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PAPER TITLE : **Water, Wastewater Management & Biochemical Impact of Sludge on Soil Properties In Port Harcourt, Rivers State, Nigeria**

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ABSTRACTS

This paper, presents an overview about water, wastewater management and biochemical impact of sludge on soil properties in Port Harcourt. Port Harcourt here means Port Harcourt City and Obio/Akpor Local Government Areas. The main problems related to the availability of water resources and their preservation from pollution are described. Moreover, a detailed description of the different efforts done in Port Harcourt in recent years to overcome the technical, economical and organizational problems of water and wastewater management and to catch up the considerable delay regarding sanitation and recovery of treated wastewaters has been reported here too. And such as the establishment of Port Harcourt Water and Sewage Corporation with the aim of providing, regulatory, adequate water resources infrastructure and affordable water supply for the growing population and sewage treatment. The use of Sequencing Batch Reactor (SBR) method is considered as the most appropriate and suitable treatment mechanism to treat the increasing flows of domestic wastewater in Port Harcourt. However, the effluent produced were found to be, up to standard as recommended by National Environmental Standards and Regulation Enforcement Agency (NESREA) and World Bank. Also, it is also established the usefulness of sludge obtained from the treatment of sewage in the production of fertilizer that is use for the improvement of the soil properties to enhance high agricultural productivity. This was done through the investigation of the biochemical parameters such as Nitrogen(N), Phosphorous(P), Potassium(K) and TOM (Total Organic Matters). The parameter levels for the test soil (2.37 mg/kg, 32.89 mg/kg, 32.15 mg/kg, and 3.12 mg/kg) respectively while the control (0.93 mg/kg, 11.09 mg/kg, 36.35 mg/kg, and 2.14 mg/kg) respectively. Zn, Pb, Ni and TOC (Total Organic Carbon). These parameters are essential to plants and animals' growth. And are found to be significantly higher in the test soil (19.26 mg/kg, 5.71 mg/kg, 1.60 mg/kg, and 1.81 mg/kg) respectively over the control (8.62 mg/kg, 2.58 mg/kg, 0.52 mg/kg, and 1.24 mg/kg) respectively.

1.0 WATER RESOURCES

Port Harcourt is located in the south-southern part of Nigeria in Africa and it comprises basically of two (2) local government areas namely Port Harcourt City and Obio/Akpor local government area. Therefore, in the context of this paper presentation, when we refer to Port Harcourt, we are indeed talking about both Port Harcourt City Council and Obio/Akpor local government. It's a land mass of 39,000 Ha and an approximate population of about 3 million inhabitants with a climate in sharp contrast in temperature between rainy and dry season with mean average of 26^oC and 38^oC respectively. Like many local government areas within Rivers state and other part of the country Nigeria, Port Harcourt is faced with the problem of the development and sustainable management of its water resources. Although it's had favourable weather with frequent rainfall due to its location along the coastal line of the Niger Delta Nigeria, sharing boundary with the Atlantic Ocean at the south, the scare water resources marked by wide geographical disparities and highly sensitive to vagaries, come under heavy pressure due to demand resulting from population growth, improved living conditions and the implications of economic development. To support this trend, there is a need for sustained development of water resources in quantity and quality in order to ensure widespread access to drinking water and reduced inequality between the two local government areas.

1.2 WATER CONSUMPTION AND NEEDS

In Port Harcourt, water resources exploitation is 100% underground, although there are several surface water bodies that surrounds the environment. These surface water have high degree of salinity, solid, liquid and gaseous impurities due to huge presences of hydrocarbon industries. Its required huge cost in its treatment and maintenance of treatment plant, if surface water is to be extracted, treated to WHO standard for drinkable water. Therefore, it's difficult for exploitation and use of water resources from surface water. This constraint left the city with no choice than to resort to underground water extraction, treatment and use, through wells and boreholes by both government and private individuals. Port Harcourt has 45 wells established by the state government with an average production yield of 1145m^3/hour see table 1 below

S/No	Well Site	Total Well Numbers	No. of Wells Operating	No. of Wells Abandoned	No. of Wells that Can be Rehabilited	Well Yield m^3/h
1	Rumuola	17	4	6	11	300
2	Diobu	2	1	0	2	200
3	Moscow	9	5	1	3	60
4	Eagle Island	2	1	0	1	75
5	Trans-Amadi	6	4	2	3	100
6	Rumuokwurusi	2	1	0	2	100
7	Elelenwo	2	1	1	1	40
8	Woji	1	0	1	0	-
9	Abuloma	1	0	0	1	-
10	Olumeni	1	0	0	1	200
11	Ernest Ikoli	1	1	0	1	-
12	Borokiri	1	0	0	1	70
	Total	**45**	**18**	**11**	**27**	**1145**

Table 1: Existing wells/Boreholes & Yield. (Source: Port Harcourt Water and Sewage Corporation Feasibility Studies Design Report for the upgrading & Extension of Water supply schemes for Port Harcourt 2011

At present, the total average water demand stands at about 400,000m^3/day. It is possible that the water resources per inhabitant will reach around 970,000m^3 per capita per year, with a projection period of up to 2040. See figure 1 below

Port Harcourt is characterized by seasonal rainfall, with heavy rainfall from July to October all year round but because of the activities of hydrocarbon industries through the flare of gaseous substances into the air, but due to increasing population, lack of available extractive and treatment infrastructure to harness portable water and meet up the demand are key factors that resulted to scarcity at present it's become very difficult for the consumption of rain water by the inhabitants of the city. Those who due to inability to get private wells, end up using the rain water, therefore making them to suffer different kinds of diseases. So, to address this situation, Rivers state Ministry of Water Resources was created in 1995 with the following strategic objectives:

- To formulate water resource policies and monitor the implementation of such policies in the state.
- To source, analyze, store and disseminate information on the water resource data in the state.

- To establish, monitor and oversee water parastatals of the ministry – the Rivers State Water Board and the Rural Water and Sanitation Agency.
- To initiate and implement water supply projects in all areas of the state.
- To liaise with the federal government and international donor agencies on water supply and development for the benefit of the state.
- To set standards, regulate, supervise and control the use of all water resources in the state.
- Implementing and provision of water legislation/ by-laws.
- Collection and evaluation of hydrological and sociological data.

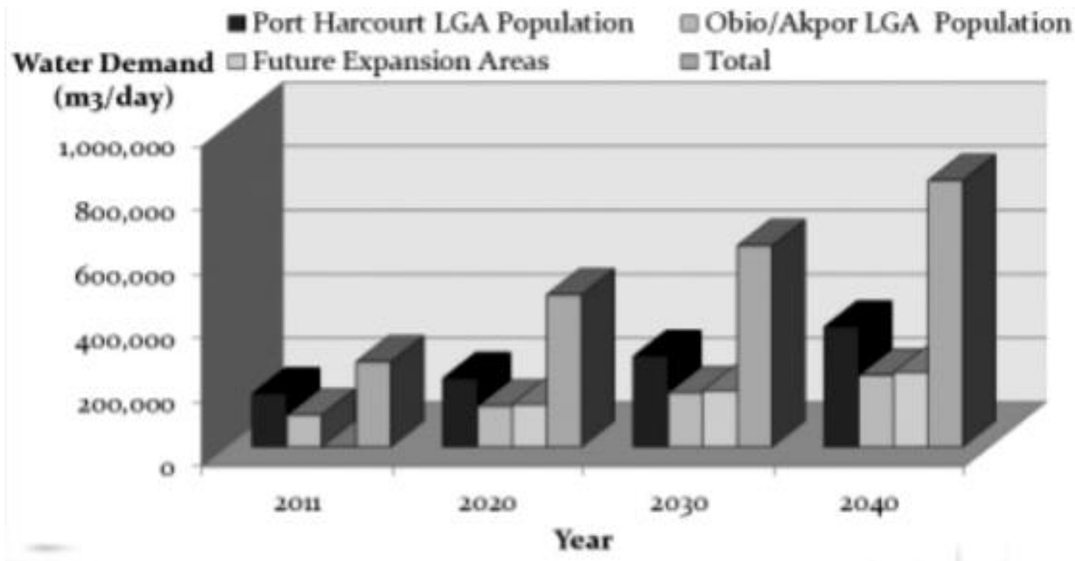

Figure 1: Water Demand. (Source: Port Harcourt Water and Sewage Corporation Feasibility Studies and Design Report for the upgrading & Extension of Water supply schemes for Port Harcourt and Obio/Akpor LGAs 2011}

1.3 LEGAL FRAMEWORK

Before the establishment of Port Harcourt Waters and Sewage Corporation, the function of providing quality and quantity of water to the inhabitants of the entire Rivers State, which comprises of 23 local government area and with a population 5,198,716 according to census data release in 2006 was rested on the Ministry of Water Resource. This mandate overwhelms the ministry due to lack of support from relevant stakeholders, therefore there is need for the establishment of the Port-Harcourt Water and Sewage Corporation, whose mandate is to provide adequate potable water through improved quality and quantity of water supplied to the current residents of the two LGA's as well as meeting the demands of the inhabitant of the both LGAs for the next 30 years (Year 2040) and adequate Sanitation system.
On May 12, 2012, a law was enacted by the Rivers State House of Assembly, to provide for the development and regulation of the Rivers State Water and Sanitation sector, the establishment of the Port-Harcourt water and sewage corporation; Rivers State Small Towns Water and Sanitation Agency; Rivers State Rural Water Supply and Sanitation Agency; Rivers State Water Services Regulatory Commission, role of government, private sector participation and other matters.

The general objectives of this Law are to provide for, but not limited to these includes**:**

- The right of access to basic sanitation and basic water supply necessary to secure sufficient water and an environment not harmful to human health or well-being;
- The setting of standards and norms for service provision and standards for tariffs in respect of water and sanitation services and a regulatory framework for water services institution and other provider.
- The formulation, monitoring and review of the Rivers State Policy for the water and sanitation sector and encouraging private sector participation in water supply and sanitation.

- Collaboration of the Sector Institutions with other National and State Agencies in the development of water and sanitation services in accordance with the National water policy, the State Water Policy, the State Water Supply and Sanitation Sector master plan and this Law.

1.3.1 THE GENERAL PRINCIPLES FOR WATER AND SANITATION SERVICES DELIVERY IN THE STATE;

1. The principles and implementation responsibilities set out in this section shall be regarded by every Ministry, Department and Agency of Government as well as the private Water Service Providers (WSP), and other non-Governmental Agencies and Organizations as being fundamental to every activity undertaken within the State water and Sanitation Services Sector.
   These principles are as follows:

   - Ensuring the affordability of water supply and sanitation services for the low income and poor sections of the populace by the development of mechanisms to ensure access to basic water and sanitation services through cross subsidies as well as targeted and justifiable Government subsidies;
   - Publicly owned water and sanitation infrastructure and assets shall be held in trust for the people by the State Government and shall be vested in public water Utilities established pursuant to this Law. Such assets may be granted to private Water Service Providers (WSP) for the purpose of service provision in public private partnership (PPP) arrangements, other than absolute divestitures as may be approved by the State Government;
   - Water and Sanitation management and development shall be based on participatory approach, involving users, planners and policy makers at all levels. Decisions shall be made at the lowest appropriate level in accordance with the provisions of this Law;
   - Government-owned water and sewage infrastructure and assets in Port Harcourt and environs shall be vested in the Port Harcourt Water and Sewage Corporation which may engage the Private Sector for the performance of any of its statutory functions with respect thereto, subject to the approval of the Governor in accordance with this Law;

1.4 PROBLEM OF WATER MANAGEMENT

1. Among the inherent problems to the water management in Port Harcourt, is the multiplicity of the stakeholders;
   - **Rural Waters and Sanitation Agency (RUWASSA)** shall be to provide technical assistance to communities and the LGAs in the rural areas in the establishment, construction, management and maintenance of water supply and sanitation infrastructure, and hygiene promotion in the communities.
   - **Small Towns Water and Sanitation Agency (STOWA)** provide safe, adequate and affordable water supply services to the residents of Port Harcourt and Obio/Akpor.
   - **Port Harcourt Waters and Sewage Corporation** to manage All existing and new State- owned water supply and sewage infrastructure in Port Harcourt and its environs. And its includes water supply, distribution and consumption.
   - **The Rivers State Government through the Ministry of Water Resources** shall be responsible for facilitating and coordinating the roles of the Ministries, Departments and Agencies as well as other stakeholders in the State Water Supply and Sanitation Services Sector by the activities of the MDAs.
   - **Rivers State Water Services Regulatory Commission**, shall be responsible to promote federal, state laws and policies. By ensure that regulation is fair and balanced for Water Services Providers, consumers, investors, and other stakeholders;

2.0 WASTEWATER MANAGEMENT

Wastewater management includes water conservation, wastewater treatment, stormwater management, and wastewater and water quality monitoring. But for the purpose of this presentation, concentration will be made on wastewater treatment and wastewater monitoring in Port Harcourt.

Prior to the establishment for Port Harcourt Waters and Sewage Corporation in 2012, wastewaters are disposed indiscriminately to surface water around Port Harcourt Metropolis. This act has affected the ecosystem leading to death of useful aquatic organism and treat to the health of inhabitants around the surface water. This prompted the state government to establish the corporation known as PHwaters Corporation. Upon the establishment of PHwaters Corporation, it is noticed that 10,000 liters of wastewater are generated in a day within Port Harcourt and its environment. This volume is always and must be treated daily, to comply with National Environmental Standards and Regulation Enforcement Agency (NESREA) and World Bank Standard, before the effluents are disposed to the environment (See Table 2). Note that NESREA is an environmental regulatory and enforcement agency established by an Act of the National Assembly in Nigeria in 2007, with a clear vision of cleaner and healthy environment.

2.1 WASTEWATER TREATMENT IN PORT HARCOURT

After the establishment of Port Harcourt Waters and Sewage Corporation, wastewater treatment plant was put in place for the treatment of wastewater in order to avoid the resultant effect of indiscriminate disposal of wastewater into surface water. The wastewater treatment plant in Port Harcourt is situated at Eagle Island, off AGIP road Port Harcourt. Influents from around the city and other states are brought by trucking. The Aerobic Sequencing Batch Reactor (SBR) Treatment Method is use for the treatment of wastewater in this plant and have the capacity to treat 1000m^3 of wastewater per day. This treatment system is a combination of unit operations and processes designed to reduce constituents of wastewater to an acceptable level and it has three levels of treatment; Primary, Secondary and Tertiary with the principle of filtration, reduction in organic load, nutrients reduction and pathogens deactivation.

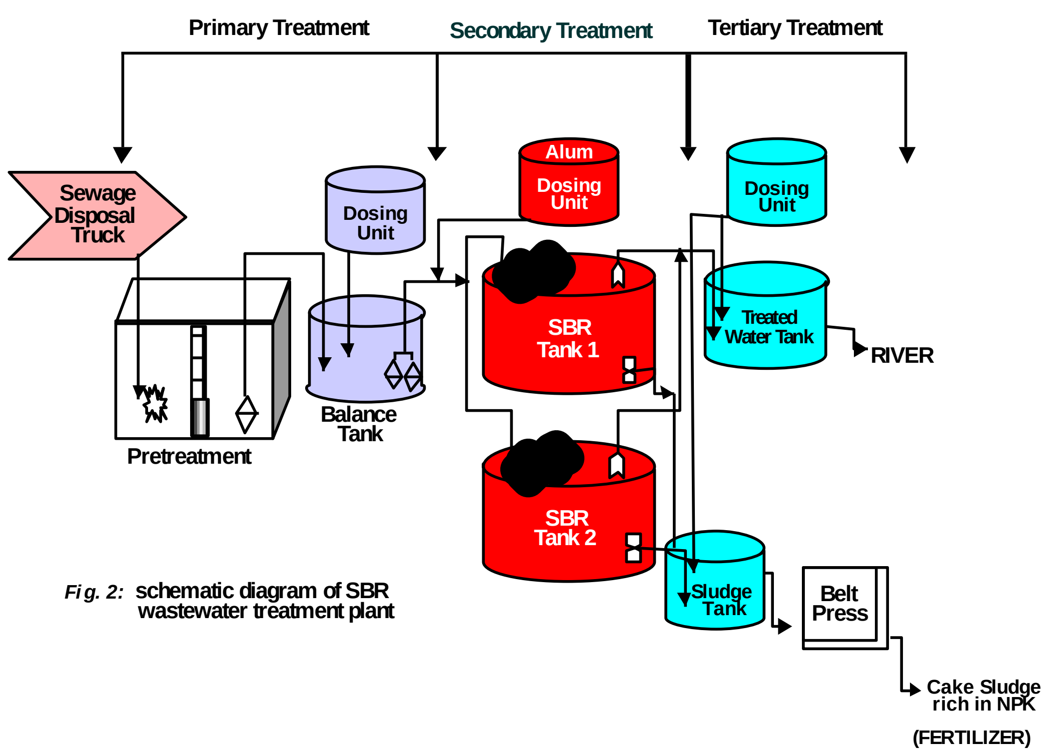

Fig. 2: schematic diagram of SBR wastewater treatment plant

2.1.1 PRIMARY TREATMENT:

This section uses the principle of filtration: a portion of the suspended solids and organic matter is removed from incoming wastewater (Influent) as well as non-mixable particles. This removal is usually accomplished with physical operations such as Bar Screening (which removes most of the bigger and longer visible objects such as leaves, sticks, rags, debris, sanitary pads, condoms, wrappers, etc, present in the influent, thus protecting the pumps and other mechanical equipment, and also to prevent clogging of valves and other appurtenances), Grit Removal (which removes inorganic solids such as pebbles, sand, silt, eggshells, glass, metal fragments, etc - when collected together, constitute grit are removed from wastewater to prevent damage to pumps). Then follow the Air Bubbling System which introduces oxygen and blows up the fats, oil and grease (FOGs) for possible scooping from the surface. Thereafter, with the help of a submersible pump, the filtrate is transferred to the Balance Tank where dosing of biological nutrient media is achieved using the dosing pumps.

2.1.2 SECONDARY TREATMENT

This section uses the principle of reduction in organic load & nutrients: This is achieved in the SBR Tank which is operated in batches, where the different conditions are all achieved in the same reactor but at different times. The treatment consists of a cycle of five stages: Fill, React, Settle, Draw and Idle. During the reaction type, oxygen is introduced by an aeration system using the Aerators for a period of about 4hours. During this phase, bacteria oxidize the organic matter. Thereafter, coagulants and flocculants such as Potassium Aluminum Sulphate also known as Alum ($KAl_2(SO_4)_2$) are added using the dosing pump which on thorough mix to form a gelatinous precipitate called floc, and aeration is stopped to allow the sludge to settle. In the next step, the water and the sludge are separated by decantation using the Aqua Decanter and the clear layer (supernatant) is transferred to the Treated Water Tank (TW TANK), while the sludge is transferred to the sludge tank using the Sludge Pumps.

2.1.3 TERTIARY TREATMENT

This section of the treatment uses principle pathogens deactivation. In this phase, the decanted supernatant in the TW Tank is disinfected using hypochlorite and Samples are collected and taken to the QAQC Laboratory for analysis prior to discharge. While the sludge in the sludge tank is dewatered using the Belt-Press Machine (which is a physical-mechanical unit operation) used to reduce the moisture content of the sludge. Pressure is applied in a low-pressure section, where the sludge is squeezed between opposing porous cloth belts. On some units, the low-pressure is followed by a high-pressure section, where the sludge is subjected to shearing forces as the belts pass through a series of rollers. The squeezing and shearing forces thus induce the release of additional quantities of water from the sludge. The final dewatered sludge cake is removed from the belts by scraper blades).

S/No	PARAMETER	UNITS	NESREA	WORLD BANK	PHWC TARGET	Average (2017)	Average 2018
1	Ph		6.5-9.0	6.0-9.0	6.5-8.0	7.45	7.39
2	BOD	Mg/l	50	30	30	28.75	25.33
3	COD	Mg/l	250	125	50	24.8	30.7
4	Total Suspended Solid (TSS)	Mg/l	50	50	10	25.0	27.5
5	Total Dissolved Solid (TDS)	Mg/l	10	10		1,315.75	1663.75
6	Total Phosphorous (TP)	Mg/l	2	2	2	12.40	11.20
7	E. Coli	uS/cm				1812.38	2987.5
8	Total Coliform count (TCC)	mpn/1000L	200	400	200	220	420

Table 2: Summary of Influents Indicators. (Source: PHwaters Wastewater Treatment Plant)

2.2 BENEFIT OF USING SBR TREATMENT PLANT TO PORT HARCOURT SURROUNDING AND INHABITANTS

- Protects the public health from disease-causing bacteria and viruses.
- Protects our water bodies from microbial and environmental contaminations.
- Reduces the level of organic loads and nutrients that enters the river.
- Prevents the growth of green algae.
- Restores sufficient oxygen to support life in our water bodies.
- Generates organic fertilizers as soil conditioner.

3.0 BIOCHEMICAL IMPACT OF SLUDGE OBTAINED FROM WASTEWATER TREATMENT PLANT ON SOIL PROPERTIES

3.1.0 Introduction.

Sludge is an essential component of the product of wastewater management. Industrial effluents have an impact on the soil, if dumb directly without further treatment and improvement. Land degradation and declining soil fertility are increasingly being viewed as critical problems affecting agricultural productivity and human welfare in tropical Africa. It has been established that over the years, there is constant and continual loss of Nitrogen (N), Phosphorus (P) and potassium (K), as a result of both natural and human cause in Port Harcourt and other parts of Nigeria. However, building up and maintaining soil fertility with inorganic fertilizers which are very expensive under the poverty faced by farmers is alarming, as the need for addition of external nutrient is imperative. A huge amount of solid wastes generated daily from the various universities, markets, hotels, homes etc, in Port Harcourt which are usually disposed off either into the sea or land as a solid amendment material can result in the formation of landfill gases, pollution of the receiving waters and water-borne diseases would be widely distributed, thus constituting health hazards to people living around the area. Worldwide, water bodies are the primary dump sites for disposal of waste, especially the effluents from industries that are near them. These effluents from industries have a great toxic influence on the pollution of the water body, as they can alter the physical, chemical and biological nature of the receiving water body. These rivers are now considered environmental health hazards due to the high concentrations of chemical and bacteriological pollution. Despite this, nearly half of the urban populations are at one time or the other, dependent on them as a source of water for domestic use and in worst cases for drinking. Discharge of untreated wastewater into the environment will pollute and decrease water quality in the rivers and soil pollution will occur when used for irrigation. Recently, one of the issues that have attracted the attention of researchers and environmentalists is wastewater chemicals and heavy metals, especially those that can penetrate the soil, plant and finally food chain. Heavy metals represent a portion of important environmental pollutants which causes pollution problems as their use in products have increased in recent decades. In spite of gradual accumulation of heavy metals in the soil, the stability of heavy metals in the environment will cause accumulation and pollution since they could not be decomposed, like organic pollutants, by biological or chemical processes. These untreated sewage wastes can, however be converted into a renewable source of energy (biogas), fuels and other valuable products, such as sludge which can be used to replenish the declining fertility of the soil. Wastewater can originate from the following; natural, human and industrial waste. Domestic sewage is mainly comprised of water (99.9%) together with moderately small concentrations (0.1%) of suspended and dissolved organic and inorganic solids. Sewage sludge is reported to be rich in N, P, K, organic matter and trace elements that are beneficial for plant growth and better yield. And it is also considered a suitable substitute for commercial fertilizers as its use in soil conditioning decreases the requirement for commercial fertilizers. Commercial fertilizers require large amount of phosphorus in its composition, whereas phosphorus is known to be a limited resource. Even though the nitrogen available in commercial fertilizers may not be a limited resource, its production requires significant amount of energy. Soils can be contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas; mine tailings; fertilizer applications; animal manures; sewage sludge; pesticides; and wastewater irrigation. Soils are the major sink for heavy metals released into the environment by anthropogenic activities and unlike organic contaminants which are oxidized to CO_2 by microbial action, most metals do not undergo microbial or chemical degradation], and their concentration persists for a long time after their introduction. The study was therefore carried out to investigate potential biochemical impact of natural organic fertilizer (sludge) that can be used to replace very expensive artificial inorganic fertilizer with little cost and side effects.

3.1.1 Materials and Methods

In order to achieve the desire results, Soil samples were collected within Port Harcourt using a hand soil auger in random replicates of three, at 20 cm depth and were bulked to form a composite sample from the control site (vegetable farm with zero sludge application) and test site (wastewater treatment plant with sludge used as soil amendment), The samples were air-dried under room temperature to ensure constant weight for 3 days. They were homogenized using a ceramic mortar and pestle to obtain finer texture and to remove sticks, pebbles and rock particles. The homogenized soil samples were then sieved through a 2 mm polythene sieve and stored in a sample container prior to analysis according to Singh et al. A 5.0 g of the sieved sample was accurately put into the flask and ignited in a muffle furnace for 6 hours, opening the cover for escape of gases at 500°C. This was checked periodically until complete ashing (a grey white ash) was obtained. The ashed samples were allowed to cool in a desiccator, and 5 ml of 10% HCl was added to each sample to enhance dissolution, and 5 ml of 10% HNO_3 was added thereafter and set on a water bath to dissolve completely. The solution was evaporated to near dryness on the water bath. On cooling to room temperature, the digest dish and the filter paper were washed into the flasks, made up to mark with deionized water. The resultant solutions from the respective digestions were kept in the refrigerator prior to metal analysis.

3.1.2 Analytical procedure

A multi-parameter (HI 98129) was used to determine the pH as well as the temperature, total dissolved solids and electrical conductivity of the samples. The multi-parameter was calibrated using the manufacturer's standard reagents.

Nitrogen: N was determined by macro kjeldahl method. 2.0 g of air-dried soil sample was digested using a dry 500 ml macro kjeldahl digestion flask and subsequently followed by distillation. Thereafter, 150 ml of the distillate was collected. The NH_4-N in the distillate was determined by titrating with 0.01 N HCl. The color change at the end point was from green to pink. Thereafter, the percentage content of nitrogen in the soil was calculated.

Phosphorus: P was determined by Ascorbic acid method. The absorbance of each sample was read at 880 nm, using a Vis S23A spectrophotometer with infrared phototube and light path of 2.5 cm, and phosphorus was calculated.

Organic carbon: OC was determined by Wet oxidation method. The organic carbon was oxidized by $K_2Cr_2O_7$ in the presence of H_2SO_4 leading to the formation of O_2 according to the equation given below:

$$2K_2Cr_2O_7 + 8H_2SO_4 \rightarrow 2K_2SO_4 + 2Cr_2(SO_4)_3 + 8H_2O + 3O_2$$

The solution was titrated using ferrous ammonium sulphate while swirling the flask until color changes from blue violet to green was observed. The burette reading was recorded, and then 0.5 ml of 1 N $K_2Cr_2O_7$ was added to the solution and titrated again with ferrous ammonium sulphate to the same end point. The burette reading was recorded and organic carbon was calculated.

Heavy metal: HM contents in the samples were determined by digestion method using GBC-Avanta PM AAS [23]. The digested sample was introduced into the AAS by direct aspiration after calibration. The results were expressed as mean ± standard deviation of the mean (SD) in triplicates. All the data obtained were subjected to the statistical ANOVA analysis of the mean, using computer aided statistical package for the social sciences (SPSS) version 20.

S/No	Parameter	Sludge	Control Soil	Test Soil
1	pH	5.86± 0.13	6.66± 0.14	6.94± 0.10*
2	Temperature (°C)	27.20± 0.10	28.17± 0.06	28.00± 0.00*
3	TDS mg/l	1190.67±19.76	20.67± 0.58	96.67± 0.05*
4	EC (µS/cm)	2350.00± 19.96	42.00± 0.00	194.00± 1.73*
5	Nitrogen (N)	2.63± 0.65	0.93± 0.04	2.37± 0.07*
6	Phosphorus (P)	20.32± 3.65	11.09± 1.15	32.89± 2.62*
7	Potassium (K)	208.69± 0.02	36.35± 0.23	32.15± 0.05*
8	Total Organic Matter (TOM)	0.48± 0.04	2.14± 0.03	3.12± 0.24*
9	Zinc (Zn)	31.70± 0.04	8.62± 0.19	19.26± 0.06*
10	Nickel (Ni)	2.66± 0.03	0.52± 0.03	1.60± 0.13*
11	Lead (Pb)	11.14± 0.02	2.58± 0.10	5.71± 0.16*
12	Total Organic Carbon (TOC)	0.28± 0.02	1.24± 0.02	1.81± 0.14*

Table 3: Physico-Chemical, Nutrients & Heavy Metals Parameters investigated on the different soil sample in mg/kg. Values are expressed as mean ± standard deviation of triplicate determinations (n=3): Key: asterisks (*) significant different at (p<0.05).

Results and Discussion

The result as shown in table 3 are categories into physicochemical parameters from serial number 1-4, nutrient parameters from serial number 6-9 and heavy metal parameters from serial number 9-12. A significant increase ($p<0.05$) was observed in the pH of the test soil sample (6.94) over the control (6.66) as shown in Table 3. This result implies that acidic soils can experience increase in pH following sludge amendment due to the exchangeable calcium and other cations present in sewage sludge. The presence of ammonium in the inorganic fertilizers usually reduces soil pH and increases the rate of soil acidification as well as increase the percentage of aluminum saturation. This study is suggestive that the sludge is suitable and more preferable to the inorganic fertilizer due to its pH increasing capacity and thus recommended for application as fertilizer.

There was a significant increase ($p<0.05$) in the total dissolved solid (TDS) of the test soil (96.67 mg/l) over the control (20.67 mg/l) as shown in Table 3. This trend suggests a significant contribution from the TDS of the sludge (1190.67 mg/l) to the soil TDS as seen in Table 3. There was also a significant increase ($p<0.05$) in the electrical conductivity (EC) of the test soil (194.00 uS/cm) when compared to the control (42.00 uS/cm) as shown in Table 3. This trends also suggests a significant contribution from the EC of the sludge (2350.00 uS/cm) to the test soil EC as seen in same Table 3.

There was a significant increase ($p<0.05$) in the nitrogen (N) content of the test soil (2.37 mg/kg) over the control (0.93 mg/kg) as shown in Table 3. This increase is expected as the sludge may have contributed its N (2.63 mg/kg) to increasing the soil nitrogen content of the test soil due to high concentration of urea and nitrogen found in sewage. Nitrogen is an essential nutrient for plant growth since it is a constituent of all proteins and nucleic acids. Normally crop yield increases with increase in the application of sewage sludge, and nitrogen is often the rate limiting factor in the application of sewage sludge to agricultural lands. Only a small part of the total nitrogen is immediately available for plants after application of sewage sludge, whereas the reverse is the case on the inorganic fertilizer. In the course of mineralization of sewage sludge, nitrogen is transformed into available forms. Sludge decomposition is reported to occur within 28 days. The amount of nitrogen mineralized is inversely proportional to the carbon to nitrogen (C/N ratio). Soils with large C/N ratio result in low quantities of mineralized nitrogen. Inorganic fertilizers by contrast increase the C/N ratio which increases organic matter mineralization and nitrate leaching. The phosphorus (P) content of the test soil (32.89 mg/kg) showed a significant increase ($p<0.05$) over the control (11.09 mg/kg) as shown in Table 3. This increase is expected as the sludge may have contributed its P (20.32 mg/kg) to increasing the soil phosphorus content of the test soil. Phosphorus is an essential nutrient needed for plant growth and is required in large quantities by plants while it is relatively immobile in soils. Phosphorus availability can be as high as 50% in the application of sewage sludge. Phosphate helps in the formation of nucleic proteins and co-enzymes for plants. Hence, its suitability for irrigation in a phosphate deficient soil.

A significant difference ($p<0.05$) in the potassium (K) content of the test soil (32.15 mg/kg) was observed when compared to the control (36.35 mg/kg) as shown in Table 3. This observed decrease may be attributed to mineral uptake by crops deficient in K within the area of study as the sludge may have contributed its K (208.69 mg/kg) to the overall build-up of the crops. The total organic matter for the test soil (3.12 mg/kg) showed a significant increase ($p<0.05$) when compared to the control (2.14 mg/kg) as shown in Table 3. This may be due to high organic matter content in the sludge (0.48 mg/kg), indicating the sludge's importance. An increase in organic matter reduces the bulk density, increases water holding capacity of soils, increases aggregate stability, and promotes greater water infiltration. Organic matter also influences nutrient storage and turnover, soil biota and diversity as well as vulnerability to erosion, infiltration capacity and air recirculation increase in fine textured soils as a result of sludge application. By contrast, the increased bulk density of fine textured soils without sludge amendment causes poor aeration which adversely affects plant growth. Sewage sludge is reported to be rich in N, P, K, organic matter and trace elements that are beneficial for plant growth and better yield. And it is also considered a suitable substitute for commercial fertilizers as its use in soil conditioning which decreases the requirement for commercial fertilizers.

There was a significant increase ($p<0.05$) in the zinc (Zn) content of the test soil (19.26 mg/kg) over the control (8.62 mg/kg) as shown in Table 3. The major sources of zinc in this site is probably the attrition of soaps, detergents, lubricating oils, found in wastewater which zinc is found as part of many additives as zinc dithiophosphates. Zinc is essential to plants and animals in very low concentrations by serving as components of enzymes, structural proteins, pigments and also helping to maintain the ionic balance of cells. These and other trace elements are important for proper functioning of biological systems. Even though zinc is an essential requirement for a healthy body, excess zinc above 25 mg/kg can be harmful, and cause zinc toxicity. Nickel (Ni) showed a significant increase in the test soil (1.60 mg/kg) over the control (0.52 mg/kg) as seen in Table 3. This may be due to accumulation of heavy metals from the sludge. The supply of various bio-solids for example: composts, cattle's manure and municipal sewage sludge (MSS) to land unconsciously points towards the build-up of heavy metals like nickel in the soil. Heavy metals most usually established in bio-solids include Ni, Pb, Zn, Cr, Cu, and Cd, and the metal contents are ruled by nature and the strength of the industrial processes. Under specific situations, metals supplied to soils by applying bio-solids can be percolated downwards by the soil horizons and may have the ability to pollute groundwater. There was also a significant increase ($p<0.05$) in the lead (Pb) and total organic carbon (TOC) for the test soil (5.71 mg/kg; 1.81 mg/kg) respectively when compared to the control (2.58 mg/kg; 1.24 mg/kg) respectively as shown in Table 3. Organic carbon in sludge amended soil can increase as far as three-fold compared to inorganic fertilizer amended soils.

4.0 CONCLUSION

Port Harcourt is situated in watershed area and has been faced with several water management problems. The activities of the oil and gas industry has impacted negatively on both surface and rain water. In addition, the discharge of wastewater indiscriminately into the surrounding surface water increases the threat of water pollution and reduces the availability of water resources. In spite of big effort on water availability and water supply for the growing population in Port Harcourt, and though legislative, organizational upgrading of the management of water sector, a big delay has to be catch up in the sanitation and wastewater treatment. The high costs of conventional treatment processes have led state government to search for creative, efficient and environmentally sound ways to control water pollution. The development of simple and cost-effective water treatment aerobic sequencing batch reactor is of interest to Port Harcourt. These processes that use relatively more and are lower in energy and operational costs are becoming attractive alternatives for many wastewater treatment applications. The sludge obtained from wastewater treatment becomes natural organic fertilizer, which is an alternative source to enrich the soil for better crop yield all year round.

5.0 REFERENCES

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