Study On Pit Latrine Minimum Design Requirement And Considerations In Northern Nigeria.

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Abstract— An estimated 69.5 million people in Northern Nigeria rely on pit latrine to defecate due to the lack of proper excreta disposal system in the region. However, many studies extensible indicates the environment and environmental resources contamination with pit latrines. It is the intent of this study to explore the numerous design features of pit latrines and which type needed to improve, thus, set a guideline on minimum pit latrine design standard. The studies on pit latrine design and structural characteristics were systematically reviewed including their evolution and improvement over a millennium, environment and environmental contamination especially groundwater and the study further assessed the extent at which the Northern Nigeria lives are at stake and knowledge gaps were found. The study found no original research on design or materials to prevent groundwater contamination despite the rises in groundwater levels due to climate change that is limiting the vertical separation distance between groundwater levels and pit latrines. Moreover, harvesting long noted greenhouse gases and additional 198 detected volatile gases emanated by pit latrine are inhabited limited data. This indicates that the concurrent pit latrine designs are less-effective in mitigating environmental and environmental resources contamination. Future pit latrine improvement or modification should focus on an integral model approach to developed a well improved and sustainable pit latrine.

Index Terms— Pit Latrine Design, Groundwater Contamination, On-site Sanitation, Northern Nigeria, Nigeria.

1 INTRODUCTION

The vulnerability of public to faecal contamination remains the primary health concern [1] in Northern Nigeria, where approximately 64.03% and 44.7% rely on pit latrines to defecate and unimproved water sources [2].

Northern Nigeria the defunct British Protectorate of Northern Nigeria (Figure 1) was an autonomous region within Nigeria bordered with Niger, Cameroon, Chad and the Benin Republic. The region is comprised of 3 geopolitical zones, 19 Northern states and Abuja, Federal Capital Territory (Figure 1). It estimated that the Northern Nigerian population to approximately 108,491,992 consisting of 59.4% of Nigeria's population [3].Northern Nigeria tend to have worst environmental conditions in and around the homes, disposals of excreta have remains the central issues in the region do to the lack of proper city's sewer system and garbage collecting system. of human excreta in this nature is in two categories; improved and unimproved pit latrines (Figure 2). Improved and unimproved pit latrines sanitation facilities include: 1) Septic tank 2) Flush to Pit latrine 3) VIP (Ventilated-Improved-Pit) Latrine 4) Pit Latrine with Slab or Cover 5) Pit Latrine without Slab or Open Slab. These pit latrines are difficult to sustain as they fill quickly; the factors contributing to that and the design features or qualities for the pit latrine are far from being understood [5]. Therefore, understanding the characteristics and conditions of a pit latrine and extent to which pit latrine is so essential to the SDG sanitary agenda 2030 and efficiently work toward sanitation strategy [6].

Fig. 1. Map of Nigeria Showing the Northern Region [4]

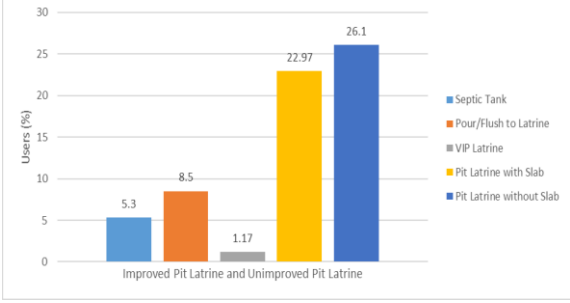

Fig. 2. Variable Pit Latrine Use in Northern Nigeria.

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In the region, pit latrine remained the most reliable sanitation facility to dispose of their excreta due to the lack of proper sewer system in the country unlike developed European countries where citizens are obliged to connect their households to the central sewer system provided by the government. Most of these pit latrines that generates faecal sludge (FS) a solid and liquid excreta mixture [7] in northern Nigeria, however, are inadequately design, poorly positioned and constructed and rarely maintained over their lifespan.

There is concern that pit latrine contaminants' discharged to the groundwater may affect human health negatively [8]. In the region diseases and infections which are uncommon continue to surface which are mostly link to poor hygiene and contaminated water. Hence, against this backdrop, the public is being confronted with challenges that required to mitigate. Therefore, controlling these diseases and infections, and their ensuing outbreak lies in Northern Nigerian proper excreta disposal and access to quality water.

Previous studies have varied in their emphasis on pit latrine design selection. However, it is not clear which types of pit latrine construction to be used to reduce exposure to infections association to faecal contaminants and to improve health quality. It is the intent of this study to explore the numerous structural design features of pit latrines and their impact on the environment and environmental resources extensively; thus, human health risk. Furthermore, to find knowledge gaps on pit latrine design and its effects

2 Pit Larine

2.1 Groundwater Contamination in Relation to Pit Latrine

The study estimated 64.03% (Figure 3) corresponding to approximately 69.5 million people use pit latrine for defecation in Northern Nigeria. The figure 3 indicated that a large number of the population relied on unimproved pit latrine without a slab or open slab approximately 28.3 million people in the region and 53.2million uses both simple pit latrine with slab and without for defecation in. Based on the variability of unimproved water sources in Northern Nigeria (Figure 4), the study estimated 44.7% corresponding to approximately 49 million people in the region rely on unimproved water sources. Thus, the groundwater contamination in relation to pit latrine is evident in the region, the study conducted in Katsina state found total and faecal coliforms in sampled existing wells that are proximity to the pit latrine [9], another preliminary survey conducted in the Northcentral zone reveal the Nitrate in the well sample [10]. Other studies in Nigeria associated the groundwater contamination to pit latrine, for instance, the study conducted on domestic wells where the study showed the deteriorating quality of shallow domestic wells water [11] and 1200 domestic wells sampled revealed the nitrate distribution in those wells [12]. Study further established evidence on microbial and chemical groundwater quality in relation to a pit latrine. Previous studies on groundwater contaminants such as viruses, bacteria, microbial eukarya, helminths, the main contents of human faeces [13] indicate that they came from pit latrines. Most of the studies used culture-based testing to assess the microbial quality of groundwater as a result of pit latrine seepage [14]. The study summarized the previous studies on the quality of groundwater as a result of contaminants discharged from a pit latrine in the table (1).

Table 1: Selected Studies on Pit Latrine Impact on Groundwater Quality

Reference	Year	Country	Study Design, Cases and Water Quality Parameters
[15]	2012	India	Sampled Domestic wells near pit latrines and septic tanks revealed faecal coliforms total dissolved solids, and nitrate present.
[16]	2012	South Africa	Sampled Existing Wells found ammonia and nitrate content.
[17]	2011	India	Installed test wells revealed total coliforms, and faecal coliforms content.
[18]	2009	Benin	Sampled 287 water wells, pump and surface near 220 pit holes. 40 cases found after sampling many times. Cases founds are viruses: Adenoviral DNA and Rotaviral RNA
[19]	2006	Zimbabwe	Sampled Existing Wells found total coliforms, faecal coliforms, Ammonia, nitrate, turbidity, pH, and conductivity
[20]	2005	Zimbabwe	Sampled existing wells and boreholes revealed that more than 75% of boreholes and domestic wells were contaminated with microbial content of total coliform and faecal coliforms, and chemical content of *Na, Zn, Cu, Co, Fe,* phosphate and nitrate

Studies further established the widespread infection and diseases associated with pit latrine in Northern Nigeria. However, cholera infection the acute diarrhoea caused by vibrio cholera when ingested from contaminated food or water [21] is a major borne water infection that consumed many lives in Northern Nigeria for over a decade. However, cholera cases in Northern Nigeria as a result of contaminated water associated with pit latrine data from previous and the most recent reports for each most of the affected were obtained from different sources and estimated 161,865 were recorded between 1991-2018 (Figure 2).

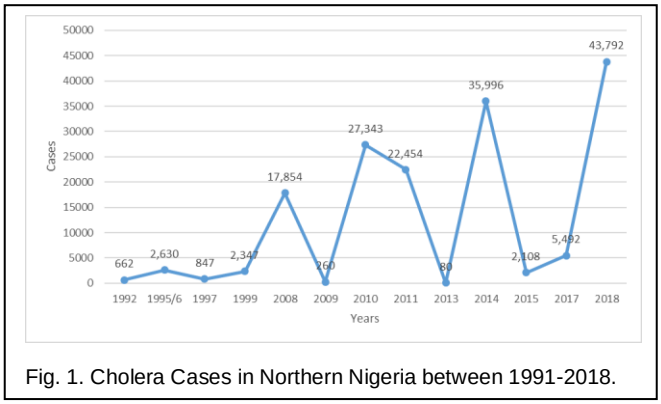

Fig. 1. Cholera Cases in Northern Nigeria between 1991-2018.

For viral hepatitis, there is no reliable data on the infection cases in the region except one that was published Daily Trust Newspaper online [22] reported that more than 300,000 people tested positive with hepatitis B in the Northeastern state of Taraba. Therefore, these issues called for a great cause of concern; the risk associated with the current pit latrine construction and management in Northern Nigeria

needed to be addressed. Despite the potential of groundwater been polluted by contaminant from pit latrine, however, there was no single study found suggesting or introduced a design with a view to preventing contaminant discharge from pit latrine to the groundwater. Although some studies attempted to establish minimum vertical distances between the bottom of a pit latrine and table water, the studies vary, the vertical distances suggested to avoid the groundwater from being contaminated by pit latrines are between 3m-50m. Table water is one of the parameters to be considered before sitting any pit latrine [15]. The summary of the selected studies on vertical distances between the bottom of a pit latrine and extent the contaminant travelled and the variation of table water distances in Northern Nigerian based on the hydrogeological formation are presented in table (2).

Table 2: Selected Studies on Vertical Distance Travelled by Contaminants and Variation of Table Water Distances in Northern Nigeria

Studies on Vertical Distance Reached by Contaminants

Reference	Year	Country	Vertical Distance Observed (m)
[23]	2015	No data	10
[17]	2011	India	<10.2
[19]	2006	Zimbabwe	>5
[24]	2002	No data	15-30
[25]	2000	Zimbabwe	5-20
[26]	1997	Zimbabwe	20
[27]	1921	No data	≥3–4.5
[28]	1941	No data	<7

Variation of Table Water Distances in Northern Nigeria

Reference	Year	Category	Depth	
			Water Table (m)	Borehole (m)
[29]	2018	Basement Aquifers	5-15	10-70
[30]	No data	Igneous Aquifers	<5	15-50
[29], [31]	2018 and 2002	Sedimentary Aquifers	10-40	20-150
[31]	2002	Unconsolidated	0-10	15-30
[29]	2018	Basement Aquifers	5-15	10-70

2.2 Usage and Maintenance

Disposing of human faeces properly are of great importance than the clean and safe water provision as it lowers the chance of getting environmental resources from contamination with faecal and further minimise the transmission of borne water diseases [8], [32]. Proper excreta disposal in pit latrine is the most appropriate way of providing improved sanitary. However, pit latrine should be free from odour, insects and other animals [33-34]. Many steps have been taken to address the aforementioned issues. Thus, pit latrine has undergone many modifications and improvement to meet the users' satisfaction. Few studies found linking hygienic nature of pit latrine with smell, insects and other animals' accessibility [35] and these are what make users discomfort. Studies detected 198 more volatile gases constituents [36] by using gas chromatography and by olfactive analyses [36]. Among these volatile constituents, eight found odorants other than the long noted causing smelly substances in pit latrine known as greenhouse gas [37]. The studies further linked the flies with pit latrine smells or odours [38], materials used for the construction and the topography where the pit latrine is sited [39]. Moreover, pit latrine types, size and maintenance (cleanliness) contribute to pitting latrine smells and insects' nuisances [40]. [33] recommended that pit hole to remain dark, it's an effective way of keeping insects away; therefore, pit hole should be covered or slabbed with concrete. Other methods noted by the studies are employed to control the pit latrine smell or odour and insect nuisances; using organic and inorganic substances [41]-[42], 33] and traditionally using kerosene, ash, soil, oil disinfectants [43]-[45]. Despite series of modifications undergoes by pit latrine to address some issues associated with it, VIP the most improved pit latrine with it vertical vent pipe design makes any odour/smell emanated by faecal material to pass through [46-47] and the ground hole are kept dark, thus, keeps flies away, however, remain less effective in keeping mosquitoes away [48] and in controlling smells and odours based on user perceptions on the studies conducted in Ghana and Mozambique revealed that the smell is relatively higher [49] indicating no clear differences between simple pit latrines and VIP in terms odours/smells generation and insects' attraction [39] which linked to the fact that, those VIPs did not meet the required minimum design standards and the sludge accumulation within the VIPs that affect the ventilation conditions of the latrines [37]. Therefore, 10 m3 /h and 6 ground holes' air volume changes/h (ACH) ventilation odour most be achieved VIP latrines satisfactory smell/odour control [37]. Moreover, the studies recorded the higher the ventilation flows at a rate greater than 10 m3 /h, the inadequately enough to achieve 6 ACH odourless conditions [50]. Therefore, the larger the ground holes' volume, the lower in maintaining its odourless conditions [48], [37]. Furthermore, other factors associated with VIP latrines inadequate enough to maintain it odourless conditions, sizes of the vent pipe and the opening and entrances of the structure constructed facing away from the wind direction [48]. SanPlant pit latrines other improved pit latrine designed mitigate smell and odours, unlike the VIP most of the odours and smells remain within the pit hole [51]. Pit latrine filling is another issue associated with pit latrine, once pit latrine is filled new one is dug to replace it. This practice is generally considered inappropriate and not alternative [37]. However, determining the pit latrine filling rate remain the primary way of achieving sustainable and effective pit latrine management [37]. In this notion, pit latrine should be emptied when it fills to about 0.5m top [52]. Although, from the data obtained from the previous studies (Table 3) couldn't establish the actual filling rate, however, indicates it fill faster, and this is as a result of faecal sludge accumulation within the pit [37] which also attributed to the number of users and the pit latrine size. Therefore, many studies proposed variable design on the sludge accumulation rate which ranges from 40-90 l/capital/year [53], [33].

Table 3: Summary on Pit Latrine Filling Rate (Year), Accumulation Rates and Actual Filling Rates per Annum Design

Summary on Pit Latrine Filling Rate (Year)

Reference	Year	Country	Filling Rate (Year)
[54]	2014	Ghana	6-10
[55]	2013	Ghana	4.2, >10 and 0.25
[56]	2012	South Africa	5-9 and 20
[57]	2011	Uganda	5
[58]	2010	Uganda	<1
[41]	2006	East Africa	Over 30
[53]	1992	Many	15-25
[48]	1958	Zimbabwe	Over 30

Annual Accumulation and Filling Rates' Design

Reference	Year	Country	Filling Rates l/c/a
[59]	2012	South Africa	39, 48, 21 (median) and 19 (mean)
[60]	2008	South Africa	24.1, 69.4, and 18.5 (mean), 29 and 34 (median)
		Tanzania	27.5 (implied)
[53]	1992	USA Brazil	42 47
[33], [53]	1985 and 1992	No Data	40, 60 and 90
[33], [53]	1985 and 1992	India	25
[33]	1985	Philippines	40
[48]	1982	Zimbabwe	20

Studies also found factors other than human excreta that affect the pit latrine filling rate, factors such as rubbish disposing into the pit latrine [59], [61] which includes non-degradable materials [62]. They developed a model to observe a pit latrine content during the wet season and data collected were simulated and parameters tested by sensitivity analysis [63]. The result obtained indicates that inflows of water into the pit latrine affect the sludge accumulation, thus, increasing the pit latrine filling rate. Pit latrine anaerobic and aerobic decomposition processes also other factors contributing to pit latrine filling especially anaerobic processes [33], [61], [64]. During this process, the excreta will be broken down into a firmly fixed product [37] with releasing gas into the atmosphere and mineral compound and microbial drained into the ground. This processes substantially reduced the pit latrine volume [53], [49] 50-70% [65] even up to 80% [33], [66]. The experiments have been conducted in batches in the laboratory to quantify the pit latrines mass stability and lost as a result of decomposition. The result indicates that the moisture has significant effects on gas production rate [61] the increase in moisture increases the gas production. However, there was no evidence indicated that the sludge accumulation decreases by an increase of moisture from VIP latrine samples tested [65].

Pit latrine when filled, it should be properly emptied to prevent endangering the public health and contaminating the environment [67]. This involved multi-steps processes (Figure 4), on-site-treatment, collection and transportation and further treatment for the clean disposal [67], [37].

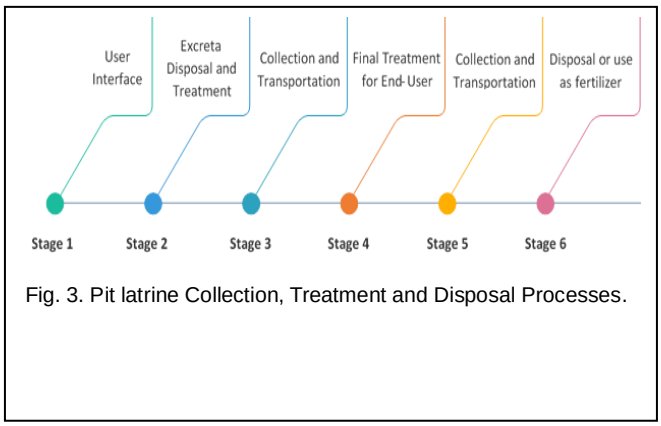

Fig. 3. Pit latrine Collection, Treatment and Disposal Processes.

2.3 Pit Latrine Designs

Studies on pit latrine relation to groundwater contamination and pit latrine design and construction standard in Northern Nigeria. Studies have shown that pit latrines are only designed to collect human excreta not to mitigate pathogen concentrations [68]. Pit latrine an onsite-sanitation facility consists of a hole in the ground to accumulate human excreta lined with concrete, concrete bricks, etc. [69] covered with slabs or floor. They further explained, pit latrines are made from all types of construction materials depending on the users' preference; available materials at the locations and financial status of the user. The ground hole that accumulates faecal sludge is 3m height minimum and 1m wide [69] covered with the slab with 0.25m dropping hole [70]. The pit latrine varies in type depending on the user preference and financial status. Open defecation and cat method; burying human faecal in shallow holes has long been practice and there is no technical construction support required [37]. These practices are still in use especially in some part northern region of Nigeria. The pit latrine was developed in the early 20th century by the developed nations to mitigate the widespread diseases and pollution associated with human excreta that consumed many lives [37]. The menace was successfully curtailed by human excreta disposal programs [33]. The variabilities of pit latrine designs are presented below:

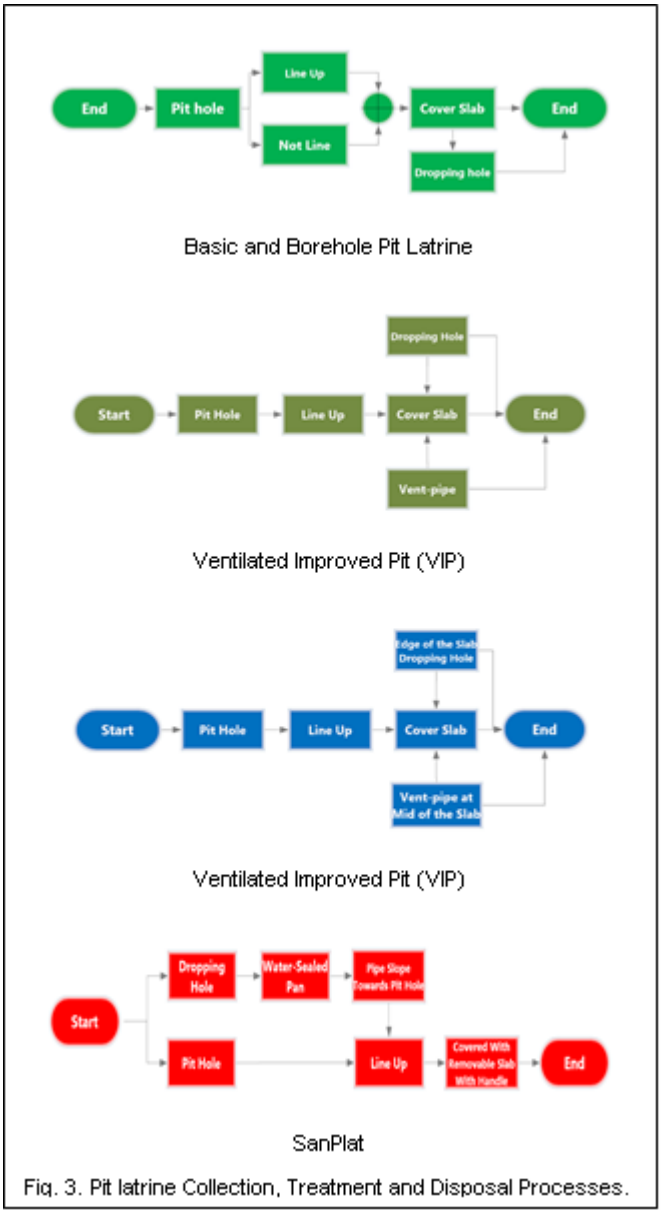

Fig. 3. Pit latrine Collection, Treatment and Disposal Processes.

3 Discussion

The review study on pit latrine minimum design requirement found that this simple sanitation' type, design, construction and materials used for the construction are what influenced leaching [14], smells, odours and insects' nuisance [40]. There are variations in design and construction ranging from tradition (figure 5) [49], [32] to the reed odourless earth closet (ROEC) (figure 7) [71], ventilated improved pit (VIP) (figure 6), Kumasi ventilated improved pit (KVIP) [72]-[73], borehole pit (figure 5) [37] ventilated improved double pit (VIDP) or revised improve closet II [74]-[75] and SanPlat (figure 8) [51]. Studies found that pit latrine undergoing a series of modification and improvement since the beginning of 20th to mitigate some issues such as smells, odours and insect nuisance associated with pit latrines, however, have no or little effect on preventing groundwater contamination coming from pit latrine, the infections related to contaminated water continue to surface. With this notion, therefore, the study investigated the spread of infections such as cholera, hepatitis, dysentery, diarrhoea, etc., the data from studies on the major cholera outbreak in Northern Nigeria (Figure 4) recorded about 161,865 cases between 1991 to 2018. However, the highest cases recorded were from 2010 to 2018, where 137,265 cases where recorded and 2018 has the highest recorded cases; 43,792 since the outbreak. Other bone water infections data were not available except that of hepatitis which was published on 4th of August 2019 by Daily Trust Newspaper online were narrated over 300,000 tested positive with viral hepatitis in Taraba state, North Eastern region. The systematic studies on microbial and chemical groundwater quality indicate (Table 1) the contamination are influence by pit latrine seepage through the soil [9]-[12], [15]-[20]. However, the vertical ground distances travel by contaminants from the bottom of pit latrine varies (Table 1) depending on the topography of the places where the pit latrines are sited and the subsurface conditions [19], [23]-[28]. Therefore, there was no clear empirical investigation used to drive 10-30m as distances from pit latrine bottom to groundwater siting guidelines [14]. They further recommended that the pit latrine and groundwater safety should be adequately evaluated; both environmental and environmental pollutant factors must be considered before constructing any pit latrine. Therefore, parameters such as water table depth should be evaluated before constructing any pit latrine [14]. In this regard, we evaluate the water table of the region and we found the variation in hydrogeological formation in the region (Table 1) thus, the single vertical distance between the bottom edge of the ground hole and water table cannot be suggested for the entire region. To determine what will be the minimum size of pit latrine or considered as a standard for the region, however, we looked at the previous studies that proposed variable design on the pit latrine filling rates (Table 2) ranges between less than one (1) year to over 30 years [41], [48], [53[-[58] and sludge accumulation and actual filling rate per annum design (Table 2) ranges between 20 and 90 Liter/Capita/Annum [59]-[60], [52], [33], [48], these depend on the number of users and the size. Therefore, determining the pit latrine filling rate remain the major way of achieving sustainable and effective pit latrine management [37]. Studies also found both chemical and traditional methods have been applied to mitigate the pit latrine smells, odours and insects' nuisances [33], [41]-[45]. However, no study extensively found investigating these practices on its impact on the environment.

3.1 Study Gaps and Way Forward

The reliance on pit latrine for defecation in Northern Nigeria is high and on the rise, as the population is increasing, thus, putting peoples' lives at stake. Although, studies show that it's difficult to suggest a single vertical distance between the bottom of the pit latrine and water table in the region due to the variation of the hydrogeological formation. However, the further approach needed since the pit latrine is still evolving to serve the users' satisfactory levels and prevent the environment and environmental resources from getting polluted is to develop an integrated model that can be adopted anywhere.

Gaps identified from this review include:

1. In spite the extensive reliance on pit latrine and groundwater sources, no study found examined which materials are suitable, durable and cost less for pit latrine construction with a view to preventing contaminant seeping from pit latrine to groundwater level. Moreover, most of the improvements and modifications underwent by pit latrines indicates by the studies, are to comfort the user by minimising the issues such as smell, odour and insect

nuisances. Furthermore, climate change recognised by the WHO (2009) [76] and World Bank (2012) [77] as a threat to the drinking water sanitary supplies safety and reliability, therefore, rise in sea levels as a result of the climate courses more flooding, thus, rising groundwater levels gradually and there will be no safe vertical separation between table water and pit latrine [14]. However, no specific studies were focusing on addressing this climate change threat on both pit latrine and groundwater. Therefore, an integrated modelling approach in pit latrines design and construction may substantially mitigate the contaminants threats to the environment and environmental resources, thus, endangering the humans' lives.

2. VIP latrine tends to show less effective in addressing the pit latrine smells, odours and insect nuisance especially if its inadequately designed and sited [48]-[50], [37], [39] even if it's adequately designed and sited, it less effective in keeping mosquitos away [48]. However, the studies indicated that the SanPlant is the most effective in smell controlling as it keeps smells and odours within the pit holes [51] as such there will be no nuisances from insects as they are only attracted to the smells [39]. Therefore, more studies needed to improve this sanitary facility to address other issues associated with pit latrine
3. Apart from integral model development, a proper pit latrine maintenance is crucial and the studies stressed this, it depends on the users. Although in Northern Nigerian states, there are urban sanitation policies, the specification of minimum pit latrine options, standards, maintenance and enforcement of the policies could not be found by the studies. Furthermore, users' awareness levels on how quality pit latrine construction better function remained low. However, there is a need to increase the level of awareness and sensitisation programs on pit latrine specification design selection and construction policy enforcement.

Human bio-waste are the primary sources of greenhouse [37] long noted by many studies with the addition of 198 detected volatile gases constituents after using gas chromatography and by olfactive analyses [36]. Harvesting long noted greenhouse gases and emerging volatile gases emanated by pit latrine are however, generally inhabited by limited data. Therefore, a better understanding of pit latrine greenhouse emission is needed to make a more informed decision.

4 Conclusion

Pit latrines remain the alternative sanitary facility and essential strategy for disposing of human excreta in Northern Nigeria regardless of its potential for contaminating the groundwater. The study estimated approximately 69.5 million people in Northern Nigeria use both improved and unimproved pit latrine sanitary facility and this number is expected to increase due to the increase in population, urbanisation and government negligence to provide proper sewerage. However, reliance on groundwater sources, the primary water sources will also increase. Thus, there is growing concern that peoples' lives in this region are susceptible to infection associated with environment and environmental resources contamination.

Although, the improvements and modifications undergo by pit latrine over a millennium is comfort the users by minimising issues such as smell and insects' nuisances, modification or improvement with a view to minimizing pit latrines contents' seepage to groundwater, however, could not be established. Moreover, to date, there has been a limited focus greenhouse gases emanated by human faecal sludge in the pit latrine. Therefore, further investigation is needed to set a minimal design requirement for the pit latrine. Future improvement or modification in pit latrine should focus on integral model approaches to developed well improved and sustainable pit latrine. Understanding of costless materials with a view to preventing contaminants discharge from pit latrine, average annual excreta rate and filling rate per household, harvesting the greenhouse gases emanated by faecal sludge in the pit latrine, on-site treatment and collection when filled are the precursor and essential for pit latrine minimum design standard. Furthermore, awareness and sensitisation should include and subsequently, the minimum pit latrine design standard should be enforced by the relevant authorities.

References

[1] Angela R. Harris, Amy J. Pickering, Alexandria B. Boehm, Mwifadhi Mrishod and Jennifer Davisae. (2019) Comparison of analytical techniques to explain variability in stored drinking water quality and microbial hand contamination of female caregivers in Tanzania. Environmental Science: Processes & Impacts, Journal of the Royal Society of Chemistry, 21, 893-903.

[2] National Survey Finding Report, February. (2018). The fifth round Multiple Indicator Cluster Survey (MICS5), Multiple Indicator Cluster Survey 2016-17.

[3] National Nutrition and Health Survey (NNHS). (2018). Report on the Nutrition and Health Situation of Nigeria.

[4] Fanen Terdoo, Olalekan Adekola. (2014). Assessing the role of climate-smart agriculture in combating climate change, desertification and improving rural livelihood in Northern Nigeria. African journal of agricultural research, 9(15):1180-1191

[5] Michael R. Templeton, Acile S. Hammoud, Adrian P. Butler, Laura Braun, Julie-Anne Foucher, Johanna Grossmann, Moussa Boukari, Serigne Faye and Jean Patrice Jourda. (2015). Nitrate pollution of groundwater by pit latrines in developing countries. AIMS Environmental Science. 2(2), 302-313.

[6] Joshua V.Garn, Gloria D. Sclar, Matthew C. Freeman, Gauthami Penakalapati Kelly T. Alexander, Patrick Brooks, Eva A. Rehfuess, Sophie Boisson, Kate O. Medlicott, Thomas F. Clasen. (2017). The impact of sanitation interventions on latrine coverage and latrine use: A systematic review and meta-analysis. International Journal of Hygiene and Environmental Health, 220(2B), 329-340.

[7] Morella E, Foster V, Banerjee SG. (2008). Climbing the ladder: the state of sanitation in sub-Saharan Africa. 13.

[8] Fredrick Owino Gudda, Wilkister Nyaora Moturi, Omondi Steve Oduor, Edward Wanee Muchiri and Jeroen Ensink. (2019). Pit latrine fill-up rates: variation determinants and public health implications in informal settlements, Nakuru-Kenya BMC Public Health, (19)(68).

[9] Amadi, A. N., Okoye, N. O., Alabi, A. D., Aminu Tukur and Angwa, E. M., (2014). Quality assessment of soil and groundwater near Kaduna Refinery and Petrochemical Company, Northwest Nigeria. Journal of Scientific Research & Reports, 3(6), 884-893.

[10] Mbonu, M. & Ibrahim-Yusuf, A. I. (1994). Groundwater quality in the Basement Complex region of north-central Nigeria – A preliminary survey of nitrate concentration. Water Resources, 5, 16–21.

[11] Ophori, D. (2006). Groundwater Quality in Shallow Domestic Water Wells, Ughelli, Nigeria. Retrieved December 2, 2019, from http://www.iseg.giees.uncc.edu/abuja2006/Abstracts/Abstract_ID_284.
[12] Adelana, S. M. A. & Olasehinde, P. I. (2003). High nitrate in water supply in Nigeria: implications for human health. Water Resources, 14, 1–11.
[13] Feachem RG, Bradley DJ, Garelick H, Mara DD. (1983). Sanitation and Disease: Health Aspects of Excreta and Wastewater Management. New York: John Wiley & Sons Ltd.
[14] Jay P. Graham and Matthew L. Polizzotto, (2013). Pit Latrines and Their Impacts on Groundwater Quality: A Systematic Review. Environmental Health Perspectives, 121(5).
[15] Pujari PR, Padmakar C, Labhasetwar PK, Mahore P, Ganguly AK. (2012). Assessment of the impact of on-site sanitation systems on groundwater pollution in two diverse geological settings--a case study from India. Environ Monit Assess, 184(1), 251-63.
[16] Vinger B, Hlophe M, Selvaratnam M. (2019). Relationship between nitrogenous pollution of borehole waters and distances separating them from pit latrines and fertilized fields. Life Sci J., 9(1), 402–407.
[17] Banerjee G. (2011). Underground pollution travel from leach pits of on-site sanitation facilities: a case study. Clean Technol Environ Policy, 13(3), 489–497
[18] Verheyen J, Timmen-Wego M, Laudien R, Boussaad I, Sen S, Koc A, Uesbeck A, Mazou F, Pfister H. (2009). Detection of adenoviruses and rotaviruses in drinking water sources used in rural areas of Benin, West Africa. Appl Environ Microbiol, 75(9), 2798-801.
[19] Dzwairo B, Hoko Z, Love D, Guzha E. (2006). Assessment of the impacts of pit latrines on groundwater quality in rural areas: a case study from Marondera district, Zimbabwe. Phys Chem Earth, 31(15–16), 779–788.
[20] Zingoni E, Love D, Magadza C, Moyce W, Musiwa K. (2005). Effects of a semi-formal urban settlement on groundwater quality Epworth (Zimbabwe): case study and groundwater quality zoning. Phys Chem Earth, 30(11–16), 680–688.
[21] World Health Organisation. (2019). Unsafe drinking water, sanitation and waste management. Retrieved September 13, 2019, from https://www.who.int/sustainable-development/cities/health-risks/water-sanitation/en/
[22] Daily Trust Online Newspaper. (2019). 300,000 persons infected with Hepatitis B in Taraba. Retrieved September 20, 2019 from https://www.dailytrust.com.ng/300000-persons-infected-with-hepatitis-b-in-taraba.html.
[23] CABI. (2015). Communicable Disease Epidemiology and Control: A Global Perspective. p. 52. ISBN 9780851990743.
[24] Banks D, Karnachuk OV, Parnachev VP, Holden W, Frengstad B. (2002). Groundwater contamination from rural pit latrines: examples from Siberia and Kosova. J Chartered Inst Water Environ Manage, 16(2), 147–152.
[25] Chidavaenzi M, Bradley M, Jere M, Nhandara C. (2000). Pit latrine effluent infiltration into groundwater: the Epworth case study. Schriften Ver Wasser Boden Lufthyg. 105, 171–177.
[26] Chidavaenzi M, Jere M, Bradley M. (1997). Pit latrine effluent infiltration into groundwater. In: Proceedings of the 23rd WEDC Conference, Durban, South Africa. Available: http://wedc.lboro.ac.uk/resources/conference/23/Chidavae.pdf
[27] Kligler IJ. New York:Rockefeller Institute for Medical Research. (1921). Investigation on Soil Pollution and the Relation on the Various Types of Privies to the Spread of Intestinal Infections.
[28] Dyer BR. (1941). Studies of groundwater pollution in an alkaline alluvium soil. Ind J Med Res., 29(4), 867–877.
[29] Tijani M, Crane E, Upton K, Ó Dochartaigh BÉ and Bellwood-Howard I. (2018). Africa Groundwater Atlas: Hydrogeology of Nigeria. British Geological Survey. Accessed 26 August 2019
[30] Jamiu Alao Alimi. Programme officer (Groundwater) Regional Centre for Integrated River Basin Management National Water Resources Institute, Kaduna, Nigeria. Groundwater Resources and Management in Nigeria (PowerPoint Presentation). http://www.unesco.org/new/fileadmin/MULTIMEDIA/FIELD/Nairobi/nigeria.pdf
[31] Offodile ME (2002). Groundwater study and development in Nigeria. Mecon Services Ltd, Jos, Nigeria.
[32] Kalbermatten JM, Julius DS, Gunnerson CG, Mara DD, Mundial B. (1982). Appropriate sanitation alternatives; a planning and design manual, vol. 2: Baltimore, USA, John Hopkins University Press; 1982.
[33] Wagner EG, Lanoix JN. (1958) Excreta disposal for rural areas and small communities.
[34] World Health Organisation, (1992). A Guide to the Development of on-site Sanitation, Retrieved December 25, 2019 from https://www.who.int/docstore/water_sanitation_health/onsitesan/ch04.htm.
[35] Tumwebaze IK, Mosler H-J. (2014). Shared toilet users' collective cleaning and determinant factors in Kampala slums, Uganda. BMC Public Health, 14(1), 1260.
[36] Lin J, Aoll J, Niclass Y, Velazco MI, Wünsche L, Pika J, et al. (2013). Qualitative and Quantitative Analysis of Volatile Constituents from Latrines: Supporting Information. Environ Sci Technol, 47(14), 7876–82.
[37] Anne Nakagiri, Charles B. Niwagaba, Philip M. Nyenje, Robinah N. Kulabako, John B. Tumuhairwe and Frank Kansiime. (2016). Are pit latrines in urban areas of SubSaharan Africa performing? A review of usage, filling, insects and odour nuisances. BMC Public Health, 16:120.
[38] Curtis, C. F., and Hawkins, P. (1982) 'Entomological studies of on-site sanitation systems in Tanzania and Botswana'. Transactions of the Royal Society of Tropical Medicine and Hygiene, pp99-108.
[39] Nakagiri A, Kulabako RN, Nyenje PM, Tumuhairwe JB, Niwagaba CB, Kansiime F. (2015). Performance of pit latrines in urban poor areas: a case of Kampala, Uganda. Habitat Int. 49, 529–37
[40] Irish S, Aiemjoy K, Torondel B, Abdelahi F, Ensink JHJ. (2013). Characteristics of Latrines in Central Tanzania and Their Relation to Fly Catches. PLoS One, 8(7), e67951.
[41] Pickford J. Low-Cost Sanitation. (2006). A survey of practical experience. London: ITDG Publishing.
[42] McCabe LJ, Haines T. (1957). Diarrheal disease control by improved human excreta disposal. Public Health Rep, 72(10), 921.
[43] Nwaneri CF, Foxon KM, Bakare BF, Buckley CA. (2008). Biological degradation processes within a pit latrine. In: Water Institute of Southern Africa (WISA) Biennial Conference & Exhibition 18–22, 2008.
[44] Nwaneri CF. (2009). Physico-chemical charactristics and biodegradibility of contents of ventilated improved pit latrines (VIPs) in eThekwini Municipality. In. South Africa; Master's Thesis: University of KwaZulu-Natal.
[45] Zhang R, Day D, Christianson L, Jepson W. A (1994). computer model for predicting ammonia release rates from swine manure pits. J Agr Eng Res., 58(4), 223–9.

[46] Mara D. (1984). The design of Ventilated Improved Pit latrines. In: Technology Advisory Group (TAG) Technical Note No13. USA: International Bank for Reconstruction and Development/The World Bank.
[47] Ryan BA, Mara DD, Mundial B. (1983). Pit latrine ventilation; field investigation methodology. TAG Technical Note. vol. 4. In. Washington, DC: World Bank.
[48] Morgan PR, Mara DD, Mundial B. (1982). Ventilated improved pit-latrines: recent development in Zimbabwe (Technical Note No. 2) vol. 3. In. Washington, D.C: World Bank.
[49] Cotton A, Franceys R, Pickford J, Saywell D. (1995). On-Plot Sanitation in lowincome urban communities. A review of literature. Loughborough: WEDC Loughborough Univ. of Technology.
[50] Dumpert JW. (2008). Performance Evaluation of VIP Latrines in the Upper West Region of Ghana. In Houghton, Michigan: MSc Thesis Michigan Technological University.
[51] Solsona F. (1995). The South African Sanplat. An alternative low-cost pit latrine system for rural and peri-urban areas. Technical guide. South Africa: CSIR Pretoria.
[52] François Brikké (2003). Linking technology choice with operation and maintenance in the context of community water supply and sanitation. World Health Organization. p. 108. ISBN 9241562153.
[53] Franceys R, Pickford J, Reed R. (1992). A guide to the development of on-site sanitation. London: World Health Organisation; 1992.
[54] Appiah-Effah E, Nyarko KB, Gyasi SF, Awuah E. (2014). Faecal sludge management in low income areas: a case study of three districts in the Ashanti region of Ghana. J Water Sanit Hyg Dev., 4(2), 189–99.
[55] Adubofour K, Obiri-Danso K, Quansah C. (2013). Sanitation survey of two urban slum Muslim communities in the Kumasi metropolis, Ghana. Environ Urban. 25(1), 189–207.
[56] Still DA, Foxon K. (2012). Tackling the challenges of full pit latrines. Volume 2: How fast do pit toilets fill up? A scientific understanding of sludge build up and accumulation in pit latrines. In., vol. 2. South Africa: Water Research Commission (WRC).
[57] Günther I, Horst A, Lüthi C, Mosler H-J, Niwagaba CB, Tumwebaze IK. (2011). Where do Kampala's poor "go"?-Urban sanitation conditions in Kampala's lowincome areas.
[58] Kulabako RN, Nalubega M, Wozei E, Thunvik R. (2010). Environmental health practices, constraints and possible interventions in peri-urban settlements in developing countries - a review of Kampala, Uganda. Int J Environ Health Res., 20(4), 231–57.
[59] Still DA, Foxon K. (2012). Tackling the challenges of full pit latrines. Volume 1: Understanding sludge accumulation in VIPs and strategies for emptying full pits In., vol. 1. South Africa: Water Research Commission (WRC).
[60] Bhagwan JN, Still D, Buckley C, Foxon K. (2008). Challenges with up-scaling dry sanitation technologies. Water SciTechnol. 58(1), 21–7.
[61] Buckley CA, Foxon KM, Brouckaert CJ, Rodda N, Nwaneri CF, Balboni E, et al. (2008). Scientific support for the design and operation of ventilated improved pit latrines (VIPS) and the efficacy of pit latrine addtives. In. South Africa: Water Research Commission (WRC).
[62] Brouckaert C, Foxon K, Wood K. (2013). Modelling the filling rate of pit latrines. Water SA., 39(4), 555–62.
[63] Todman LC, van Eekert MH, Templeton MR, Hardy M, Gibson WT, Torondel B, Abdelahi F, Ensink JH. (2014). Modelling the fill rate of pit latrines in Ifakara, Tanzania. Journal of Water, Sanitation and Hygiene for Development 5(1), 100–106.
[64] Chaggu EJ. (2004). Sustainable Environmental Protection Using Modified PitLatrines. In. Netherlands: Ph.D thesis: Sectie Milieutechnologie; Wageningen University.
[65] Bakare, B. F. (2014). Scientific and management support for ventilated improved pit latrines (VIP) sludge content. PhD Thesis, University of KwaZulu Natal (UKZN), Durban, South Africa.
[66] M.A. Lopez Zavala ; N. Funamizu ; T. Takakuwa (2002), Onsite wastewater differential treatment system: modeling approach. Water Sci Technol, 46 (6-7), 317–324.
[67] Strande, Linda; Brdjanovic, Damir (2014). Faecal Sludge Management: Systems Approach for Implementation and Operation. IWA Publishing. p. 1, 6, 46. ISBN 9781780404721.
[68] Orner, K.D., Naughton, C. and Stenstrom, T.A. (2018). Pit Toilets (Latrines). In: J.B. Rose and B. JiménezCisneros, (eds) Global Water Pathogen Project. http://www.waterpathogens.org (J.R. Mihelcic and M.E. Verbyla) (eds) Part 4 Management of Risk from Excreta and Wastewater) http://www.waterpathogens.org/book/pit-toilets Michigan State University, E. Lansing, MI, UNESCO.
[69] Tilley, E.; Ulrich, L.; Lüthi, C.; Reymond, Ph.; Zurbrügg, C. (2014). Compendium of Sanitation Systems and Technologies (2nd ed.). Dübendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag). ISBN 978-3-906484-57-0.
[70] World Health Organisation. (1996). Simple pit latrine (fact sheet 3.4)". Retrieved August 15, 2014 From, who.int. 1996.
[71] Rybczynski W, Polprasert C, McGarry M. (1978) Low-cost technology options for sanitation. A state-of-the-art review and annotated bibliography. Ottawa: IDRC.
[72] Saywell D, Hunt C. (1999). Sanitation programmes revisited. Loughborough, UK: WEDC, Loughborough University.
[73] Thrift C. (2007). Sanitation policy in Ghana: Key factors and the potential for ecological sanitation solutions. Stockholm: Stockholm Environment Institute.
[74] Winblad U, Kilama W. (1985). Sanitation without water. Revised and enlarged edition. London: Macmillan Education.
[75] Van Nostrand J, Wilson JG. (1983). Rural ventilated improved pit latrines: a field manual for Botswana. Technical Advisory Group technical note; no. 8. In. Washington, DC: World Bank.
[76] World Health Organization. (2009). Protecting Health from Climate Change: Connecting Science, Policy and People. Geneva, Retrieved December 25, 2019. http://whqlibdoc.who.int/publications/2009/9789241598880_eng.pdf.
[77] World Bank. (2012). Turn Down the Heat: Why a 4oC Warmer World Must Be Avoided. Washington, DC: Retrieved December 25, 2019 http://climatechange.worldbank.org/sites/default/files/Turn_Down_the_heat_Why_a_4_degree_centrigrade_warmer_world_must_be_avoided.pdf