Indian Journal of Environment Engineering (IJEE)
ISSN: 2582-9289 (Online), Volume-1 Issue-1, May 2021

Physico-Chemical and Biological Characteristics of Faecal Sludge in Pit Latrines with Depth

Ugwu Francis ifeuzu, Agunwamba Jonah Chukwuemeka

Abstract:** There is limited information about the characteristics of faecal sludges in ordinary pit latrines. Knowledge of the physico-chemical and biological characteristics of pit sludge from different layers of the pit apart from providing an indication of the nature of pit contents endeavoured to provide information and decision support for managing pit latrines during their normal lifespan. Therefore, this paper was aimed at investigating the physico-chemical and biological characteristics of pit sludge samples to equip latrine owners with environmental and health implications of this sludge. Legislation that establishes regulations specifically for the treatment and discharge, enduse, or disposal of faecal sludge is therefore essential. Thus, faecal sludges sampled from ten (10) pit latrines were subjected to laboratory analyses with particular reference to selected parameters. From the study, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total solids (TS), moisture content, suspended solids (SS) and volatile solids (VS) showed decreasing trend throughout as the pit depth increased. Temperature presented double scenarios, increasing initially and decreasing afterwards with the highest values within 0.4m to 0.6m pit depth in all the pit latrines. Efforts to understand and mitigate the health effects of particulate matter (PM) air pollution have a rich and interesting history. This review focuses on six substantial lines of research that have been pursued since 1997 that have helped elucidate our understanding about the effects of PM on human health. There has been substantial progress in the evaluation of PM health effects at different time-scales of exposure and in the exploration of the shape of the concentration-response function. There has also been emerging evidence of PM-related cardiovascular health effects and growing knowledge regarding interconnected general pathophysiological pathways that link PM exposure with cardiopulmonary morbidity and mortality. Despite important gaps in scientific knowledge and continued reasons for some skepticism, a comprehensive evaluation of the research findings provides persuasive evidence that exposure to fine particulate air pollution has adverse effects on cardiopulmonary health. Although much of this research has been motivated by environmental public health policy, these results have important scientific, medical, and public health implications that are broader than debates over legally mandated air quality standards.

***Keywords:** Ordinary Pit Latrine; Biodegradation; Pit Sludges; User-Behaviour; Favourable Conditions; Physico-Chemical and Biological Characteristics; Microbial Density. Aerobic and Anaerobic Decomposition*

Manuscript received on 9 April 2021 | Revised Manuscript received on 25 April 2021 | Manuscript Accepted on 15 May 2021 | Manuscript published on 30 May 2021.

***** Correspondence Author

Ugwu Francis ifeuzu*, Department of Civil Engineering, University of Nigeria, Nsukka. E-mail:ugwufrancisifeuzu@yahoo.com

Prof. Agunwamba Jonah Chukwuemeka, Department of Civil Engineering, University of Nigeria, Nsukka. E-mail: Jonah.Agunwamba@unn.edu.ng

I. INTRODUCTION

Faecal matter deposited into the pit latrine undergoes some level of biodegradation. The extent to which this occurs depends on several factors such as type of food consumed by the household, population, type of anal cleansing materials, soil characteristics and ground conditions, age of depositor, total solids content, amount of moisture in the substrate, inflow and infiltration capacity of the soil, characteristics of the surrounding soil, etc.

Decomposition will involve communities of organisms working together. If the population of viable micro-organisms present in the waste heap is high and environmental conditions are suitable, a high rate of stabilization of feed material will be achieved. Micro-organisms are usually introduced into the pit with faeces and other organic materials such as anal cleansing material, soil and leaves that are thrown into the pit.

The aim of this paper was to study the physico-chemical and biological characteristics of faecal sludge with depth in ordinary pit latrines. Subsequently, faecal sludge samples were collected from ten (10) pit latrines at five different layers of the pits across the study community, Aku with the aid of a designed sampler. The samples were then subjected to laboratory analyses to find out their physico-chemical and biological characteristics, using standard methods of measurement in the laboratory (APHA, 1998).

II. LITERATURE REVIEW

Work on the degradation of faeces in VIP latrine was carried out by Nwaneri et al (2008). In their work, they carried out the physico-chemical and biological characteristics of fresh faeces from a household and established that there was a regular decrease in chemical oxygen demand (COD), moisture content, and organic solids fraction with increase in the depth of the pit.

Available literatures on the processes occurring inside a pit latrine remain limited. Furthermore, it is difficult to understand processes occurring inside the pit without background knowledge on the nature of pit latrine contents. The pit, if well operated contains faeces, urine, anal cleansing material and/or anal cleansing water (Foxon et al., 2008; Buckley et al., 2008). Kirsten Wood estimated that the useful life of the pit latrines could be extended 75% (of upwards of five to fifty years) if we could stop rubbish being dumped into the latrines and by using enzymes that can degrade fibre and the walls of cells. Within any given pit, the properties vary according to depth. However, disposal of multiple wastes into the pit results in non-homogenous properties of pit contents.

2.1 Decomposition Processes of Faecal Sludge in Pit Latrines

2.1.1 Aerobic and Anaerobic Decomposition

Twenty six percent (26%) of the pit contents undergoing aerobic digestion do not degrade as against 20% that undergo anaerobic digestion. Thus aerobic digestion, whilst quicker leaves more solids and therefore accumulation is greater. This explains the field observation that wet pits fill more slowly as they are more anaerobic. Anaerobic conversion to methane gas provides relatively little energy to the microorganisms, resulting in a slow growth rate and a small portion of the waste being converted to new biomass. Moreover, anaerobic digestion generally produces gaseous methane as an energy resource (Lettinga, 1995; Sekiguchi et al., 2001).

In anaerobic digestion, the acid-forming and the methane-forming microorganisms differ widely in terms of physiology, nutritional needs, growth kinetics, and sensitivity to environmental conditions (Pohland et al., 1971).

2.2 Characteristics of pit sludge

Earlier studies have been done by Foxon et al (2008) to characterize pit contents. Studies done by (Lopez et al., 2002) and (Lopez et al, 2004) to characterize faeces and to describe the biodegradability of organic matter present in faeces showed that 75-80% of human faeces comprised of slowly biodegradable organic matter while 15-20% is inert material. Readily biodegradable organic matter was not regarded as a component of faeces (i.e. = 0%). The study went further to show that only 15% of the slowly biodegradable material was easily hydrolysable whereas 65% was slowly hydrolysable (Lopez et al., 2014). Human faeces is high in organic matter, contributing about 44% of COD load in domestic wastewater (Almeida et al., 1999).

2.3 Factors affecting the efficiency of faecal decomposition processes in pit latrine.

One of the factors affecting the efficiency of faecal decomposition is temperature. Most of the microorganisms exhibit a narrow range of temperature over which they can be active (Lopez et al., 2004). Thermophilic anaerobic digestion at between temperatures of 55^0C – 65^0C has additional benefits including a high degree of waste stabilization and destruction of viral and bacterial pathogens (LoK et al., 1985). Climate has a direct influence on faecal sludge characteristics, mainly due to temperature and moisture. The moisture content of faecal sludge in the pit latrine affects the rate of degradation that occurs in the pit. This is also in line with Lay et al. (1997)in their study of the influence of moisture content on the methanogenic activity in the anaerobic digestion of wastewater treatment plant sludge cake which showed that methanogenic activity dropped from 100% at a moisture content of 96% to 53% of the maximum activity when the moisture content was reduced to 90%.

Geological characteristics of the surrounding soil where the pit latrines are placed can have an important influence in the processes happening inside the pit (Bhagwan et al., 2008). These include type of soil/rock, porosity and permeability of the soil, natural moisture content and particle size distribution, infiltration capacity and long-term acceptance rates, percolation rate, hydraulic conductivity, topography of the site.

Oxygen is extremely toxic to the obligate anaerobic methanogens and these bacteria are inhibited by even small concentrations (Bitton, 1994; Muyima et al., 1997). Household habits associated with toilet usage influence the variability of faecal sludge in the pit latrine.

III. RESEARCH METHODOLOGY

With the aid of designed sampler, samples were carefully collected from eight pit latrines, without allowing mixing of sludge in the sampler, with multiple samples taken in the different layers. Samples were taken at six (6) different pit depths namely the surface layer, 0.2m, 0.4m, 0.6m, 0.8m and 1.0m with 1.0m being the bottom of the pit. Samples were analyzed within 30 minutes from the time of collection using standard methods of measurement of faecal parameters (ALPHA, 1998). Results were compared using graphs to find correlations between various parameters.

3.1 Description of study area

Ordinary pit latrines in this study were those identified in Aku community, Igbo-Etiti local Government Area in the Northern part of Enugu State. Aku community has a population of over 500,000 people with average of 10 persons per household with a total number of households being approximately 2,000. Most buildings are of sandcrete blocks with few thatched houses depending on the financial disposition of the family. The area has an annual rainfall of 800 millimetres. The average annual temperature is 30oC with daytime maxima of 40oC from January to April. Daytime highs from June to September are approximately 30oC with minimum of approximately 20oC.

Eventhough few households still adopt the open defecation system, there are six (6) different forms of sanitary facilities in the area, namely the VIP latrine, septic tank, water closet, sanitation platform (SanPlat) latrine, traditional pit latrine which is predominant and pour flush latrines.

Aku is made of upland and lowland areas with the upland mainly sandy making the soil to be well drained. The lowland area has a mixture of lateritic and sandy soils resulting to massive erosion during the rainy season at the upland area.

3.3 The Sampler

The length of sampler used was 1.5m to allow 1.0m sludge level be sampled from the pit. It measured 100mm x 100mm square and calibrated into six segments. Each segment has opening through which the sludge enters into it. It was constructed in such a way that the segments are sealed up by a sliding device when being lowered into the pit and opened up after the lowering to allow the sludge enter the segments through gentle rotation of the sampler a few times. After the sludge has entered, the sliding device was pushed back into its original position and the sampler withdrawn. Sealing up the segments of the sampler before lowering and withdrawal was to prevent mixing up of sludge from different layers.

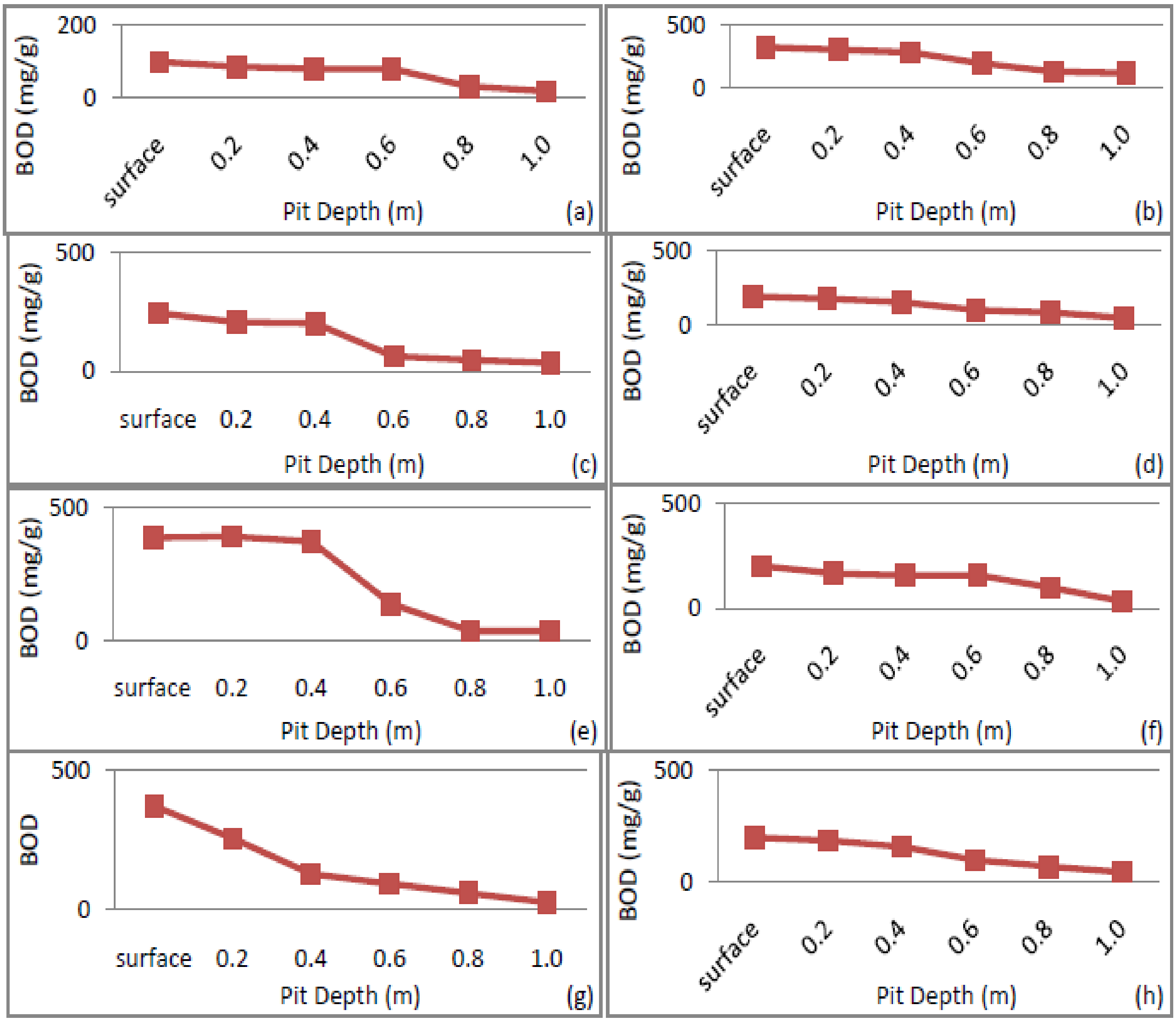
After withdrawing the sampler, the sliding cover was removed with care and small plastic containers well washed and sterilized were used to collect samples from the different segments and wrapped in a black cellophane bag to imitate the dark environment of the pit and to ensure that the bioactivity of the samples was not altered. Samples were properly stored in cool container in the laboratory until it was time for the laboratory analysis.

IV. RESULTS AND DISCUSSIONS

4.1 Variation of BOD with Depth

Figure1 showed the decreasing trend of BOD throughout the experiment as the pit depth increased. The amount of oxygen available for microorganisms decreased resulting in decreased biological activity. Thus, a considerable portion of the biologically degradable portion of faecal disappeared through aerobic bioconversion processes as it lied on the surface of the pit contents. The readily biodegradable components in the faeces have already been consumed on the surface.

As organisms depleted, the supply of oxygen from the existing spaces and pores between bits of organic matter, the decomposition process slowed down.



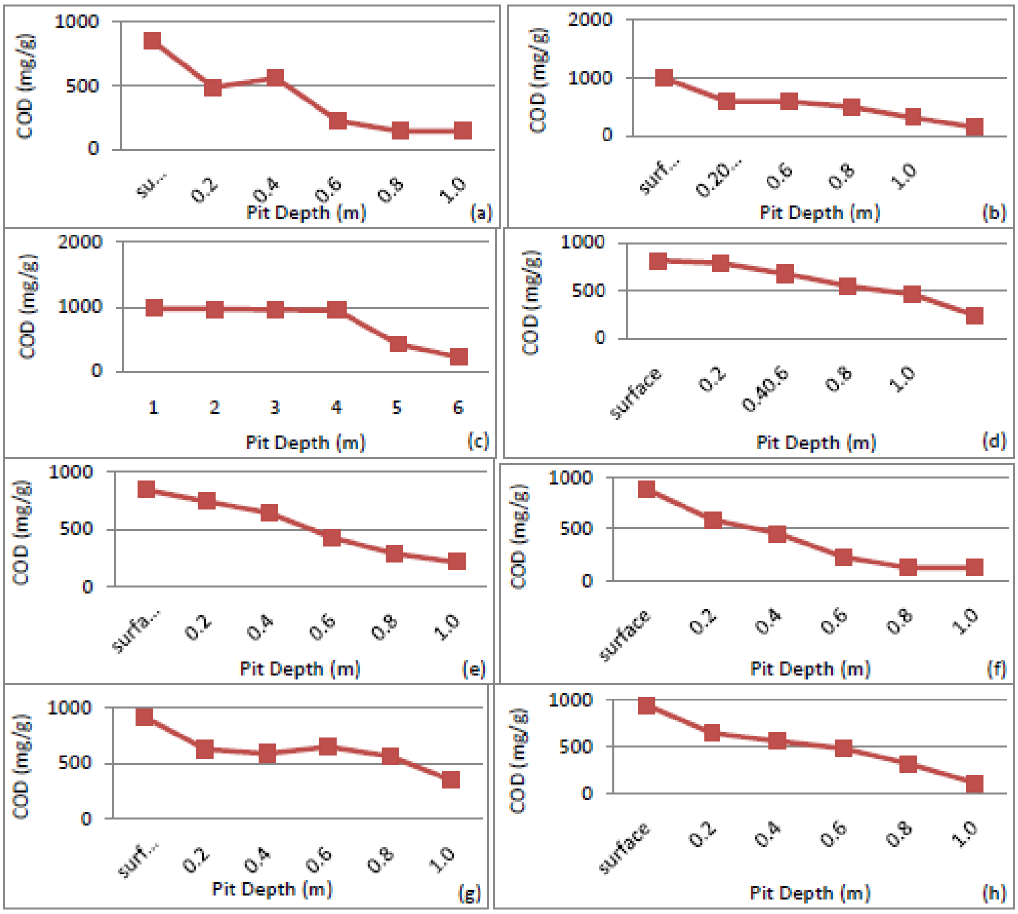
Figures 1: Variation of BOD with Pit Depth for Pits (a) - (h) for the 8 pits.

4.2 Variation of COD with depth

Figure 2 showed varying trends in the value of COD with increase in pit depth. Figure 5a and g showed that as the pit depth increased, the COD decreased, increased and decreased thereafter. This was attributed to user-behaviour by the households concerned and the composition of the faecal sludge in the pits. However, the COD in Figures 2b, c, d, e, f and h showed continuous decrease as the pit depth increased. COD is anaerobic and as the organic activities increased due to increased microbial action, the organic content decreased in most cases and so, the amount of COD decreased. The highest value of COD was recorded in Pit 2 (Figure 2b) while the lowest recorded value was in Pit 4 (Figure 2d). Generally, the anaerobic decomposition was high due to favourable temperature, moisture content, pH, soil conditions coupled with good user-behaviour.

Retrieval Number:100.1/ijee.A1803051121
DOI: 10.54105/ijee.A1803.051121
Journal Website: www.ijee.latticescipub.com

Published By:
Lattice Science Publication (LSP)

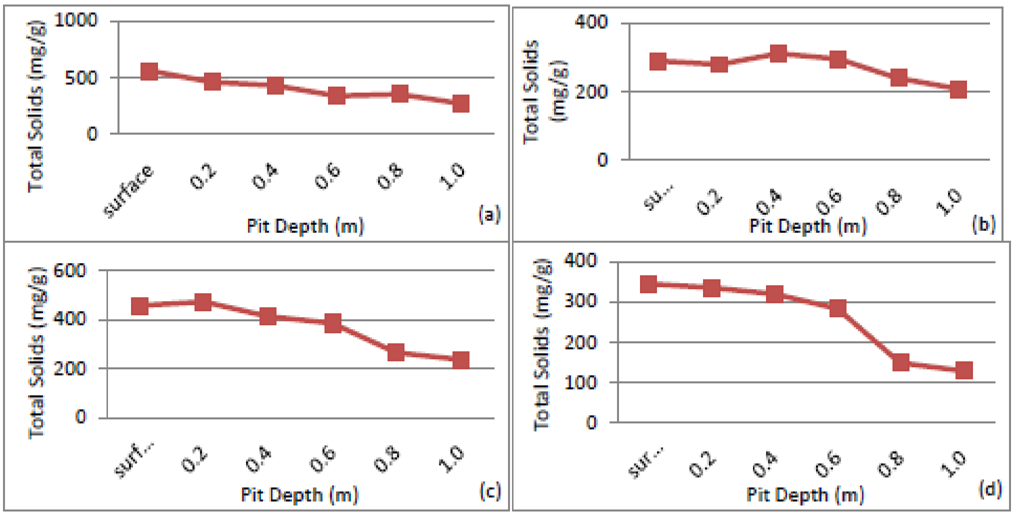


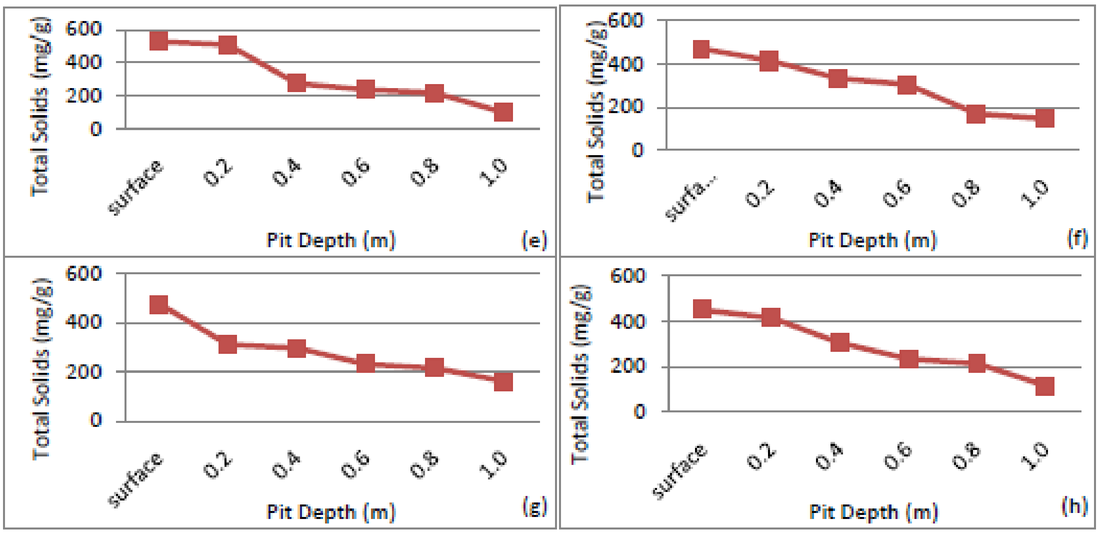
Figures 2: Variation of COD with Pit Depth for Pits (a) - (h) for the 8 pits.

4.3 Variation of total solids with depth.

Figure 3 showed the plots of the variation of total solids with pit depths for the 8 pit latrines sampled.. With the exception of Figure 4.8b, the total solids content decreased as the pit depth increased in Figure 3a,c,d,e,f,g and h. Total solids content in Figure 3b (Pit 2) presented double scenarios of increasing initially to 0.4m depth and then decreased afterwards in the remaining layers. The high amount of total solids measured in this study showed poor user-behaviour by the households concerned, depositing reasonable amount of solid wastes into the pit latrines, thus adversely affecting biodegradation process in the pit latrines.

Excessive dumping of solid wastes into the pit latrine led to so much total solids accumulation that possibly resulted in the reduction of the amount of moisture that should have been available for biodegradation. It could also impair the flocking of the microorganisms for sludge digestion thereby inactivating the microorganisms to digest the faecal sludge adequately.

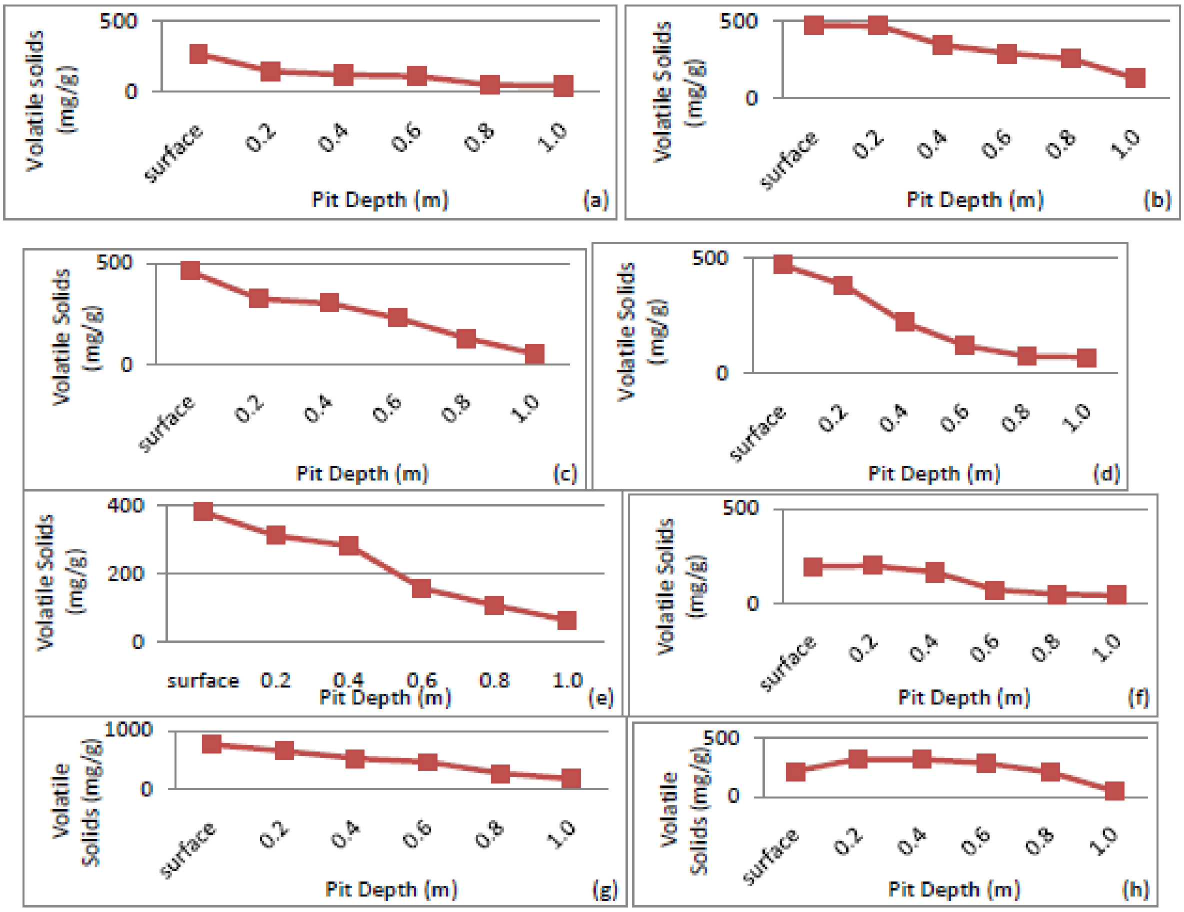




Figures 3: Variation of Total Solids with Pit Depth for Pits (a) - (h) for the 8 pits

4.4 Variation of volatile solids with depth

Figure 4 showed the variation of volatile solids with increase in pit depth for the 8 pit latrines. There was initial increase in volatile solids content as the pit depth increased in Figure 4b and f when the pit depth is 0.2m and then decreased later while in Figure 4h, the volatile solids increased at pit depth of 0.4m and decreased later to the bottom of the pit. In Figure 4a, c, d, e and g the volatile solids decreased throughout as the pit depth increased. The ratio of the volatile solids to the total solids in most of the pit latrines was high indicating high organic content in the faecal sludge.



Figures 4: Variation of Volatile Solids with Pit Depth for Pits (a) - (h) for the 8 pits

4.5 Variation of moisture content with depth

Figure 5 showed the variation of moisture content with depth for the 10 pit latrines. The moisture content variation of the faecal sludge with pit depth in Figures 5o a, c, d, e, f, g and h positively affected the rate of degradation that occurred in the pit. This was corroborated by Lay et al. (1997)in their study of the influence of moisture content on the methanogenic activity in the anaerobic digestion of wastewater treatment plant sludge cake which showed that methanogenic activity dropped from 100% at a moisture content of 96% to 53% of the maximum activity when the moisture content was reduced to 90%. On the other hand, in Figure 5b of Pit 2, the moisture content decreased initially and increased when the pit depth was 0.2m and increased at pit depth of 0.4m. Addition of new material on top of heap might cause moisture to be squeezed out of the pit contents. Pit 8 had the highest moisture content of 87.73% while Pit 4 had the lowest with 43.45%.

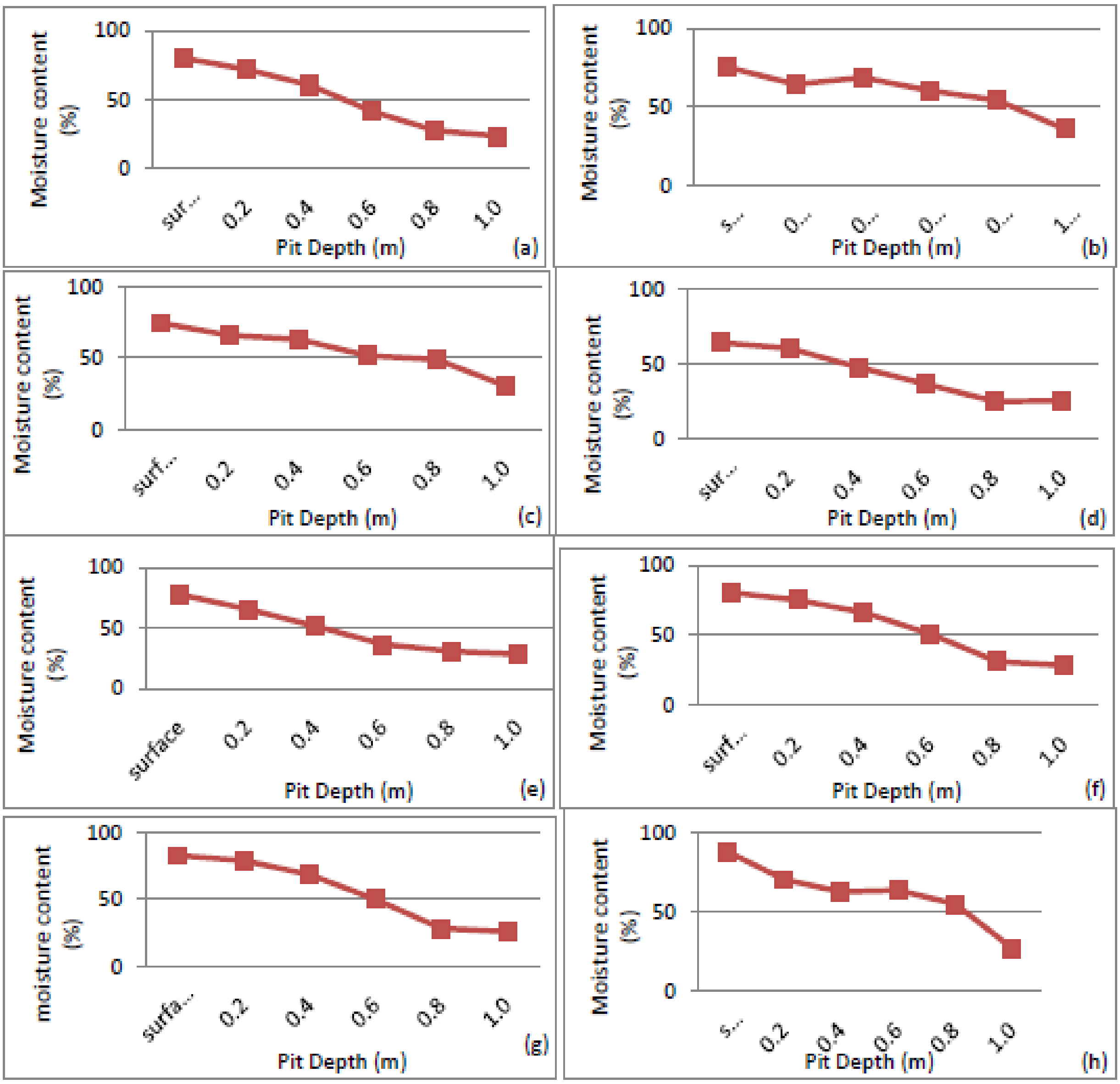


Figure 5: Variation of Moisture Content with Pit Depth for Pits (a) - (h) for the 8 pits.

4.6 Variation of suspended solids with depth

Figure 6 showed the variation of suspended solids with increase in pit, presenting different scenarios. Figure 6a and g (for Pits 1 and 7) showed that as the pit depth increased, the amount of suspended solids increased initially but later decreased. It showed that biodegradation increased and decreased later due to varying microbial activities dependent upon available microorganisms acting on the faecal sludge as the pit depth increased. Figure 6c (Pit 3) presented triple scenarios of decreasing, increasing and decreasing thereafter. Moreover, a lot of wastes could have been dumped into the pit resulting in changes in pit content which of course, affected faecal decomposition as the pit depth increased. Figure 6b, d, e, f and h showed that as the pit depth increased, the amount of suspended solids decreased. Reduction in suspended and volatile solids means gradual stabilization of the faecal sludge as anaerobic decomposition proceeded.

Retrieval Number:100.1/ijee.A1803051121
DOI: 10.54105/ijee.A1803.051121
Journal Website: www.ijee.latticescipub.com

Published By:
Lattice Science Publication (LSP)

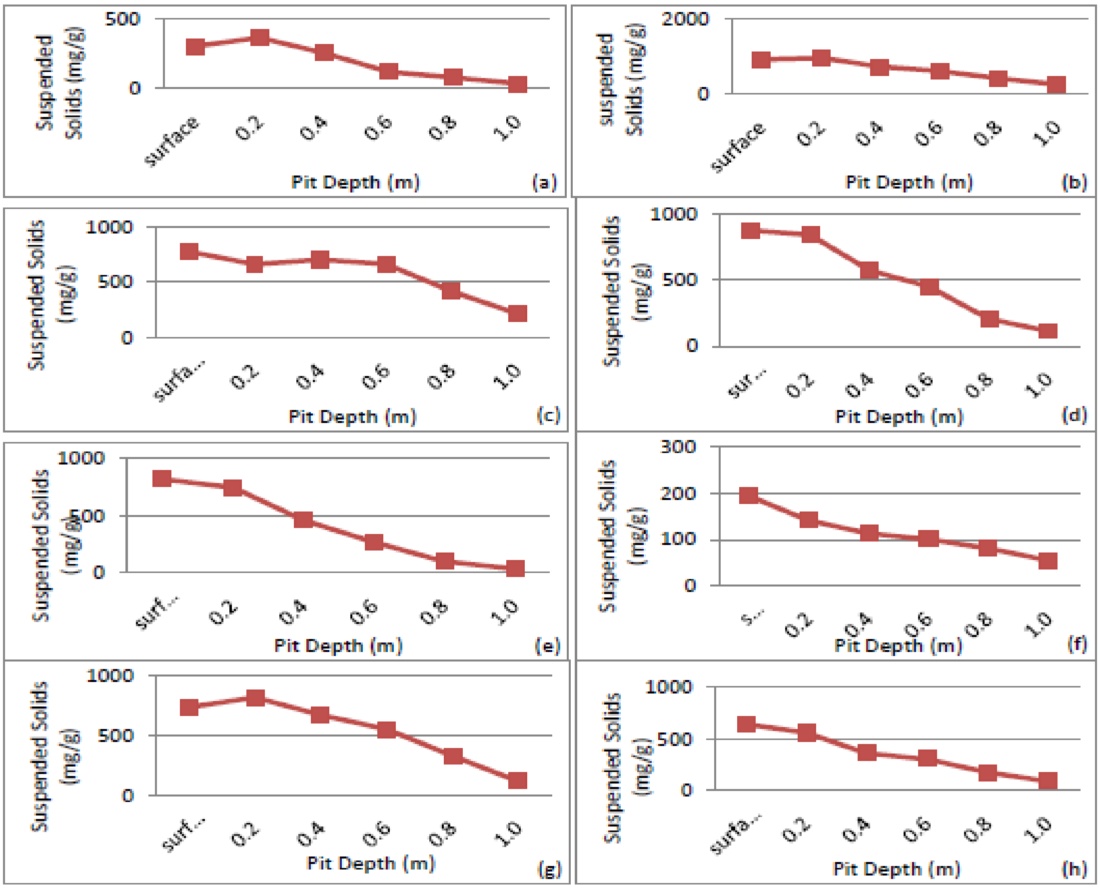
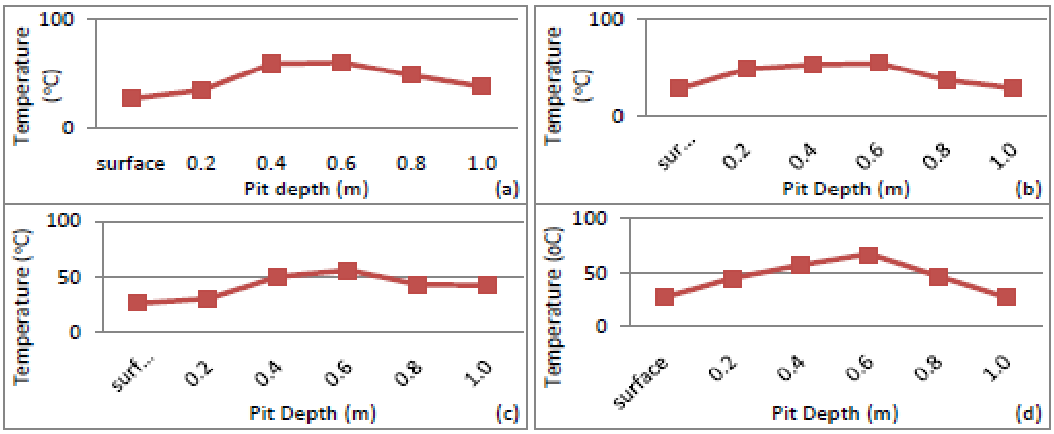


Figure 6: Variation of Suspended Solids with Pit Depth for Pits (a) - (h) for the 8 pits.

4.7 Variation of temperature with pit depth

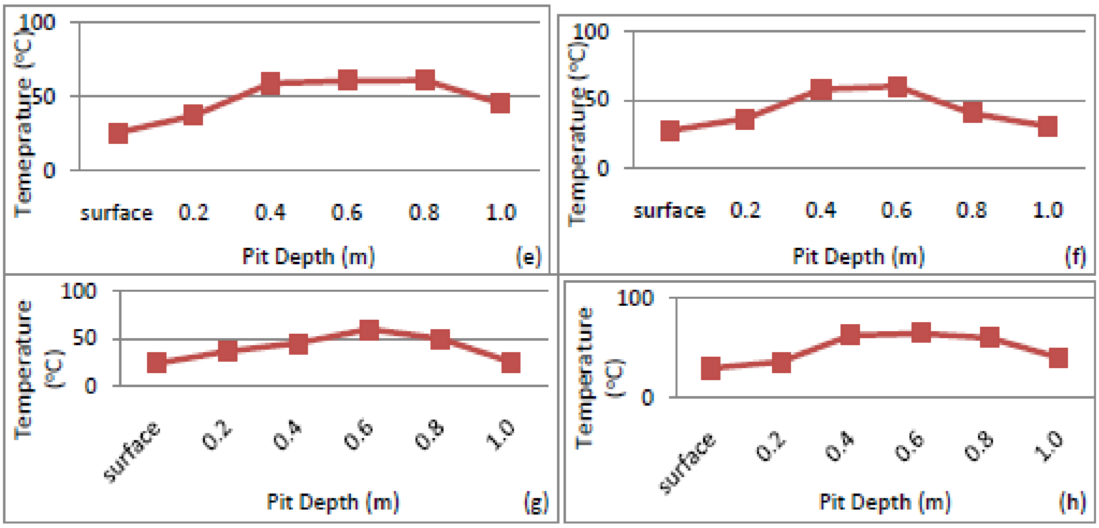
Figures 7 showed that the temperature presented double scenarios of increased initially and decreasing afterwards in all the pit latrines sampled as a result of biodegradation changing from aerobic to anaerobic with continued decomposition process. There could be possible increase in microbial activity from the surface to the methanogenic stage with methane gas resulting in temperature rise. Thereafter, the level decreased as the faecal sludge gradually stabilized. From the laboratory analyses, the temperature was highest within 0.4m and 0.6m layers of the pit in most cases suggesting methanogenic region where methane was being produced.

In this study, the highest temperature range was in Pit 4 (Figure 7d) from 27°C – 67°C with the lowest in Pit 1 (Figure 7a) from 27°C – 38°C. This is within the thermophilic range established by Lo.K et al (1985) who found a temperature range from 55°C – 65°C in his study. Rise in temperature between layers 0.4m and 0.6m, as recorded in all the pits (Figures 7a-h of Pits 1-8) during faecal decomposition anaerobically destroyed the pathogens, making them safe for land conditioning.



Retrieval Number:100.1/ijee.A1803051121
DOI: 10.54105/ijee.A1803.051121
Journal Website: www.ijee.latticescipub.com

Published By:
Lattice Science Publication (LSP)



Figures 7: Variation of Temperature with Pit Depth for Pits (a) - (h) for the 8 pits.

4.8 Reasons for the variability of data obtained

Household habits associated with toilet usage influenced the variability of faecal sludge in the pit latrines. The total solids concentration was dependent on factors such as the volume and nature of solid wastes dumped into the pit, the type of food consumed by households, characteristics of the faecal sludge including the amount of nutrients contained therein and microbial activities, type and characteristics of the soils encountered, sampling method and testing procedures. Some of the pit latrines were put out of use about 3 months before sampling while some have filled up about 6 months earlier. Consequently, it was unlikely that equal aerobic and anaerobic degradation would have taken place in all the pits sampled. In some of the pits, the temperatures were below ambient while some were as much as 67ºC. Under these conditions, some pits would be more active than others. Due to the fact that the pits have been abandoned for some time, there was depletion in the moisture content and this might have affected biodegradation of the faecal sludge sampled. On the whole, the temperature, moisture condition, nutrient, soil type and characteristics, activation level and climatic conditions were some of the reasons for the variability of data obtained.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The physico-chemical and biological characteristics of faecal sludge sampled from ten (10) different pit latrines have been analyzed using standard laboratory method of analysis for such data.The laboratory investigation of the physico-chemical and biological characteristics and biodegradability measured in the 10 pit latrines faecal sludges sampled led to the following conclusions

- Depending on what was dumped into the pit latrine, the physical, chemical and biological properties of pit contents varied in this study;
- There was decrease in BOD, COD, total solids, volatile solids, moisture contents and suspended solids with increase in pit depth. Significant differences existed among faecal sludge samples of the same pit as well as samples from the 10 pits;
- Temperature measured increased initially and decreased thereafter with increase in depth of the pit contents throughout this study;
- The major limitations in this study related to the heterogeneous nature of faecal sludge samples collected from the different pits.

5.2 Recommendations

The following recommendations, arising from the outcome of this study, were made:

- Biodegradability of faecal sludge in terms of COD and volatile solid measurements as obtained in this study should be compared with biodegradability analysis in terms of methane (CH_4) production for a more reliable result as the two can be used to measure the biodegradable organic content of a material as well as potential changes that have occurred in the organic content of material over time;
- In order to improve user-behaviour, users should be educated on proper waste management system so that they will not dispose off their solid wastes into pit latrines.
- This study of the physical and chemical composition and biological characteristics of faecal sludge in pit latrines should be considered pilot with more studies for confirmation of data obtained.

REFERENCES

1. ALPHA (1998) Standard Methods for the Examination of Water and Wastewater. 20th Edition. American Public Health Association
2. Almeida, M.C; Butler, D and Friedler, E. (1999). At- Source Domestic Wastewater Quality. J. Urban Water. Vol.1 pp 49-45. [CrossRef]
3. Bhagwan J.N, Still D, Buckley C, Foxon K. (2008). Challenges with Up-Scaling Dry Sanitation. Technologies. Water Sci Technol. 58(1) ; 21-27 [CrossRef]
4. Bitton G,ed.(1994). Wastewater Microbiology. New York: Wiley-Liss Publishers.
5. Buckley C, Foxon K, Brouckaert C, et al (2008). Scientific Support for the Design and Operation of Ventilated Improved pit latrines (VIPs) and the Efficacy of Pit latrine Additives. KwaZulu-Natal: Pollution Research Group School of Chemical Engineering University of KwaZulu-Natal.

6. Foxon K, Buckley C.A, Broukaert C and Babatunde Bakare (2008). How fast do pits and septic tanks fill up. Implications for design and maintenance. Pollution Research Group, Department of Chemical Engineering, University of KwaZulu-Natal, Durban 404
7. Foxon, K., Still, D. (2014). Do pit additives work? Water Research Commission (WRC), University of KwaZulu-Natal, Partners in Development (PiD), South Africa
8. Lay, J., Li, Y and Noike, T. (1997). "Influences of pH and moisture content on the
methane production in high-solids sludge digestion." Water Research 31(6), 1518-1524.
9. Lettinga G.(1995). Anaerobic Digestion and Wastewater Treatment Systems. Antonie Van Leeuwenhoek: 67(1); 3-28. [CrossRef]
10. Lo.K, Liao P, March A. (1985). Thermophilic Anaerobic Digestion of Screened Diary Manure.Bioamass. ;6: 301-315 [CrossRef]
11. Lopez Zavala, M.A; Funamizu, N and Takakuwa, T. (2002). Characterization of [CrossRef]
Faeces for Describing the Aerobic Biodegradation of Faeces.J. Environ.Syst.and
Eng. JSCE 720/VII-25 pp.99-105[CrossRef]
12. Lopez Zavala, M.A; Funamizu, N and Takakuwa, T. (2004). Temperature Effect on Aerobic Biodegradation of Faeces Using sawdust as a Matrix. Water Research 38 0043-1354 pp.2405-2416. [CrossRef]
13. Muyima N, Momba MNB, Cloete TE, eds.(1997). Biological Methods for the Treatment of Wastewaters. England: In Cloete TEAM, N.Y.O. Microbial Community, Systems ATKttDoBWT,eds. IWAQ Scientific and Technical Report No. 5.International Association on Water Quality.
14. Nwaneri, C.F (2008).Biological Degradation Processes Within A Pit Latrine Pollution Research Group, Department of Biological and Conservation Sciences, University of KwaZulu-Natal, Durban 4041.
15. Pohland F.G, Ghosh S. (1971). Developments in anaerobic stabilization of organic wastes of the two-phase concept. Environ. Lett;1(4); 255 – 266. Population. Appl Microbiol Biotechnol. Oct.; 59 (4): 495 – 501. [CrossRef]
16. Sekiguchi Y, Kamagata Y, Harada H.(2001). Recent Advances in Methane Fermentation Technology. Curr Opin Biotechnol. June; 12(3); 277-282. [CrossRef]