JJBS

Volume 9, Number 4,December .2016
ISSN 1995-6673
Pages 243 - 248

Jordan Journal of Biological Sciences

Effect of Thermal Treatment on Microbial load of Faecal Sludge From Some Faecal Sludge Collection Sites in Oyo State, South Western, Nigeria

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Received September 29, 2016 Revised November 14, 2016 Accepted November 18, 2016

Abstract

Faecal sludge which is usually highly laden with pathogenic microorganisms serves as a route of disease transmission especially when used as organic amendment or when it contaminates water sources. Therefore, the present study investigates the effect of thermal treatment on the microbial load of faecal sludge. Faecal sludge samples were collected from two major faecal collection points in Ibadan metropolis, the samples were subjected to chemical (proximate minerals and heavy metals) and microbiological (bacteriological, mycological and parasitological) analysis before and after thermal treatment. The chemical analysis of the faecal sludge samples before and after treatment revealed the presence of heavy metals such as lead, chromium and zinc among others; proximate matter, such as protein, fat and fibre, and minerals contents such as sodium and potassium. Microbiological examination before treatment revealed that the faecal sludge samples had a high microbial load of species such as *Bacillus, Salmonella, Aspergillus* among others and ova of *Ascaris*. However, after the thermal treatment of the faecal sludge samples, it was observed that the microbial load was reduced as only spore forming organisms such as *Bacillus* and *Aspergillus* could be observed. It was observed that most organisms present in faecal sludge were removed as a result of thermal treatment; this implies that faecal sludge can be made safe for use in agricultural practices by application of thermal treatment. The present study shows the efficacy of thermal treatment in reducing the microbial load of faecal sludge, thereby increasing its chances of been used as organic amendment in agricultural practices.

Keywords: Heavy Metals, Proximate Minerals, Bacteriological, Mycological, Parasitological.

1. Introduction

According to Klingel *et al*. (2002), faecal sludge is made up of sludge of various consistencies accumulating in and evacuated from so-called on-site sanitation systems, such as septic tanks, aqua privies, family latrines and un-sewered public toilets by vacuum trucks. In most cities, faecal sludge collection and haulage are faced with great challenges, such as emptying vehicles having no access to pits, traffic congestion which prevents efficient emptying and haulage, and often times emptying services are poorly managed.

Faecal sludge is a highly variable organic material with considerable levels of grease, grit, hair and debris. In addition to its variable nature, faecal sludge tends to foam upon agitation, resists settling and dewatering and serves as a host for many disease-causing viruses, bacteria, and parasites (USEPA, 1999). The concentrations of helminth eggs, ammonium, organic compounds and solids in faecal sludge are typically higher by a factor of ten or more than that obtainable in wastewater (Montangero and Strauss, 2002). Major components of faecal sludge include grease, kitchen/solid waste and various materials which have the potential to cause groundwater intrusion. However, the physical characteristics of faecal sludge vary significantly due to factors, such as climate, tank emptying technology and pattern, storage duration (months to years), performance of tank, among others (Montangero and Strauss, 2002).

Faecal sludge management is the collection, transport and disposal/reuse of fresh faecal material (night soil) or digested faecal material (faecal sludge) from non-sewered sanitation facilities, such as latrines and septic tanks. It is a notoriously difficult aspect of sanitation in low-income urban communities, where pits and septic tanks are typically emptied by manual operators without proper hygienic protection, and the sludge is

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dumped haphazardly in the local environment (for example in open drains) (Misaki and Matsui, 1996).

According to Vision 21 of the Water Supply and Sanitation Collaborative Council (WSSCC), sanitation is a basic human right, and one of the major components of poverty eradication (WSSCC, 2000). Globally, at least 2.6 billion people lack access to basic sanitation and the most affected population are those in Africa and Asia continents (WHO, 2004a). More than 90% of the sewage generated in developing countries is discharged untreated (Esrey, 2001; Langergraber and Muellegger, 2005). Consequently, around the world, there is a drive to ensure the provision of proper sanitation and access to clean water supply. In line with this, the Millennium Development Goal (MDG) 7 aims at halving the proportion of the world's population without safe drinking water and basic sanitation between 1990 and 2015 (UN, 2002, Eales, 2005). There have been various documentations on the importance of improved sanitation in safeguarding the health and well being of humans (WHO, 2001; Cairncross, 2003; WHO, 2004a; Moe and Rheingans, 2006). According to Kulabako *et al*. (2007), in societies where sanitation is lacking, human excreta may accumulate around homes, in nearby drains and in garbage dumps, leading to environmental pollution, whereas in some societies where conventional sanitation systems are in use, insufficiently treated excreta from latrines and wastewater systems often end up in deep pits and recipient waters. One way to decrease the environmental pollution in residential areas, as well as in recipient surface waters and groundwater, and thereby decrease the negative impacts of untreated excreta on society is to use the nutrients present in the excreta for plant production (Vinnerås and Jönsson, 2002). The use of excreta-based nutrients closes the nutrient loop, thereby enabling an increase in the sustainability due to recycling of renewable nutrient content (WHO, 2006). The safe use of excreta nutrients can be simplified by collecting the excreta fractions separately, treating them and applying them in plant production. A major challenge in the utilisation of excreta-derived nutrients is that they may contain pathogenic microorganisms, which can be a route of disease transmission that needs to be properly managed. Most of the pathogens of concern are excreted in large concentrations via faeces (WHO, 2006) and only a few of them via urine (Höglund et al., 1998). Fresh faeces are always considered unsafe due to the potential presence of high concentrations of pathogens (Feachem *et al*., 1983; WHO, 2006). Therefore, both faeces and urine need to be sanitised in order to safely recycle their nutrient content to production of food (Schönning and Stenström, 2004; WHO, 2006). Various techniques used for treatment and sanitation of faecal sludge include storage, composting, incineration and chemical treatment (Schönning and Stenström, 2004; Austin and Cloete, 2008; Jönsson et al., 2004; Nordin et al., 2009a,b). The present study is therefore designed to study the effect of thermal treatment on the microbial load of faecal sludge collected from two feacal sludge dumping site in Ibadan metropolis, Oyo State, South western Nigeria.

2. Materials and Method

Sample Collection

Composite faecal sludge samples were collected from two different sources in a sterile polythene bag and transported immediately to the laboratory. Sample A was collected from a faecal sludge dump site in Omi Adio, Ido Local Government Area of Oyo State while sample B was collected from the sewage facility of the University College Hospital (UCH), which is located in Ibadan North Local Government Area of Oyo State located in South-western, Nigeria.

Physico-Chemical Analysis of the Faecal Sludge Samples

Physico-chemical analysis was carried out on the faecal sludge samples before and after the thermal treatment to determine the following: concentration of heavy metals, such as lead, chromium, zinc, nickel and manganese present in the sludge. The concentration of the heavy metals was determined by digesting the samples and analysing the digested samples using Buck Scientific 210/211 VGP Atomic Absorption Spectrophotometer (AAS) (APHA, 1992). Concentration of proximate matter such as percentage fat, percentage fibre, percentage ash; mineral content, such as nitrogen, carbon, calcium, magnesium, average phosphorus, sodium, potassium, and physical properties, such as pH, percentage sand, percentage silt, percentage clay, were determined using standard methods as described by AOAC (2012).

Microbiological Analysis

Bacteriological, mycological and parasitological analyses were conducted on the faecal sludge samples before and after thermal treatment. Culture media, such as Pseudomonas Centrimide Agar (PCA), Eosin Methylene Blue agar (EMB), Salmonella-Shigella agar (SSA), Manitol Salt Agar (MSA) and Nutrient Agar (NA), were used for the bacteriological examination of the faecal sludge samples. Pure cultures of the bacterial isolates obtained were Gram stained and subjected to various biochemical tests, such as catalase test, oxidase test, starch hydrolysis test, citrate utilization test, indole test, methyl red test, oxidative fermentation test etc. after which they identified using Cowan and Steel (1993) and Holt *et al*. (2000).

Potato Dextrose Agar (PDA) was used for the mycological examination of faecal sludge samples. Pure cultures of the fungal isolates were identified by staining them with lacto-phenol cotton blue and were viewed under the microscope. Images observed under the microscope were compared to those in a compendium (Domsch *et al*., 1980).

Parasitological analysis was carried out to concentrate the eggs of parasites present in the faecal sludge samples using the formol-ether concentration technique as described by Cheesbrough (2009).

Thermal Treatment of Faecal Sludge Samples

Five kilograms of the faecal sludge collected from each source was put in a clean sterile crucible and oven-dried at standard temperature of 100oC for 1 hour.

3. Results

Physico-Chemical Analysis of the Faecal Sludge

Table 1 shows the result obtained for the physico-chemical analysis of the faecal sludge samples before and after thermal treatment. For the pre-treatment analysis, it was observed that the faecal sludge collected from Ibadan North Local Government had a higher concentration of heavy metals, proximate matter and mineral contents present in it than the faecal sludge collected from the sewage facility of UCH. Though there was a reduction in the quantity of heavy metals, proximate matter and mineral contents present in the faecal sludge samples from both Ibadan North Local Government and UCH sewage facility after the treatment exercise, it was however observed that faecal sludge samples collected from Ibadan North Local Government still had a higher concentration of heavy metals and proximate mineral contents present in it than the faecal sludge samples collected from UCH sewage facility.

Table 1: **Physico-chemical properties of the faecal sludge samples**

Physical parameters	Before treatment		After treatment	
	A	**B**	A	B
pH	6.6	6.76	6.88	7.13
% Sand	80.96	84.96	78.21	82.87
% Silt	8.77	7.24	7.10	6.18
% Clay	7.9	7.8	9.80	10.95
Heavy metals				
Lead	25.7	13.2	18.6	11.9
Chromium	44.2	18.4	37.3	16.8
Zinc	96.3	31.28	84.5	26.74
Nickel	56.3	8.3	47.8	6.5
Copper	14.2	7.6	43.8	11.9
Manganese	61.2	47.36	53.6	43.29
Mineral content				
% Organic Carbon	36.79	26.7	31.38	19.75
% Nitrogen	3.18	3.75	2.69	2.86
Average Phosphorus	1126	987	993	886
% Calcium	1.23	2.4	0.79	1.34
% Sodium	0.31	0.18	0.24	0.25
% Magnesium	0.29	0.64	0.21	0.75
% Potassium	0.78	0.43	0.65	0.51
Proximate matter				
% Crude protein	18.38	12.60	12.76	9.67
% Crude fat	2.94	1.80	3.11	2.10
% Crude fibre	31.86	25.44	25.91	18.11
% Ash	6.28	3.33	7.13	2.43

Key: A- Faecal sludge sample from Ibadan North LG

B- Faecal sludge sample from UCH sewage facility

When microbiological analysis was carried out on the faecal sludge samples before thermal treatment using different agar media, it was observed that faecal sludge samples collected from Ibadan Local Government had higher microbial load compared to the faecal sludge samples collected from UCH sewage facility as seen in Figure 1. Fifty-eight bacterial and twenty fungal isolates were obtained from the untreated faecal sludge samples, parasitological examination revealed dominance of *Ascaris* spp ova in the two samples.

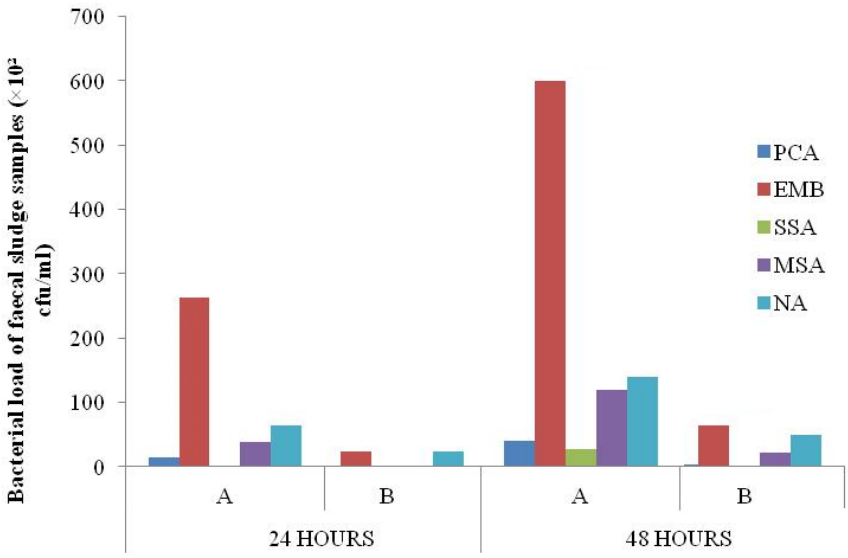

Figure 1. Growth of bacteria on different media

Key : PCA-Psendomonas centrimide agar; EMP-Ension methulene blue agar; SSA-Samlonella-Shigela Agar; MSA-Manitol salt agar.

Biochemical characterization of the bacterial isolates revealed that that the organisms belong to *Bacillus* sp (15), *E. coli* (6), *Enterobacter* sp (10), *Pseudomonas* sp (12), *Salmonella* sp (5) and *Staphlococcus* sp (10). When the fungal isolates were stained and viewed under the 40× objective lens and compared to the Compendium of soil fungi, it was discovered that they were all *Aspergillus* sp viz: *Asspergillus niger, A. flavus* and *A. fumigatus.* Figures 2 and 3 show the frequency of occurrence of the bacterial and fungal isolates in the faecal sludge samples collected before thermal treatment. It was observed that *Bacillus* sp had the highest frequency of occurrence among the bacterial isolates while *Aspergillus niger* had the highest frequency of occurrence among the fungal isolates.

No microbial growth was observed on the selective media (PCA, EMB, SSA and MSA) used for culturing the treated faecal sludge samples however some bacteria were observed to grow on nutrient agar medium. When the bacteria were characterized, they were discovered to be predominantly Bacillus sp.

Mycological analysis of the treated faecal sludge samples revealed that the treated faecal sludge samples still had some fungal load but was reduced compared to the initial fungal load and the fungi were all Aspergillus sp.

Parasitological examination of the treated faecal sludge samples revealed no eggs of parasites in the treated faecal sludge samples.

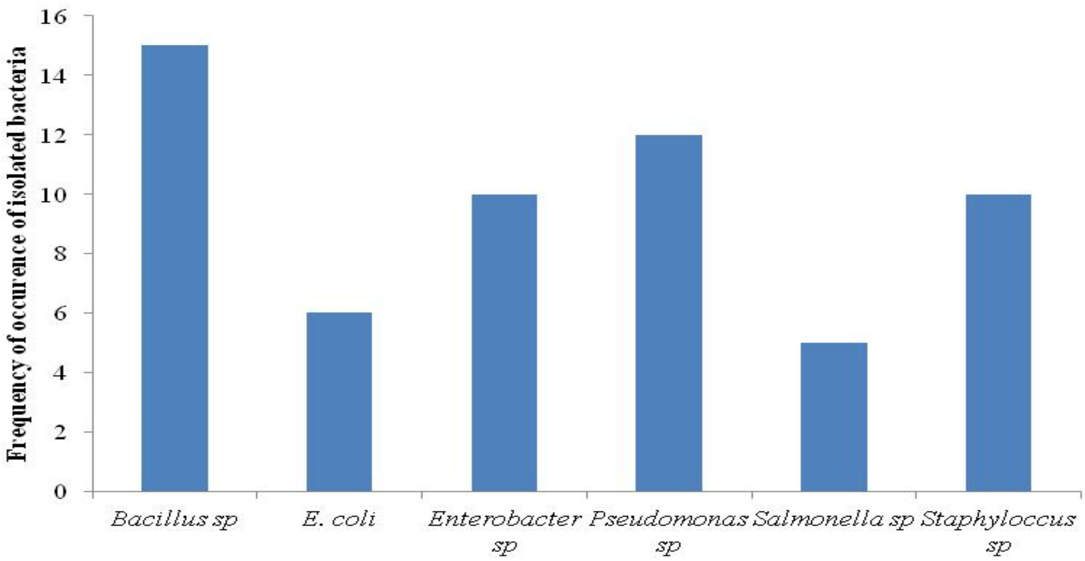

Figure 2. Frequency of occurrence of bacterial isolates from untreated faecal sludge samples

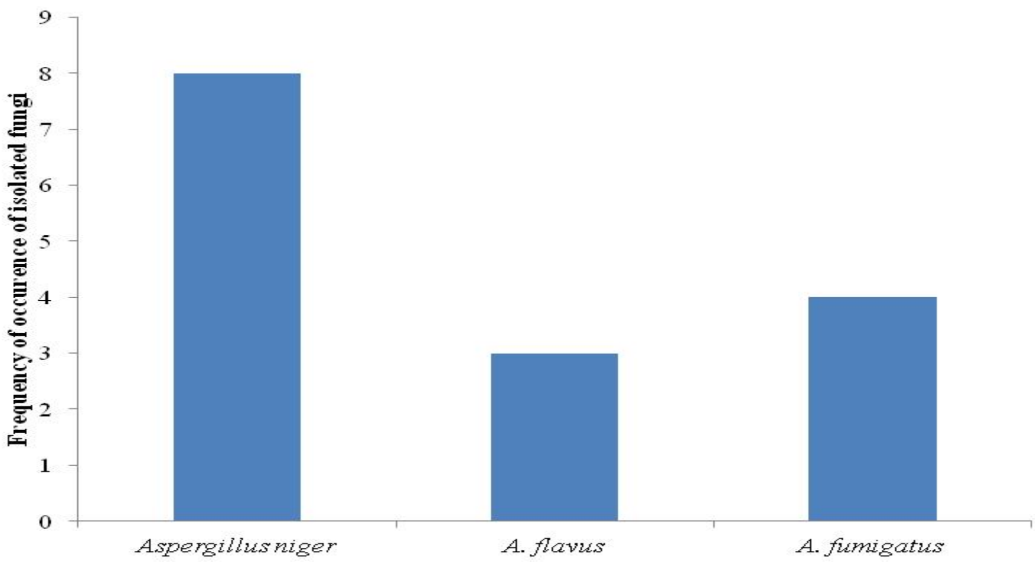

Figure 3. Frequency of occurrence of fungal isolates from untreated faecal sludge samples

4. Discussion

Faecal sludge collected from various points were usually dumped in a dug hole and covered with chemicals, such as izal and kerosene (Ayeni, 2012), though there were some desludgers which empty the faecal sludge into rivers or water bodies, this however is illegal. According to Ayeni (2012), some farmers usually request for faecal sludge to be used on their farms and this is often sold to them either in the raw form, i.e., directly from the emptied soakaways or after it had been dumped in holes; this is a way of turning waste into wealth.

Upon collection of the faecal sludge samples for the study, it was observed that the samples were moist and had varying characteristics; this was supported by an earlier studies by Pescod (1971), Pradt (1971), Um and Kim (1986), Guo *et al.* (1991) and Strauss *et al.* (1997), in which it was noted that the characteristics of collected faecal sludges varied greatly. The characteristics depend, to mention some, on the season, type of the on-site sanitation system (e.g., water closet/septic tank system, "dry" aqua privy, watertight vented pit latrines), the emptying frequency (i.e., the retention time in the facility), the extent of storm water or groundwater infiltration into the sanitation facility and also the users habits.

The treatment methods used in the treatment of faecal sludge by UCH and the municipal desludgers differs, UCH sewage treatment was done using decomposition method while that of the municipal desludgers was done through sun drying. The faecal sludge sample collected from UCH had less microbial load and heavy metal concentration compared to that from the municipal desludgers, this therefore indicates that decomposition might be a better treatment option for faecal sludge than sun drying methods.

During the microbiological examination of the untreated faecal sludge samples, organisms isolated include some bacteria, such as *Bacillus sp*, *E. coli*, *Enterobacter sp*, *Pseudomonas sp*, *Salmonella sp* and *Staphylococcus sp*; the fungi isolated all belong to the *Aspergillus* genera, such as *A. niger*, *A. flavus* and *A. fumigatus.* Also ova of worms especially the *Ascaris* sp were present in the faecal sludge samples. Most of these organisms are commonly found in fresh faeces indicating that microorganisms that can be found in fresh excreta can be invariably found in faecal sludge samples in agreement with earlier studies carried out by Schönning and Stenström (2004).

The chemical analysis of the untreated faecal sludge samples revealed the presence of mineral matter, such as nitrogen, phosphorus, sodium, magnesium, calcium etc. in varying concentrations. Also, heavy metals, such as lead, chromium, zinc, nickel, copper and manganese, were seen to be present in the faecal sludge samples. According to Pehlivan *et al.* (2009), toxic heavy metals, such as lead, cobalt and cadmium, are capable of causing various diseases and disorders even in relatively lower concentrations in living organisms. Heavy metals, with soil residence times of thousands of years, pose numerous health dangers to higher organisms. They are also known to have an effect on plant growth, ground cover and have a negative impact on soil microflora, since some farmers utilize faecal sludge as organic amendment (Roy *et al.*, 2005).

Faecal sludge samples were subjected to thermal treatment using 100^{o}C for one hour. All pathogens had threshold temperatures beyond which their viability ceases (Madigan and Martinko, 2006). The mechanism of temperature inactivation differs for different types of pathogens. Elevated temperatures irreversibly inactivate enzymes of bacteria, protozoa and helminths, thereby resulting in cellular inactivation (Madigan and Martinko, 2006; Wichuk and McCartney, 2007). The degree of thermal inactivation of pathogens is a function of both the temperature and time of exposure (Feachem *et al*., 1983; de Bertoldi, 1998; Wichuk and McCartney, 2007). It was observed that there was a reduction in the microbial load of the faecal sludge samples as there were no growth on most of the agars used except a minimal one on nutrient agar and potato dextrose agar. There was also a reduction in the concentration of the heavy metals, proximate matter and mineral content in the faecal sludge samples after treatment even when the treatment temperature was far less than the boiling points of these metals. Hence, it must be that these heavy metals are of organic origin, thus they were volatile and escaped with the organic component of the faecal sludge samples.

In conclusion, the major challenge combating the use of faecal sludge for agricultural purpose is that they may contain pathogenic microorganisms, which can be a route of disease transmission. The present study has shown that thermal treatment can reduce the microbial load and in faecal sludge. Hence ensuring the safe use of excreta nutrients for agricultural purposes as well as serving as a means of recycling waste (faecal sludge) to wealth.

Conflict of Interest

There is no conflict of interest.

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