda. Retrieved from https://saniup.org/wp-content/uploads/2018/01/FINAL-PhD-THESIS-2017-SWAIB-SEMIYAGA.pdf

[47] Semiyaga, S., Okure, M. A., Niwagaba, C. B., Katukiza, A. Y., & Kansiime, F. (2015). Decentralized options for faecal sludge management in urban slum areas of Sub-Saharan Africa: A review of technologies, practices and end-uses. *Resources, Conservation and Recycling, 104*, 109–119.

[48] Singh, S., Mohan, R. R., Rathi, S., & Raju, N. J. (2017). Technology options for faecal sludge management in developing countries: Benefits and revenue from reuse. *Environmental Technology and Innovation, 7*, 203-218.

[49] Strande, L. (2014). The global situation. In L. Strande, M. Ronteltap, & D. Brdjanovic (Eds.), *Faecal sludge management: systems approach for implementation and operation* (pp. 1-14). London: IWA Publishing.

[50] Strande, L., Ronteltap, M., & Brdjanovic, D. (Eds.). (2014). *Faecal Sludge Management: Systems Approach for Implementation and Operation.* London: IWA Publishing.

[51] Strande, L., Schoebitza, L., Bischoff, F., Ddiba, D., Okello, F., Englund, M.,... Niwagaba, C. B. (2018). Methods to reliably estimate faecal sludge quantities and qualities for the design of treatment technologies and management solutions. *Journal of Environmental Management, 223*, 898-907.

[52] SuSanA. (2012). *Planning of Sustainable Sanitation for Cities.* Netherlands: Sustainable Sanitation Alliance.

[53] Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., & Zurbrugg, C. (2014). *Compedium of sanitation systems and technologies.* Duebendorg: Eawag-Sandec/International Water Association/Water Supply & Sanitation Collaborative Council.

[54] United Nations Department of Economic and Social Affairs. (2018). *World urbanisation prospects: the 2018 revision.* New York: United Nations.

[55] Van Vuuren, L. (2008). Back to basics: Research looks down the pit. The Water Wheel. *Sanitation, Health, and Hygiene Supplement, 12*, 10-13.

[56] WHO and UNICEF. (2017). *Progress on drinking water, sanitation and hygiene: update and SDG baselines.* Geneva: WHO and UNICEF.

[57] WHO and UNICEF. (2019). *Progress on household drinking water, sanitation and hygiene I 2000-2017.* Geneva: World Health Organisation.

[58] Fakere, A. A. (2017). Effects of Levels of Residents' Participation in house design on residential satisfaction in public housing estates in Akure, Nigeria. *Covenant Journal of Research in the Built Environment, 5* (1), 86-98.

[59] Kennedy-Walker, R. (2015). *Planning for Faecal Sludge Management in informal urban settlements of low-income countries: A study of Lusaka, Republic of Zambia*. (Doctoral Thesis, Newcaslte University, UK). Retrieved from https://theses.ncl.ac.uk/jspui/bitstream/10443/2856/1/Kennedy-Walker,%20R.%202015.pdf

[60] Ondo State Bureau of Statistics. (2012). *Report of integrated household survey in Ondo State 2011*. Akure: Ondo State Bureau of Statistics.