Heavy Metals Sludge from Septic Tank Sewage: Implication for Use as Fertilizer

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Abstract: Sludge contains nutrients, heavy metals, and metalloids some of which are essential macronutrients, such as N, P, K, Ca, Mn and other essential trace elements, such as Cu, Fe and Zn. This paper examines the heavy metals within the septic tank system and their eventual accumulation as components of sludge with implication for agricultural use. Sludge samples from the inlet and outlet chambers of the septic tank were randomly collected from three study locations in the south-south region of Nigeria. The composite samples were made for each of these study locations from which nine trace metals (Fe, Zn, Mn, Pb, Cu, Cr, Cd, Ni and Va) were analysed. The concentrations of the metals were determined using standard methods for water and wastewater examination. Results showed that sludge samples from the anaerobic bioreactors contained a high concentration of various trace metals. Iron had the highest mean concentration level of 556 ± 0.2 mg/kg – 3391 ± 1.13 in the raw sewage sludge sample, while vanadium was the least in abundance with mean concentrations of 0.86, 0.77, and 1.52 mg/kg in locations A, B and C respectively in the inlet chamber sludge samples. Although, sludge is variously used for agricultural purpose, there is need for treatment to reduce the concentration levels of heavy metals prior to its use as fertilizer as a matter of public health importance.

Key word: Fertilizer, food chain, heavy metals, septic tank, sewage sludge

INTRODUCTION

Heavy metals are elements whose densities are high typically above 5 g/cm^3 (Hawkes, 1997; Chu, 2018; Ali *et al.*, 2019; Briffa *et al.*, 2020; Sayo *et al.*, 2020). Examples of heavy metal elements include lead, zinc, chromium, cadmium, arsenic, mercury, vanadium, manganese, and iron. These metals are found in the environment from geogenic and anthropogenic sources (Tchounwou *et al.*, 2012; Ibrahim and Ibrahim, 2016). The metals exist in the air, surface and groundwater, and soil. Thus, can be transported through the soil to plants and up the food chain to man (Nkwunonwo *et al.*, 2020), as well as through air and water pollution. Man is the major receiver of these metals in the environment from the uptake of these heavy metals through plants, surface and groundwater, and airborne pollutants (He *et al.*, 2005; Usman *et al.*, 2020). This makes man a veritable bio-accumulator of these heavy metals which eventually arrive at the septic tank.

Septic tanks are digestion chambers where anaerobic bacteria breakdown organic matter from human domestic activities is treated in a two-step process effected by acid- and methane-forming microorganisms (Abatenh *et al.*, 2017). The process of microbial remediation of heavy metals in the sewage of septic tank systems is dependent on the pH of the system (Ademoroti, 1996; Abatenh *et al.*, 2017). This therefore, determines the threshold and balance of equilibrium between acid-loving bacteria (acidophiles) and bacteria that thrive in alkaline environment (methanogens). Bio-precipitation of trace metals onto cell surfaces by microbes is favoured by acidic conditions (Ademoroti, 1996; Canovas *et al.*, 2003; Jin *et al.*, 2004; Yuncu *et al.*, 2006; Hassan *et al.*, 2009; Igiri *et al.*, 2018; Osman *et al.*, 2019; Rose *et al.*, 2019; Delangiz *et al.*, 2020;). By convention, septic tank systems are designed to have two chambers; that is, the raw (inlet) chamber and the semi-treated (outlet) chamber. Hence, the components of the septic tank be classified into suspended solids, effluent and sludge.

For septic tank to work optimally, it should be evacuated every 3 to 5 years, however, inspection should be conducted biannually to confirm that the system is working optimally, and that there are no leaks. It is also necessary to check that the levels of sludge and scum in the tank has not risen drastically (USEPA, 1997) that would necessitate evacuation should it exceed 25 percent of the working liquid capacity of the tank or the level of the layer of scum is within three inches of the bottom of the outlet baffle (USEPA, 1994). These situations make the sludge readily available for utilization for agricultural purpose as organic fertilizers.

Sludge is the visco-solid component of sewage which is about 57.0 per cent water (Ademoroti, 1996). The precipitation of both the solvated and insoluble substances leads to the development of sludge (Diep *et al.*, 2018; Zhang *et al.*, 2021). Sludge is composed of proteins, carbohydrates, pathogens and heavy metals (Zhang *et al.*, 2021). Even though sewage sludge contain a deluge of plant nutrients, the heavy metals content can be a problem (Oudeh, 2002). Therefore, there is a need to treat accumulated sludge in a wastewater before safe disposal especially into water bodies, which is usually the practice. The essence of treating sludge is to reduce the amount of organic matter, potentially toxic heavy metals and the population of disease-causing microorganisms. The most common treatment options include anaerobic digestion. Others, include aerobic digestion and composting. Treated sludge can be disposed off or utilized as fertilizers for agricultural land, providing cheap manure for farmers (El sokkarry, 1993). Waste water sludge is a useful source of nitrogen, phosphorus and organic matter. However, there are limits to what can be applied. For example application of waste water sludge should not exceed 250 kg nitrogen per hectare per annum, particular within nitrate vulnerable zones (EEC, 1986; USEPA, 1997).

Fertilizers are substances which are formulated to aid plant growth, where the normal soil may lack sufficient nutrient to support plants growth and development. Application of inorganic fertilizer to crops has become difficult owing to its expensive nature and sometimes unavailability. Sludge therefore, provides cheap and readily available means of supplying essential nutrients to plants – Green Science. However, as beneficial as the use of sludge as fertilizer is, the process is frost with some misgivings as waste water sludge contains large concentration of heavy metal than that present in most soils (Gomez-Canela *et al.*, 2012). Once applied, the heavy metals will accumulate in the top soil until it is picked up by plants.

However, the case is being made by green environmentalists for organic fertilizers to make up the heavier source of fertilizers use by farmers. Reasons given for this include, the advantage organic fertilizers have in terms of their composition apart from it having a natural source. Manure as organic fertilizers as often called, possess minerals, organic matter, moisture content, and microbes, some of which could be beneficial to the soil and plant eventually, unlike the inorganic fertilizers whose components are hewn out of source rocks and lack the same compositions as organic fertilizers (Zhou *et al*., 2022). In spite of the fact that during the formation of manures by microbes, methane gas (a greenhouse gas) is formed which adds to the burden of global greenhouse atmospheric load, manure from septic tanks – a pH controlled anaerobic digester can mitigate this problem (Oyem *et al*., 2022), while providing plant with the requisite nutrients via sludge. This paper focused on ascertaining the levels of heavy metals present in septic tank sludge and the implications of using sludge as fertilizers.

MATERIALS AND METHODS

Sample area: Sludge samples for analysis were collected from different septic tanks in three locations in Agbor in Delta State, Nigeria. Agbor has a population of 162,594 (National Bureau of Statistics, 1977), with an area covering 436 sq. kilometres.

Sample collection: Sludge samples from septic tank sewage were collected from three locations in Agbor in 1 L plastic bottles. Samples were immediately taken to the laboratory in cool ice packs. Samples were then made into a composite sample for analyses using the APHA (1995) method of wastewater analysis.

Heavy metal analyses: Heavy metals ions present in the sample were analysed using Atomic Absorption Spectrometry (AAS) instrument, model EDX 800, manufactured in Japan. The source of radiation used was a Hallow lamp which emitted the wavelength characteristics of the metal, using a different lamp source for each metal and directed through a flame into a monochromator that selected the preferred wavelength. A photomultiplier tube was the detector and converted the incident signal into an electric signal. The metals were identified at varying wavelengths and current. In all, nine (9) heavy metal ions were analysed and values obtained were recorded.

RESULTS AND DISCUSSION

Iron recorded the highest concentration of 1410 mg/kg and 615 mg/kg in both the inlet and outlet chambers of the septic tanks sampled in the immediate locality. This would be expected for a region known for its high Fe content from its geology (Avwunudiogba, 2000). The soil is characteristically reddish brown in colour and clearly depicts high iron content. One would therefore expect a high Fe content in this environment, especially in the plants cultivated on this soil and its groundwater. It is therefore not surprising that the difference between the Fe content and other heavy metal ions is significantly high.

Zinc had the second highest heavy metal content of the nine analysed in the sludge component of the study area after iron. Zinc is a trace metal needed in the body's biochemistry, it is necessary for certain important functions of the body (Roohani et al., 2013). Its presence in septic tank to this extent may not be associated entirely to diet and supplements but, also through groundwater (Oyem *et al*., 2015) from ancient corrugated zinc roofing sheets as well as zinc oxide in most ointments, creams, lotions, shampoos and antiseptics (NCBI, 2017). Decreased levels of Zn in the semi-treated sludge samples compared to the raw sewage samples was observed. These findings are in tandem with reports by Duan *et al*. (2017); Steinhardt and Egler (2018) and Agoro *et al*. (2020), who noted that sludge was a rich deposit of toxic metals and though were within normal range yet in agricultural soils may be a potential risk for human safety.

Manganese concentration in sludge sample analysed was 45.8 mg/kg in the inlet chamber and 17.3 mg/kg in the outlet chamber. These values were the third highest in the study's findings, translating to a significant proportion of the heavy metal load in the environment, a similar pattern was observed as in Zinc.

The sludge sample in the inlet chambers had Cu levels of 13.2 mg/kg and 5.38 mg/kg in the outlet chamber. The Cu is a component of some enzymes in the body besides being ubiquitous as component of many electrical appliances (Mydy *et al*., 2021). Although, naturally a trace metal, its presence in sludge to this concentration is telling and significant.

Chromium in this study represented as total chromium had a slightly significant value of 1.50 mg/kg and 1.20 mg/kg in both chambers of the septic tanks respectively. Chromium in the environment is treated with concern because of it deleterious effect on health (Oyem *et al*., 2014; Georgaki and Charalambous, 2022). Although, the values recorded in this study is benign, it is nonetheless considerable.

The concentration of cadmium in the study for the inlet and outlet chambers were 0.02 mg/kg and 0.01 mg/kg. Cadmium presence is often associated with man's industrial activities, and so in areas were Cd concentration is significant, anthropological sources are readily adduced (Singh and Liu, 2024). In this study, Cd concentration is not significant, and this signifies non-industrial activities in the area.

In the inlet chambers' sludge samples ranged from 0.35 to 0.90 mg/kg in the septic tank sewage in the area. Again, these values are low and do not depict pollution of the area arising from industrial activities (Jakubus and Graczyk, 2020).

In sludge sample Pb concentrations were slightly significant but, not suggestive of serious pollution. The Pb toxicity is treated with serious concern because of its effect on humans. The Pb causes a damage to the central nervous system (WHO, 2023). Therefore, Pb values of 0.90 and 0.50 mg/kg in the inlet and outlet chambers is of slight concern.

Vanadium was the least abundant heavy metal analysed in this study. Vanadium is present in the inlet sludge samples in concentrations of 0.50 mg/kg and 0.30 mg/kg in the study. Vanadium in this area can be traced to the activities of auto mechanics which are present in the area (Wnuk, 2023).

The main risk related to agricultural use of sewage sludge are the potential presence of heavy metals, pathogens and pollutants enrichment in soil, plants and animal pastures and the subsequent entry into the food chain (Ternes *et al*., 2004 and Gomez-Canela *et al.,* 2012).

Heavy metals, pathogens and organic pollutants can also affect soil functioning and biodiversity (Harrison *et al*., 2006 and Roig *et al*., 2012). According to literature, low application doses of sludge did not cause a significant increase in the heavy metal concentration in soil (Singh and Agrawal, 2008). On the contrary, low metal sludge has beneficial effect on microbial biomass, organic carbon and on soil microbial activity (Usman *et al*., 2012). Excessive application of sewage sludge to soil has been found to increase the bioavailability of heavy metals that have a negative effect on soil (Singh and Agrawal, 2008 and Usman *et al*., 2012). However, the option of heavy metal removal using genetically engineered microorganisms has been explored in a recent study (Diep *et al*., 2018).

Table 1: Heavy metals concentrations (mg/kg) in both chambers of the septic tanks in the study locations

S/N	Metal ion (Analyte)	Inlet chamber (mg/kg)	Outlet chamber (mg/kg)
1.	Fe	1410 ±0.20	615 ±2.00
2.	Zn	110 ±0.20	66.2 ±0.20
3.	Mn	45.8 ±0.20	17.3±0.10
4.	Cu	13.2 ±0.20	5.38 ±0.20
5.	Cr	1.50 ±0.02	1.20 ±0.02
6.	Cd	0.02 ±0.01	0.01±0.05
7.	Ni	0.90 ±0.20	0.35 ±0.01
8.	Pb	0.70 ±0.01	0.50 ±0.02
9.	V	0.50 ±0.02	0.30 ±0.02

CONCLUSION

Heavy metals distribution in the sludge components of septic tank systems was studied to understand their composition within the system. Results showed that sludge samples from the anaerobic bioreactor contained a high concentration of various trace metals. This has high implications for the use of sludge as compost material in Agriculture. Although sewage sludge is a good source of nutrients for plant growth, the presence of heavy metals in sludge can reduce its use. However, the heavy metals found in this study are not those with great health implications. That notwithstanding, the need to ensure proper treatment of sludge prior to its use as fertilizer is a matter of public health importance.

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