NATIONAL UNIVERSITY OF LESOTHO

Department of Chemistry and Chemical Technology

Characterisation and Application of Municipal Sewage Sludge to Agricultural Land in the Maseru Metropolitan Area

CTEC 404 Project – Report of a research project submitted to the Department of Chemistry and chemical Technology in partial fulfilment of the requirements for the BSc. Chemical Technology Degree

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Declaration

I hereby verify that this written document is my own individual work and contains my own individual ideas, concepts and designs. No portion has been copied in whole or part from another source, with possible exception of properly referenced materials.

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Abstract

The nutrient content and other important properties of the sewage sludge from the Wastewater Treatment Plant at Ha Ratjamose in Maseru were determined. In addition, the sludge was characterised in terms of its, pH, salinity, TDS and temperature. The sludge was found to contain 0.011 - 0.013 (wt%) PO_4^{3-} and 0.018 - 0.070 (wt%)NO_3^- with D/R 2000 Spectrophotometer. The values for some important physical properties were found to be as follows: pH,(6.35-6.59); conductivity,(335- 1674μScm^{-1}) , salinity,(0.00-0.6) , total dissolved solids (TDS) ,(355-1576mgL^{-1}) and temperature ,(24.1-25.5°C). The sludge was found to contain considerable amounts of nutrients, but lower than those found in commercial chemical fertilizers. It was also slightly acidic, hence it can be more appropriate if applied to strongly alkaline soils or be stabilized with alkalis if it is to be applied to neutral of acidic soils.

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Chapter 1 - Introduction

1.1 Background of the Study

Sewage sludge or the bio-solids is the mixture of water and the solids that results as by-products from the treatment of wastewater. The dewatered form of sludge is commonly referred to as sludge cakes. Sewage, and hence the sewage sludge, has the wide range of composition depending upon the source and type of wastewater as well as the treatment methods applied. Wastewater may originate from various places, such as residential areas, institutions, agricultural and industrial establishments, etc. As a consequence of the varying composition, the toxicity of the sludge also varies. Therefore for the sludge or the treated wastewater effluent to be used for another purpose or discharged into the environment, it has to be further treated to make it safe (Kenney, 2003).

In most wastewater treatment plants, two treatment stages are involved - the primary and secondary treatments. In primary treatment the insoluble and debris are removed. The heavier particles, such as human faecal matter settle at the bottom while greases oils and other floatable material go on top. The floatable debris is removed from the wastewater. This process is sometimes referred to as screening. The resulting wastewater is fed into the secondary treatment. If operated efficiently, the primary treatment can remove up to 80% of the total solids (Dow and Hafsi, 1998). In the secondary treatment phase, micro-organisms are introduced into the water to degrade any dissolved organic matter. The micro-organisms release their metabolites as insoluble solids, which can be easily removed from the water by physical processes (Milieu Ltd, 2008). The sludge is then concentrated or dewatered so that it is easily prepared for safe disposal. Chemicals reagents, such as ferric chloride are sometimes used as a flocculent to increase the efficiency of separation.

In spite of the toxicity, wastewater sludge has a wide range of application in agricultural and fuel-producing industries. Wastewater sludge is digested under anaerobic conditions to produce methane (Franklin Associates, 2011). Application to cropland is the major agricultural use of wastewater sludge. This is due to its high content in plant nutrients – nitrates and phosphates and organic matter. Hence it is used as a substitute for chemical fertilizers (Milieu Ltd, 2008).

The application of wastewater sludge in crop farming is an old practice and it is so widespread that most countries have formulated laws and regulations that govern and monitor its use. The regulations ensure that composition of the sludge poses no detrimental impacts on both human and environment. Thus the pathogens, chemical pollutants and vector attraction reduction is carefully controlled and monitored by these regulations. For instance, sludge is injected as a liquid under the soil or spread on the surface followed by mixing with the soil to reduce the attraction of the vectors (Franklin Associates, 2011). Furthermore, the maximum concentration limits for heavy metals, such as Cd, As, Mo Cr, and Hg in sludge meant for agricultural application and land reclamation, are well established.

In Lesotho a large proportion of the population, especially in the rural areas, depends largely on small-scale crop farming for their subsistence. Thus use of the wastewater sludge has become an advantage to these farmers, because it is cheaper, and achieves satisfactory yields of crops. In recent years, the rate at which the farmers have been scrambling for this material has aroused an interest in studying the composition of the wastewater sludge, not only for nutritious assessment, but also health and environmental risks are of major concern.

1.2 Aims and Objectives

The composition and properties of sewage sludge has important bearing on decision-making on the following issues: the suitability of the sewage sludge for application on cropland, cost-effectiveness of land application, which land application practice (agricultural, forest, land reclamation , public parks, other public contact sites), quantity of sewage sludge to be applied per unit area, quantity of sludge for both annual and cumulative application, the degree of regulatory control and the monitoring system required. These factors are vital for the safe application of sledge to for any agricultural purpose.

However in Lesotho, even though sludge is applied to land on a large scale by farmers, and it appears to be the only method of sludge disposal, there are no regulatory and monitoring systems for that use. Moreover, the composition of sewage sludge is not known and the sewage sludge properties have not been characterized. There is no classification of sewage sludge and hence no crop restrictions for sludge application. The farmers using the sludge have no technical support on its application, that the application rates – the quantity and frequency and the handling of the material - health risks, etc.

With this background, the aims of the study are to determine the composition of the sewage sludge from the Wastewater Treatment Plant at Ha Ratjomose in Maseru, characterize the properties of the sludge and hence determine its suitability for application on cropland. Such data will help us to establish the cost effectiveness of application of the sludge to cropland, the quantity of sludge to be applied per unit area, the degree of regulatory control and monitoring systems that would be required

Chapter 2 - Characteristics of the municipal sewage sludge

The characteristics of the wastewater influent entering a wastewater treatment works and the treatment processes employed are the principal determinants of the composition of the wastewater sludge. In general, sludge generated from wastewater from an industrialized community will have a greater possibility of being laden with heavy metals and other toxic chemicals. Sewerage systems in urban area also transport besides domestic sewage, industrial effluents and storm-water runoffs from roads and other paved areas. All these are usually discharged into public sewers. Thus sewage sludge from most urban sewage treatment plants will contain organic waste material, traces of many chemical pollutants used in modern societies. Many of these chemicals are found to be toxic to humans and animals, while others are phytotoxic (Dean and Suess, 1985). It is thus vital that the levels of these substances are controlled if the treated wastewater or sludge generated is to be discharged into the environment or applied to agricultural land application to the soil. The risk to health of chemicals in sewage sludge applied to land has been reviewed by that may pose a potential health and environmental risk if sludge generated from such wastewater is applied to land.

Sewage sludge also contains pathogenic bacteria, viruses and protozoa along with other parasitic helminths, which can give rise to potential hazards to the health of humans, animals and plants. Apart from those components of concern, sewage sludge also contains useful concentrations of nitrogen, phosphorus and organic matter

2.1 Plant nutrients

Wastewater sludge has been found to support growth and life of the crops satisfactorily and is presently being used as an effective supplement for the commercial fertilizers. Such property is due to the considerable levels of nutrients. Generally the common plant nutrients found in sewage sludge are nitrates, phosphates and potassium. The concentrations of these nutrients are very important in determining the quantities to be applied to land and the rates and frequency of application. Though vital for plant growth, but when the nutrient levels are in high excess due to high application rates of the sludge this can lead to serious environmental consequences. Leaching of the nutrients can contaminate groundwater and as well as surface waters. Potassium, calcium, magnesium, iron, nitrogen, phosphorus and sulphur are the necessary elements for the plant growth (Rost et al, 2006).

2.1.1 Phosphates

Municipal wastewater sludge contains a wide range of concentrations of other macro- and micronutrients that are necessary for plant growth. Some sludge constituents, such as phosphorous (P), calcium (Ca), magnesium (Mg), and iron (Fe), readily form insoluble compounds with sludge solids and thus remain at relatively high levels in sewage sludge. Other sewage sludge constituents, such as potassium (K) and sodium (Na), are water-soluble and are discharged with the treated wastewater, unless special advanced treatment processes are used to remove them. For the water-soluble constituents that do remain in the sludge, dewatering of sludge e.g., by centrifuging sludge, air or heat drying, will result in increased levels because these constituents are non-volatile.

2.1.2 Nitrates

Nitrogen is a major plant nutrient found in sewage sludge. It can be present indifferent forms- as inorganic nitrogen or organic nitrogen. The common inorganic forms are nitrates and ammonium ions. The nitrates are the most important nitrogen nutrients for plant growth and development. It is also this form of nitrogen that can easily leach to contaminate groundwater, because it is highly water-soluble. In the form of ammonium ions, inorganic nitrogen is not beneficial to plants. It is readily converted to ammonia in the soil. Organic nitrogen if present in sludge is considered as a slow release form of nitrogen. For it to be utilized by plants it must first be degraded by soil microorganisms and be converted to nitrates.

2.2 Organic matter

The amount of organic matter in sludge has a direct impact on soil properties and hence on plant growth. The microbial degradation and transformation of organic matter enhance the availability of trace elements for plant uptake. The amount of organic matter in sludge is attributed to organic component usually from domestic sewage. Sludge is used as a soil conditioner to improve the physical properties of soil, such as water-holding capacity and increased water infiltration. This kind of application is due to the relatively high organic matter usually found in sludge. The high level of organic matter in sludge has also made it a good use in land reclamation.

2.3 Microorganisms

A normal constituent of municipal sewage sludge is potential disease-causing microorganisms, which include bacteria, viruses, protozoa, and eggs of parasitic worms. These microorganisms are an environmental health risk and hazard, if not properly managed. They can contaminate food crops if applied to cropland; they can be also transported by vectors, such as insects, birds, birds and rodents. To this end, sewage sludge, which is intended for land application is stabilized either chemically or biologically to reduce Reduces pathogen levels and controls putrescibility and odour.

The presence of microorganisms in the wastewater sludge had not been given much attention in the few past decades because people were more concerned about its nutritious value. Nevertheless, people gradually became conscious about the potential hazards and subsequent risks imposed by the wastewater sludge. Studies showed that most of the contagious diseases from the wastewater sludge are due to the presence of microorganisms, mainly bacteria (faecal coliforms and enterococci), protozoa, viruses and helminths (Matsau, 2005).

Microorganisms, especially bacteria, can persist even in severely harsh conditions. The species have a protective cell wall around their structures which can protect them from such detrimental conditions. Bacteria can be found in high temperatures, acidity of hot sulphur springs even in arid areas of deserts (Boyd, 1988). For this reason, care must be taken in applying sludge cakes which are heavily loaded with microorganism in croplands, as these may persist until the harvest time.

Sewage sludge has been classified into four categories according to the improving microbiological quality (Matsau, 2005). Type A sludge is strictly prohibited in croplands. It is heavily loaded with microorganisms thus pose much danger on both environment and health. The recommended sludge on the fields is Type B. However this still requires careful control to avoid detrimental exposures of microorganisms to human beings. To ensure safety, this sludge is anaerobically digested or waste activated before it can be recommended for use in the croplands. The other classes are Type C and D, which are of acceptable microbial quality provided their metal and inorganic contents are within accepted limits. Type D sludge is the friendliest among all classes of the wastewater sludge; it is normally used without restrictions especially concerning microbiological quality.

The collection of microorganisms for analyses requires skills and carefully controlled mechanisms. The cleanliness or sterility of the sampling equipment is one of the issues which must be well recognised during sampling since microorganisms reside almost everywhere. Contamination in the sampling material would definitely increase the pathogenic concentration hence results not reflect the actual concentration. Furthermore, some organisms survive only within their hosts; once taken out, they die. Virus is one of the organisms which survive only in the living host (Boyd, 1988). The analysis of such organisms is therefore not easy.

The bio-aerosols or microorganisms are collected on a semi-solid nutrient agar and then followed by incubation for several days to identify and quantify the cells that have grown. The mounds of cells are counted as colony-forming units (CFU) for bacteria or fungi and plaque- forming units (PFU) for viruses.

2.4 Toxic Metals

Sewage sludge may contain varying amounts of metals; at low concentrations in soil, some of these metals are nutrients needed for plant growth and are often added to inorganic commercial fertilizers. But at high concentrations, some metals may be toxic to humans, animals, and plants. The heavy metals of the most health and environmental safety concerns are arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, zinc The concentrations of these metals in sewage sludge are dependent on the source, type and amount of wastewater from which the sludge is generated. Generally, the levels of these heavy metals are higher in the sludge than the treated wastewater, because of the insoluble form in which they occur in wastewater.

The earth's crust is the main source of metals, however they are not always found concentrated in large quantities in one region except the few regions where precious minerals are found and mines are usually established. Apart from the mines, the main sources of metals into marine systems are industrial effluents and chemical wastes from both domestic and institutional places.

The toxicity of a metal may depend on its concentration, oxidation state or chemical form. Those metals whose toxicity is observed when present in large quantities are considered non-toxic while those whose lethal dosages are few milligrams are considered very toxic. Cr(III) is an essential nutrient but very toxic as Cr(VI) and on the other hand the toxicity of alkylated mercury is exacerbated (Manahan, 2001). The most notorious heavy metals include Arsenic, cadmium, mercury, lead and molybdenum.

Arsenic is considered an acute poison and a potential carcinogen. It is mainly introduced in the human body via drinking and eating contaminated food stuffs. Molybdenum is essential to plants but very toxic to animals at above certain concentrations. Lead and mercury bio-accumulate in the body of organisms and these metals cause serious problems more often in communities. The reason being they are intensively used for daily activities. Lead is heavily used in paints and soldering mixtures. Both lead and mercury affect the brain and the central nervous system as a whole (Simpson and Curtis, 1974).

Their presence in large quantities, in wastewater sludge, poses a greater threat to people especially when the sludge is used in croplands. The plants absorb the metals by active transport since some of them are necessary elements for the plants' growth. The metals would stay in the plants' structures until consumption by man. It has been claimed that a careful control of pH in the fields can minimise the uptake of heavy metals by the plants. Keeping the soil pH around neutrality or slightly alkaline minimises the uptake of heavy metals by plants (Vanloon, 1973).

The metal content of the wastewater sludge which is used for agricultural applications must therefore be carefully and accurately controlled. This would lead to a sustained health and well-being of the community at large.

2.5 pH

The pH of sewage sludge can affect crop production at land application sites by altering the pH of the soil and influencing the uptake of metals by soil and plants. The major reasons for adjusting pH of sewage sludge are the control of the levels of microorganisms and vectors and availability of nutrients and metal. Sewage sludge of low pH sludge, less than pH 6.5, enhances leaching of heavy metals, while high pH sludge, greater than pH 11, can destroy many bacteria that are vital to soil fertility. When applied on neutral or alkaline soils sewage sludge can inhibit movement of heavy metals through soils.

Alkali stabilization of sewage sludge through the addition of alkalis raises the pH of sewage sludge, temporarily decreases biological activity, reduces pathogen levels and controls putrescibility and increases the dry solids mass of the sewage sludge. Because pH effects are temporary, decomposition, leachate generation, and release of gas, odours, and heavy metals may occur over time.

2.6 Total Solids Content

The total solids (TDS) content of sewage sludge can impact on its application. It can affect the land application design in many ways. These include the size of transportation and storage systems; the higher the solids content, the lower the volume of sewage sludge that will have to be transported and stored because less water will need to be handled; the method of sewage sludge application and the storage method.

In terms of cost it is generally, it is less expensive to transport well dewatered sewage sludge, i.e. sewage sludge with a high solid content than to transport liquid sewage sludge, i.e. sewage sludge with low solids content.

Chapter 3 - Benefits and hazards of application of municipal sewage sludge to land

3.1 Benefits of sludge application to agricultural land

Growers who use sludge as a fertilizer have highlighted the following advantages: they can use sludge alone or as a supplement to commercial fertilizers; sludge can be obtained at little or no cost; and most growers or farmers live near small cities and municipalities; therefore, sludge can be easily obtained at a little or no cost as it removes the burden and cost of disposal from the management of wastewater treatments plants.

Wastewater sludge is a cheaper alternative source of plants nutrients. For this reason, farmers have gained an advantage of getting more output for the corresponding minute input as compared to when using commercial fertilizers as nutrients sources. This economical advantage is not only beneficial to the farmers but also to the treatment plants. After production, sewage sludge requires proper disposal so that it does not harm the environment. Most of the disposal methods are not economically friendly compared to applying the sludge on agricultural fields. As such, the application of wastewater sludge on the croplands is cheaper method of disposal.

Cattle-farming is among the major industries which have sustained the economy of countries such as Botswana. The large number of these animals in an area ultimately leads to overgrazed lands. This becomes a major problem in sub-desert countries such as Botswana. However, the application of sewage sludge on the grazing lands tends to replenish them with forage within satisfactory time frames and the industry continues with maximum profits. In South Florida, United States of America, bio-solids have been applied on pastures for the growth of perennial grass (Spongberg and Czajkowski, 2011).

Sewage sludge is rich in organic matter. Its application on the agricultural or forest land increases the microbial activity and more minerals are extracted from the organics. This increases the nutrient content of the sludge by releasing any organic-bound essential nutrients. Studies have showed that the application of sewage sludge stimulates the soil microbial activity because of an increased carbon and nutrients content (Bettiol and Ghini, 2011). The organic matter of the sewage sludge also conditions the soil; water retention capacity which in turn reduces soil erosion and nutrients leaching is increased (Coles, 1988).

3.2 Hazards of Sludge Application to Agricultural land

As it has been seen in the preceding discussion, wastewater sludge is not only nutritious to plants but also contains harmful and hazardous substances to both health and environment. Microorganisms, toxic metals, strong smell of decaying matter as well as the increased pH are among the parameters that make the sludge not very friendly to use.

The sludge cakes provide nutrients to the plants but this can be intolerable if applied in large quantities. The increased mineral content in soil results in percolation of such minerals, mainly nitrates, into the underground water table or run-off into the surface water reservoirs during heavy rains. This happens because some of these minerals are not spent by the plants hence readily available to be washed away. In surface waters, the nutrients, especially phosphates, increases the growth rate of the algal plants. As such, the plant biota largely exceeds that of animal. The ultimate result is eutrophication.

Techniques have been devised on how to apply the sewage sludge on the croplands. Mineralization factors have been established for different types of sewage sludge and these help in the calculations of application rates of the sewage sludge per unit area of land (College of Agricultural Science, 2011).

The continuous application of sewage sludge on land affects the soil adversely. The more the sludge applied the more the content of metals and the increased conductivity of the soil. The increased content of the heavy metals in the soil results in high content of these elements in crop grains which ultimately enter the food chain. The potential toxicity of these metals, to man have been previously discussed. Therefore, the metal content in soil increases the toxicity to health.

The conductivity of wastewater sludge also affects the nature of soil. The higher the conductivity results into the conductivity of the soil being raised while the lower conductivity would also raise the soil conductivity but not very much. The highly conducting medium supports the oxidation and reduction reactions. The oxidation states of the metals and non-metals present in the soil would change hence the variation in the soil toxicity. For instance, some organic compounds may be chlorinated to yield more toxic and carcinogenic compounds (Ibanez, 2004).

Human beings are the major targets susceptible to the toxicity of sludge applied in croplands. The defence mechanisms of humans to potentials toxins are very different from those of other animals and This is why the threshold dosages for human beings are always lower than that of animals by a factor of 100 (Brunton and Parker, 2008). The presence of disease-causing microorganisms in waste sludge is the major threat to the well-being and comfort of man. These species can be carried by air to humans or reside on plants harvests and enter the human body during feeding.

A large number of microorganisms which cause different diseases is found in the sewage sludge. Not least to mention but few, Escherichia Coli is responsible for urinary infections and diarrhoea in man while Mycobacterium tuberculosis and leprosy (Matsau, 2005).

Chapter4 - Experimental

4.1 Selection of parameters

Both chemical and physical parameters are of utmost importance in characterising the waste that would ultimately be released into an environment. The selected parameters in this study include pH, salinity, conductivity, Total dissolved solids (TDS), temperature, disease-causing bacteria such as Escherichia Coli. The chemical parameters focused mainly on metals and nutrients (phosphates and nitrates). All these parameters are ~~the~~ major factors which alter the normal functioning of the ecosystems once their values exceed the accepted levels.

4.2 Sampling

Four samples of the dewatered waste sludge were collected from the Water and Sewage Authority (WASA) treatment plant at Ha Ratjomose, Maseru. At the plant, sludge is put in different dewatering cells to dry. At the time of sample collection, only four cells had contained sludge. The dry, upper portion of the sludge was collected in 250ml beakers which were then sealed with parafilm and then taken to the laboratory for analysis. Two samples of the raw wastewater were collected and treated in exactly the same way as the waste sludge. The two samples were collected at the inlet to the treatment plant. These samples were to determine the efficiency of the removal of treatment process.

Couple of readings were done on-site as some of the selected parameters are time and temperature dependent. For instance, the pH would change due to microbial activity responding to changes in temperature and oxygen content.

4.3 Sample Digestion and Analysis

In the laboratory the samples were air-dried at room temperature for three days. The samples were then crushed into smaller particles by mortar and pestle. 15g of each sample was weighed into a 250-ml beaker and digested with a mixture of concentrated H_2SO_4 and HCl in the ratio of 3:1. The samples were then heated until the white fumes of SO_2, were evolved. The samples were filtered and the final solution was made up to 100 ml -, i.e the stock solution. The stock solution was diluted 25 times to give the working solution.

Upon reaction with carbon containing compounds, sulphuric acid reacts with carbon as follows,

$C(s) + 2H_2SO_4\ (conc.) \rightarrow 2SO_2\ (g) + CO_2(g) + 2H_2O(l)$

This reaction releases any soluble compounds into an aqueous solution for further analysis.

The filtrates were coloured brown and therefore 30% hydrogen peroxide was used to decolourise them.

The samples were analysed spectrophotometrically for phosphates and nitrates according to the DR/2000 Spectrophotometer Handbook, but not the blank.

Some selected parameters could not be determined because of the time constraints and the malfunctioning of the equipment in the laboratories. For instance, ICP-AA could not work to determine the metal content in sludge.

Chapter 5 - Results and Discussions

5.1 Parameters determined on-site

Table 1- Physical properties of the sludge

Parameters	Sample1	Sample 2	Sample 3	Sample 4
Salinity	0.6	0.00	0.00	0.00
Temperature/ ˚C	25.5	25.5	24.1	24.3
TDS/ mgL^{-1}	1576	355	484	475
Conductivity/ μScm^{-1}	1674	335	492	467
pH	6.35	6.59	6.35	6.42

Table 2- Physical properties of the raw wastewater

Parameters	Sample1	Sample2
Salinity	0.6	0.4
Temperature/˚C	24.7	26.5
Conductivity/ μScm^{-1}	1578	1600
TDS/ mgL^{-1}	1553	1612
pH	7.18	7.27

5.2 Phosphates Determination

Table 3 - Amount of phosphates in working solutions (mgL^{-1})

Waste sludge				
Replicate samples	Sample 1	Sample 2	Sample 3	Sample 4
a	0.62	0.75	0.63	0.64
b	0.76	0.73	0.64	0.73
c	0.68	0.76	0.70	0.70
Mean	0.69	0.75	0.66	0.69
Wastewater				
a	0.22	0.28	-	-
b	0.21	0.27	-	-
c	0.22	0.29	-	-
Mean	0.22	0.28		

Table 4-Concentration of phosphates in stock solutions of sludge and raw water effluent

Sludge			
Sample	mgL^{-1}	$mgPO_4^{3-}$/kg sample	Wt%
1	17.25	115	0.012
2	18.75	125	0.013
3	16.50	110	0.011
4	17.25	115	0.012
Raw Water			
1	137	138.9	0.014
2	175	176.8	0.018

Table 5- Amount of nitrates in working solutions of sludge and raw wastewater(mgL^{-1}N NO_3^-)

Waste Sludge				
Replicate samples	Sample 1	Sample 2	Sample3	Sample 4
a	0.6	1.1	0.3	0.3
b	0.5	0.8	0.2	0.4
Mean	0.55	0.95	0.25	0.35
Wastewater				
a	0.3	0.2	-	-
b	0.3	0.1	-	-
c	0.2	0.1	-	-
Mean	0.27	0.13		

Table 6- Concentration of NO3- in stock solutions of sludge and raw waste water

Sludge				
Sample		mgL^{-1} NO_3^-	mg NO_3^-/kg sample	Wt%
1	Sludge	61.0	406.7	0.041
2	Sludge	105.2	701.4	0.070
3	Sludge	27.7	184.6	0.018
4	Sludge	38.8	258.4	0.026
Raw water				
1	Water	7475	7550	0.76
2	Water	3599	3636	0.36

Table 7- Concentration of nutrients in the sludge and raw waste water

Nutrients	Method	Sample	mg/kg sample	Wt%
Phosphates	DR/2000 Spectrophotometer	Sludge	110 - 125	0.011 - 0.013
		Waste water	138.9 - 176.8	0.014 - 0.018
Nitrates	DR/2000 Spectrophotometer	Sludge	184.6 - 701.4	0.018 - 0.070
		Waste water	3636 - 7550	0.36 - 0.76

5.3 Discussions

The physical parameters for the sludge were as following; pH 6.35-6.59, TDS 355-1576mgL^{-1}, Conductivity 335- 1674µScm^{-1}, salinity 0.00-0.6 and temperature 24.1-25.5˚C. For the wastewater, the parameters were 0.4 -0.6 salinity, temperature 24.7 -26.5˚C, Conductivity 1578 -1600 µScm^{-1}, TDS 1553 -1612 mgL-1 and pH 7.18- 7.27. The nitrates were found to be in the range 184.6 - 701.4mg NO_3^-/kg sludge and 3636 -7550mg NO_3^-/ kg Raw wastewater. The phosphates were in the range 110 – 125mg PO_4^{3-}/ kg sludge and 138.9 - 176.8 mg PO_4^{3-}/ kg wastewater.

The pH of the sludge was slightly acidic whilst that of the wastewater was slightly alkaline. For wastewater sludge to be applied on croplands, the pH must be slightly alkaline to neutralise any acidity that may be present in soil, stabilise organic matter and reduce the pathogens (College of Agricultural Science, 2011). The soil acidity can be attributed to microbial activities as well as acid rains in areas where photochemical smog is present. The plant growth is tolerable around neutrality thus applying this sludge on the fields would not yield desired quality of crops.

Salinity is the measure of saltiness of a sample and a salt is an ionic compound that results from an acid-base reaction (Silberberg, 2000). On the other hand, conductivity (κ) can be simply defined as ability of the ions in a substance to move and conduct electricity.

Strong electrolytes conduct electricity easily and the substances with higher salinity are therefore expected to be good conductors of electricity. Waste water treatment plants are not allowed to treat the sewer which has the conductivity more than $500mSm^{-1}$ or $5000\mu Scm^{-1}$ (Levlin, 1998). At high conductivities, the waste water causes corrosion in sewage pipe networks. The observed conductivities of both the wastewater and waste sludge are lower than 5000µScm-1 which implies that the sludge cannot impose any electrochemical problems in an environment. The lower salinity also shows the minute presence of ions. This support the lower conductivity observed.

Total dissolved solids (TDS) is another important parameter in characterising the quality of natural waters. The higher the number of these solids in water, the more they reduce the water quality. Microorganism act on such material and the resulting products, depending on their toxicity, can harm the aquatic system adversely. In countries such as New Jersey, the total dissolved solids are not expected to exceed $500mgL^{-1}$ (Patoczka and Mcdonald, 2006).

For a litre of waste water, the WASA treatment plant mages to remove 723mg out of 1583mg dissolved solids-i.e., 45.7% .This leaves 860mg (54.3%) of the solids in water. The removal efficiency is too low according to accepted standards **(**$500mgL^{-1}$**)** and this needs to be improved.

Waste waters typically contain up to $25mgL^{-1}$ of total phosphorus and the wastewater treatment plants must remove the concentration down to below $0.5mgL^{-1}$ (Manahan, 2001). This ensures the inhibition of rapid growth of algal plants in aquatic regions. The 110 – 125mg PO_4^{3-}/ kg sludge of phosphates in the sludge shows the relatively high efficiency of phosphorus removal from the wastewater. It must be noted that the concentrations in the water effluent do not reflect the direct correspondence to those of the waste sludge because the effluent from which the sludge resulted was treated long ago and its concentration would be very much different from the concentration of the effluent when the sampling for this study was carried out.

The commercial fertilizer which supplies the least amount of phosphorus to plants is known as rock phosphate fertilizer and it delivers 3-8% of phosphorus while mono-ammonium phosphate fertilizers deliver the highest percentage, 48% (www.extension.umn.edu/distribution/cropsystem). The obtained 0.011 - 0.013 wt% in this study is too small for the sludge to be used as a source of phosphates in the croplands.

Generally, the wastewater sludge is said to be rich in nutrients if it contains 5% N, 3% P and 0.5% K on a dry weight (Manahan, 2001). The lower weight percent of the nitrates also shows lack of nutrients in the sludge. As such the sludge is generally a poor source of nutrients and cannot be expected to give satisfactory results if applied on croplands.

6.0 Conclusions and Recommendations

The sludge was found to contain too low nutrients: phosphates - 0.011 - 0.013 (wt%) and nitrates - 0.018 - 0.070 (wt%). The concentrations were too low compared with commercial fertilizers. However previous work has shown a considerable high level of nutrients, comparable with commercial fertilizers. This is an indication that there are great variations in the inlet wastewater coming into the treatment plant (Mohase, 2009).

The pH of is also not tolerable for use in crop plantations. However it can be stabilized with alkalis to reduce the acidity, or can be applied to highly alkaline soils. The determinations are still yet to be done in future when chance is available.

Further work need to be done to completely characterise the sludge in order to determine its suitability to cropland application.

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