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SUITABILITY OF BIOSOLID PRODUCED AT WUPA SEWAGE TREATMENT PLANT AS ALTERNATIVE TO ORGANIC FERTILIZER IN ABUJA, NIGERIA

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Abstract

This study assessed the suitability of biosolid produced at Wupa Sewage Treatment Plant as alternative to organic fertilizer in Abuja, Nigeria. Data was sourced from primary and secondary sources; primary sources were from the field and pictorial evidence while secondary sources were from published and unpublished materials such as journals, textbooks, research projects, among others. Two sludge samples were taken from the disposal dry bed about 10m apart using a stainless-steel trowel and 500ml glass beakers. Simple random sampling was used to select sixty-six respondents in the waste water treatment plant. The result shows that fresh sludge recorded highest value for Electrical Conductivity (EC) (560 µs/cm), organic content (41%), total nitrogen (4.69%) and total phosphorus (1.93g/kg), while dry sludge recorded highest value of pH (6.25), bulk density (1.80mg/m3), and water holding capacity (54.49%). The result show that only dry sludge recorded value (12cfu/g) for E. coli, Fresh sludge lacks salmonella and E. coli while dry sludge lack salmonella. The highest value for Cadmium (0.2310g/kg), Copper (1.2417g/kg), Iron (1.2184g/kg) and Lead (0.2800g/kg) was recorded on fresh sludge. Result shows that the value of Iron (1.22g/kg and 1.22 g/kg) and Lead (0.28g/kg and 0.26g/kg) in sludge in fresh and dried sludge and E.coli (12cfu/g) on dry sludge in the study area is higher than Federal Ministry of Environment (FME) safety limit for sludge. The result further shows that there is no significant difference between properties of sludge obtained in the study area and soil requirement by Federal Ministry of Environment. Therefore, presence of pollutants especially the heavy metals in sludge should be remediated and taken into account in the scientific debate concerning the use of sewage sludge in agriculture and there must be continuous monitoring of the heavy metal pollutant in the sludge before application to farm land or disposed, so as to reduce soil pollution and reduce intake of heavy metal of the crop production.

Keywords: Alternative and Organic Fertilizer**,** Biosolid, Federal Capital Territory, Sludge, Suitability, Treatment Plant

Introduction

Municipal sewage sludge is an unavoidable by-product of wastewater treatment. An increase in the amount of sewage sludge produced has been observed for many years. The quantity of raw wastewater that is received by a Waste Water Treatment Plant (WWTP) is determined by the local population and the degree of urban and industrial development in a given region (Eid *et al.*, 2019). At present, the global production of sewage sludge is estimated at 45 million megagrams (Mg) of dry matter (DM) per year (Zhang *et al.*, 2017). Europe, East Asia, and North America are considered to be the main producers of sewage sludge in the world (Shaddel *et al.*, 2019). According to the Final Report for the European Commission (Milieu Ltd, 2010), sewage

sludge production in the European Union (EU) countries alone increased by 1.5 million Mg of DM in the last 10 years, from 11.5 million Mg in 2010 to 13 million Mg of DM in 2020.

Sewage sludge is an important type of organic wastes among the various categories of solid waste (Singh et al., 2014). In the present day, because of population growth, world of diminishing natural resources and energy crisis, the importance and need of developing a sustainable approach towards environmentally sound solid waste management cannot be ignored (Pappu *et al.*, 2007). The properties of sludge associated with the origin and amount of flushing water (public toilet, private toilet), its assortment type (on-site, off-site) and following treatment level, for example digestion. Fresh and untreated sludge will have many pathogens, a high proportion of water, high biochemical oxygen demand (BOD) and is normally putrid and odorous. Nevertheless, sludge also contains essential nutrients for plants (e.g. nitrogen and phosphorus) and is potentially a very beneficial fertilizer (Mateo-Sagasta, *et al.*, 2015). Organic carbon is an important component of sludge that, once alleviated can serves as soil conditioner by improving soil structure for plant roots and can be used, to generate energy through bio-digestion or incineration (Mateo-Sagasta, *et al.*, 2015).

Sewage sludge can be used in agriculture as a valuable source of nitrogen and phosphorus, for the production of compost, and for the reclamation of degraded areas (Farasat and Namli, 2016; Lasaridi, *et al.*, 2018). The choice of the method of sewage sludge management is particularly dictated by its quantity and properties (Latosinska, 2017). Moreover, it is subject to legal regulations. In Poland, the Act on Waste (Waste Act, 2013), the regulation of the Minister of the Environment on municipal sewage sludge (Minister of the Environment, 2013) and the regulation of the Minister of the Economy on the criteria and procedures for allowing waste to be deposited in a given type of landfill (Minister of the Economy, 2015) are in force in this respect. In Europe, the limits of heavy metals in terms of natural use are regulated by the Council Directive of 12 June 1986 on the protection of the environment, in particular of the soil, when sewage sludge is used in agriculture (European Commission, 1986); in the United States, it is the Code of Federal Regulations (Code of Federal Regulations, 2010); for China, the 2002 "Standard for Discharging Pollutants into Urban Wastewater Treatment Plants" (Ministry of Environmental Protection of the People's Republic of China, 2002); and for areas in southern Africa, "Guidelines for the Utilization and Disposal of Wastewater Sludge" (Water Research Commission 2009).

The sewage sludge or biosolids generally varied in characteristics and contain organic and inorganic chemicals, toxic metals and pathogens. It is often considered as a resource due to the widespread application in soil amendment, energy generation, nutrient supply etc. The sewage sludge, having about 1% of wastewater when entering to the sewage treatment plant for the treatment, is digested anaerobically and resulted to remove the wastewater from the sludge (Kumar and Chopra, 2016).

The Wupa Wastewater Treatment Plant has been in operation for over ten years and sludge is continuously generated, disposed in sewage lagoons and the aviation farm where sludge is majorly applied to the land for agriculture. Domestic wastewater which is the major source of wastewater for the Wupa Treatment Plant comes from household activities while industrial wastewater which is the second highest source comes from various sectors of industry like food processing, paper, laundry, and the pharmaceuticals sector. Waste waters are rich in both organic and inorganic compounds depending on the production sources, and when the wastewater is released to the water body, it can lead to a rise in nutrients (eutrophication) and chemical

composition (pollution) of such water bodies (Raghupatruni, 2020; Ansari and Gill, 2014).

However, sludge from treatment wastewater still contains heavy metals that can be detrimental to the environment depending on the wastewater sources and level of treatment. Sewage sludge could also be abundant waste biomass, as its production keeps increasing due to population growth, particularly in developing countries. The number of wastewater treatment plants in most developed countries is also on the increase because of industrialization, so more sludge is being produced (Saminu *et al.*, 2017; Ndububa, and Kawu, 2018). Effective management and handling of these generated sludge in an environmentally friendly way have become a matter of increasing importance globally, due to the potential health risks on the environment when not properly treated and disposed. Importantly, sewage sludge may contain large amounts of organic components and nutrients; hence, resource recovery from such abundant biomass is necessary (Nnamdi, 2017; APHA, 2005). Hence, this paper attempted to determine the suitability of biosolid produced at Wupa Sewage Treatment Plant as alternative to organic fertilizer in Abuja, Nigeria.

Material and Methods

Study area

Wupa Sewage Treatment Plant is located within Institute & Research District of Abuja FCT, Latitude and Longitude, 7˚23‟‟00N, 9˚0100’’E (Figure 1). It is close to Wupa River and it covers an area of 297,900 square meters. WWTP which is one of the largest in the world was constructed to treat sewage generated from phase 1, II, III of Abuja Metropolis. It was designed to handle the waste generated by 700,000 Population Equivalent (PE) and expandable to 1,000,000 PE, thus the Plant can accommodate an average dry weather inflow of 5,500 cubic meter per hour and a wet weather inflow of 9,000 cubic meter per hour. The plant operates on the activated sludge process that relies on microbial population in mixed suspension to achieve the waste water treatment. The plant was constructed to address the growing concern of the disposal of human waste, as Abuja metamorphosed into a global city (Saminu *et al.*, 2017).

Figure 1: Map of FCT showing Wupa Sewage Treatment Plant
Source: Author, 2023



Figure 2: Google Earth of Wupa Sewage Treatment Plant (2022)
Source: Goggle map, 2022 version.

The study area is predominately underlain by Precambrian migmatites, gneisses, granites and schist of the crystalline basement complex. Schist belt outcrops are found along the south western merging of the area and apart from the schist belt. Quaternary alluvium deposits are found in the Usman

River channel and this is a source of fine sand which is used for building purposes (Balogun, 2001).

The soil in the study area comprises mainly of sand, silt, clay, and gravel. Earlier before the impact of population growth and urbanization the incidence of soil erosion is quite small because of the then protective vegetation cover. The recent uncontrolled clearance over the decades as a result of population growth and urbanization result to accelerated erosion with evidence along footpaths and roads in the area (Balogun, 2001). The vegetation can be classified as park Savannah with scattered trees and tall grasses. There also exist some wooden areas along interfluves between the Usuma River and its tributaries within the area. According to Balogun (2001) the FCT is located within the Savannah. Three (3) types of savannahs namely woodlands, park savannah and shrubs cover 79% of the FCT land mass. The remaining 21% comprises two types of forest found in the FCT are rainforest and riparian vegetation complex.

Sample procedure and collection

Data were collected directly from the field. This involves questionnaire administration, field experiment done on the sludge of the selected study area, and thereafter laboratory analysis.

Field experiment

Two sludge samples were taken from the disposal dry bed about 10m apart using a stainless-steel trowel and 500ml glass beakers. Naturally dried biosolids samples were collected from the sewage treatment plant. The sample was solarized under clear polythene paper gauge 200 mm thick. After solarisation process, the biosolids were further be stored in a plastic greenhouse at the laboratory and then comprehensively analysed in the laboratory. Sampling was carried out by ensuring that: Sterilized glass sampling beakers were used for the samples collection, The sample beakers were clearly labelled for easy identification, Care was taken to avoid accidental contamination of the samples during collection and subsequent handling before the analysis, lids were tightly placed on the sampling bottles, and the samples were all be taken in the early hours of the day and, kept cool in an insulated container and driven in an air-conditioned car to the laboratory within two hours of collection.

Questionnaire administration

The questionnaire was prepared to acquire information on the process and end use of sludge in the study area. Questionnaires that seek specific answers were required for the study. These questionnaires were closed ended and was in two sections; which are, bio-data of respondents and process and end use of sludge in the study area.

Sample size

To derive the sample size, the staff nominal was used. Sample size was derived using Krejcie and Morgan (1970). The sample size from 80 staff on Krejcie and Morgan table is 66 as shown in Table 1.

Table 1: Wupa Basin Sewage Treatment Plant Staff Nominal Roll 2023.

S/N	Unit	Number of Staff	Sample Size
1	Management	4	3
2	Admin	2	2
3	Maintenance	31	27
4	Process	21	17
5	Quality Control	21	17
Total		80	66

Sixty-six (66) questionnaires in printed hard copies were physically administered to sixty-six of the staff at the Wupa Wastewater Treat Plant.

Data Presentation and Analysis

The data obtained were subjected to descriptive and inferential statistics. The descriptive statistics used were mean, range, standard deviation, frequency and percentages while inferential statistics were used in testing the hypothesis. Microsoft Excel was used to calculate the mean,

standard deviation, co-variance of the collected data from the laboratory.

Analysis of Properties of Sludge

Sludge Physical properties (pH, bulk density, porosity, humus content (Organic Matter), and water holding capacity), Chemical properties (organic carbon, Nitrogen, Phosphorus, cation exchange capacity, and potassium, Heavy Metal properties (Na, Ca, Mg, Fe, Zn, Cu, Mn, Pb, Cu and Cd) and Microbial Properties (faecal contaminants, specifically Salmonella sp., Escherichia coli and Staphylococcus sp.) analysed in the laboratory as standard to determine the nutrient content and pollution rate in the sludge. The result of the laboratory was compared against standard set by Federal Ministry of Environment and Rural Development.

Results and Discussion

Physical and chemical properties of sludge in the Wupa treatment plant

Table 2: Physiochemical result of the sludge analysis

S/N	Parameters	Unit	S1 (Fresh)	S2 (Complete Dried)
1	pH		6.20	6.25
2	EC	µs/cm	560	500
3	Organic Matter	%	41	40
4	Bulk Density	Mg/m^3	1.79	1.80
5	Water Holding Capacity	%	52.40	54.49
6	Total Nitrogen (g/kg DM)	%	4.69	4.00
7	Total Phosphorous	g/kg DM	1.93	1.50

Source: Fieldwork, 2023

Result of Table 2 shows the values of pH recorded from the sludge on fresh 6.20< 6.25 recorded for dry sludge, the value of electrical conductivity recorded on fresh sludge, 560 µs/cm > 500 µs/cm recorded for dry sludge. Organic matter recorded on the fresh sludge, 41% >40% recorded on the dry sludge. Higher bulk density was recorded on the dry sludge (1.80mg/m3) and low value (1.79mg/m3) was recorded on the fresh sludge. Value recorded on the dry sludge (54.49%) for water holding capacity was higher than value on the fresh sludge 52.49%).

Total nitrogen recorded on the fresh sludge, 4.69%>4.00% recorded on the dry sludge. Finally, value of total phosphorus recorded at the fresh sludge, 1.93g/kg> 1.50g/kg value recorded for dry sludge.

Generally, fresh sludge recorded highest value for EC (560 µs/cm), organic content (41%), total nitrogen (4.69%) and total phosphorus (1.93g/kg). while dry sludge recorded highest value of pH (6.25), bulk density (1.80mg/m3), and water holding capacity (54.49%).

Microbial properties of sludge in the study area

The result on Table 3 shows that only dry sludge recorded value (12cfu/g) for E. coli, fresh sludge lacks salmonella and E. coli while dry sludge lack salmonella.

Table 3: Microbial result of the sludge analysis

S/N	Parameters	Unit	S1 (Fresh)	S2 (Complete Dried)
1	Salmonella Sp.	cfu/g	NIL	NIL
2	E.Coli	cfu/g	NIL	12

Source: Fieldwork, 2023

Heavy metal content contains in the sludge of study area

The result on Table 4 shows high cadmium value (0. 2310g.kg) recorded on the fresh sludge and low value (0.200g/kg) recorded on the dry sludge. The values of copper recorded from the sludge on fresh 1.2417g/kg>1.2014g/kg recorded for dry

sludge. This range was within values of 895.49 - 1788.70mg/kg recorded in Ruai sewage treatment plant (Mbugua, 2015), but higher than 104 -194 mg/kg from Poland (Tytła, 2019), and 103-696 mg/kg obtained in Swaziland (Tiruneh, Fadiran, and Mtshali, 2014). The mean Cu levels was also higher compared to 193±9.6 mg/kg reported in sewage sludge obtained from Taiwan wastewater treatment plant (Wang *et al.*, 2021). Though a heavy metal, Cu is an essential component of various proteins like plastocyanin and thus an important micronutrient required by plants. Sources of copper into the environment include several industries which deal with paint, textile, metallurgical, plant protection products and fertilizer (Smiljani, 2019). The US EPA guidelines set permissible limits at 1500mg/kg. The copper concentration in Wupa Treatment Facility was below this set national and international guidelines on sewage sludge made for use in agriculture.

Table 4: Heavy metal result of the sludge analysis

S/N	Parameters	Unit	S1 (Fresh)	S2 (Complete Dried)
1	Cadmium	g/kg DM	0.2310	0.200
2	Copper	g/kg DM	1.2417	1.2014
3	Iron	g/kg DM	1.2184	1.2165
4	Lead	g/kg DM	0.2800	0.2600

Source: Fieldwork, 2023

Process and end use of sludge in the study area

Table 5: Process and end use of sludge in the study area

Variable		Frequency	Percent
Method of Sludge Disposal	Dry bed only	46	69.7
	Dry bed only plus farming	4	6.1
	Dry bed only plus farming plus research	15	22.7
	Have no idea	1	1.5
	Total	**66**	**100.0**
Type of smell created by Sludge	No offensive smell	24	36.4
	Mild offensive smell	22	33.3
	Offensive smell	16	24.2
	No Response	4	6.1
	Total	**66**	**100.0**
Do People Come to Take Sludge for Use		Yes	46
		No	18
		No Response	2
	Total	**66**	**100.0**
Negative Environmental Impact of Sludge	Yes	2	3.0
	No	60	90.9
	No Response	4	6.1
	Total	**66**	**100.0**
Complaint About Pollution Due to Sludge Application on Land	Yes	6	9.1
	No	60	90.9
	Total	66	100.0
Increase Productivity Due to Sludge Use for Farming or Gardening	Yes	44	66.7
	No	20	30.3
	No Response	2	3.0
	Total	**66**	**100.0**
Report of Leaching or Eutrophication of Any Surface Water Within the Area of Sludge Use or Disposal	Yes	6	9.1
	No	60	90.9
	Total	**66**	**100.0**

Result on Table 5 shows that 69.7% of respondents indicated they dry bed only is the method of sludge disposal used in the study area, 22.7% indicated dry bed only plus farming and research, 6.1% indicated dry bed with farming and 1.5% indicated they have no idea. The implies that the major sludge disposal method used in the Wupa Treatment Plant is dry bed only, this confirms with the similar study carried out in the same area by Francis and Ndububa (2022). According to Francis and Ndununa (2022), Wupa treatment plant produced estimated 547.2 tons of sludge produced per year about 90.28% is disposed in the dry bed of the treatment plant while only about 9.77% is disposed of through other means.

The result shows that 36.4% indicated that sludge disposal does not cause offensive smell, 33.3% indicated it create mild offensive smell, and 24.2% indicated offensive smell. The result on Table 5 further shows that 69.7% percent of respondents indicated that people come to take sludge for usage while 27.3% indicate they do not, 90.9% indicated that sludge disposal does not cause any negative environmental impact while 6.1% indicated it does, 90.1% indicated that there are no complaints about pollution due to sludge application on land while 9.1% indicated there are complaints, 66.7% indicated that sludge application increased productivity of farming and gardening while 30.3% indicated it does not and 90.9% indicate that there is no report of leaching or eutrophication of surface water within the area sludge is used or disposed while 9.1% indicated there is.

Suitability of sludge for agricultural productivity base on properties of sludge compare against the standard

Table 6: Physiochemical result of the sludge analysis

S/N	Parameters	Unit	S1 (Fresh)	S2 (Complete Dried)	Federal Ministry of Environment safety Limit
1	pH		6.20	6.25	6-9
2	EC	µs/cm	560	500	500.00
3	Organic Content	%	41	40	NS
4	Bulk Density	Mg/m^3	1.79	1.80	NS
5	Water Holding Capacity	%	52.40	54.49	NS
6	Total Nitrogen (g/kg DM)	%	4.69	4.00	2.9-5.1
7	Total Phosphorous	g/kg DM	1.93	1.50	1.05–4.26
8	Cadmium	g/kg DM	0.2310	0.200	1.00
9	Copper	g/kg DM	1.2417	1.2014	2.00
10	Iron	g/kg DM	1.2184	1.2165	0.30
11	Lead	g/kg DM	0.2800	0.2600	0.01
12	Salmonella Sp.	cfu/g	NIL	NIL	0
13	E.Coli	cfu/g	NIL	12	0

Source: Fieldwork, 2023

Result on Table 6 shows that the value of iron (1.22g/kg and 1.22 g/kg) and lead (0.28g/kg and 0.26g/kg) in sludge in fresh and dried sludge and E.coli (12cfu/g) on dry sludge in the study area is higher than FME safety limit for sludge. The result obtained for lead is similar to the result by Francis and Ndububa, (2022) recorded in Wupa treatment plant, showing higher concentration of Iron (0.27mg/l) in the water samples compared to the sludge concentration (0.20mg/l). This could be from other natural sources or human activities.

The value of pH, Electrical conductivity on dried sludge, total nitrogen, total phosphorus, are within the value set by Federal Ministry of Environment, value of cadmium, while value of E.coli on dried sludge is higher than set standard. This result show lower nitrate as compare to nitrate recorded by Francis, & Ndububa, (2022) of 10.5 g/kg, showing that sludge is safe when compare to sludge but not

good when considering with lead and iron. The result shows that the sludge contains high content of iron and lead which could pollute the soil and nearby water when washed down into river body.

Table 7: Test of level significant difference between properties of sludge obtained in the study area and soil requirement by federal ministry of environment

Groups	Count	Sum	Average	Variance
S1 (Fresh)	10	575.7911	57.57911	31168.2
S2 (Complete Dried)	10	526.6279	52.66279	24718.96
FME safety Limit	10	521.67	52.167	24768.48

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	179.0231	2	89.51157	0.003329	0.996677	3.354131
Within Groups	725900.7	27	26885.21			
Total	726079.7	29				

Using the analysis of variance (Table 7) the f calculated was 0.0033 while the f-critical at value at ($p<0.5$) is 3.35, this shows that the f-critical of $0.0033<3.35$ calculated value therefore there is no significant difference between properties of sludge obtained in the study area and soil requirement by Federal Ministry of Environment or rather the differences are not significant. Therefore, are the sludge being partially appropriate for usage.

Discussion of Findings

The study revealed that sludge is good for agricultural purposes as it enriches soil nutrients. Both dry and fresh sludge contains rich nutrients which will enrich the soil for farm production. This confirms the contradicts findings by Alvinash, Anupam, and Kam (2019) that dry sludge is rich in nutrients and organic matter that can enhance farm yields. This makes it a sought-after fertilizer as it is cheaper than other fertilizers and also as a better way of waste disposal (Usman, 2012). According to the result, it shows that the sludge contains high value of Nitrogen, Phosphorous and organic content, electrical conductivity and water holding capacity. The study indicated that process of sludge in the treatment plants is safe and not harmful to the environment, as the result shows that sludge disposal does not produce offensive smell but mild offensive smell, according to Francis and Ndububa (2022) research in Wupa, there is no offensive odour within the treatment dry bed, the host village, and at the aviation farm as only 2.7% of the treatment plant staff, representing 1% of the total respondents say there is a mild smell when the sludge is freshly disposed of.

Conclusion and Recommendation

The levels of heavy metals analyzed in this study were below national and international set standards for sewage sludge application in agriculture and therefore deemed safe in the short term. However, the study recommends further research to ascertain the levels of persistence toxic elements such as Cadmium, Chromium, Mercury and other environmental contaminants including pharmaceuticals and pathogenic microorganisms that were not studied due to financial constraints. As per the macronutrient levels observed in this study, its concluded that the sewage sludge from Wupa Treatment Facility is rich in nutrients and thus a potential fertilizing agent that can be used to boost plant growth. During the study, it was also observed that increased productivity of farming and gardening. The following recommendations are proffered to

improve the disposal of sludge and its application for crop production:

1. A Periodic monitoring of water parameters of water bodies close to area of land application (especially the Aviation farm river, close to the treatment plant), this is to ensure it is not polluted by sludge disposal as this is the major source of water used for domestic activities by the locals.
2. The presence of pollutants especially the heavy metals in sludge should be remediated and taken into account in the scientific debate concerning the use of sewage sludge in agriculture.
3. There must be continuous monitoring of the heavy metal pollutant in the sludge before application to farm land or disposed off so as to reduce soil pollution and reduce intake of heavy metal of the crop production.
4. There should be more scientific research on the different aspects of biosolids or sewage sludge to make it more feasible resource for the sustainable development and soil nutrients application. This should include further study on the amount of nitrate needed by plants to know if the Wupa sludge contains more than plants' need; as reviewed literatures shows that excess nitrate not used by plants, can leach through soil into groundwater.

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