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Research Article

Heavy Metal Potential of Domestic Biological Wastewater Treatment Plant Sludge

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Abstract The use of sludge as fertilizers helps to the recycling of nutrients to the environment due to its beginning from wastewater and therefore relatively high content of nutrients and organic matter. However, wastewater does also contain hazardous compounds like heavy metals and micro pollutants which eventually are separated to the sludge during the treatment processes at the wastewater treatment plant. In order to improve the sludge quality, source tracking is a relatively cheap and effective way to find and eliminate hazardous compounds and prevent them from ending up in the sludge. The aim with this thesis was to investigate the fertilizer potential in sludge from wastewater treatment plant. The sludge is analyzed in terms of nutrient and heavy metal contents as well as physiochemical parameters. In order to determine the potential as fertilizer, the quality of the sludge is compared with other fertilizer alternatives, other sludge types and regulations for sludge use in agriculture. The work with sludge quality improvements in Gaborone is also investigated. Sludge from different stages along the treatment processes were collected in order to see differences in quality related to the treatment. The results shows that the samples of primary an aerobically treated sludge tend to have higher heavy metal content than the secondary sludge. The quality of the dry sludge samples indicates lower nutrient content than both the primary and secondary sludge, but similar heavy metal content. The analysis of dry sludge from indicates a low nutrient value and high heavy metal content in comparison to other selected fertilizer options and sludge from other. The processes for removal of nutrients from the wastewater are an important factor for the nutrient content in the sludge.

Keywords *wastewater; fertilizers; nutrients; sludge treatment*

1. Introduction

The use of fertilizers in agriculture has for a very long time improved the life situation for people all over the world because of increased crop growth. However, as the population increases, the demand for food and fertilizers is also increasing [1]. The way that nutrients for fertilizer are extracted and used today is not sustainable in all manners and there is a great need of finding innovative solutions for returning nutrients to the agriculture.

There are several different types of fertilizer products used on the market today; artificial fertilizers, manure, dig estate from biogas production and sewage sludge for example. Still a fertilizer must be able to meet certain requirements in order to be used on the agricultural market. The main requirements for a fertilizer is that it should contain high content of plant nutrients like nitrogen, phosphorous, potassium etc., and also be free from hazardous compounds and heavy metals [2]. In addition to this, it is also desirable that the fertilizer will improve the soil structure and be convenient to handle with the current used agricultural machinery [3].

Water consumption of the communities is increasing day by day. Every community produces both liquid and solid wastes. When the water and waste combines together it produces wastewater. As the amount of water consumption for human activities increase day by day, the production of wastewater is also increase day by day. This was a huge problem for the establishment of equilibrium in nature. To overcome this issue wastewater engineering was started. Wastewater engineering is a branch of environmental engineering. The major task of wastewater engineering is to control the water pollution by using basic principles of science and engineering [4].

The production of wastewater in Sri Lanka is comparatively high, as we consume a lot of water annually. Because of that large quantity of wastewater production, we have to treat them and reuse them. In the wastewater treatment process sludge treatment is one of the major parts that have to pay much attention. The sludge resulting from wastewater treatment operations and processes is usually in the form of a liquid or semisolid liquid typically, waste water contains an amount of solid waste weighting from 0.25% to 12% [5]. Processing and disposal of sludge is the most complex problem which engineers faced. Nowadays, the sludge of wastewater treatment plant is used as a backfill material, building material and as an alternative fuel source.

Using wastewater treatment plant sludge as a fertilizer is another option that engineers recommend. Direct use of treatment plant sludge for agricultural applications is not recommended by engineers because of the amount of heavy metals, toxic chemicals, fecal contaminants and other hazardous wastes it contains. But comparatively domestic wastewater has low rates of heavy metals and hazardous wastes and due to that we can improve a method to use domestic wastewater sludge as a fertilizer. In Sri Lanka lots of wastewater plants have been established to treat industrial wastewater. There is less number of treatment plants in which only domestic wastewater can be treated. To treat and use the domestic wastewater sludge as a fertilizer in a most effective manner, there should be a knowledge regarding the characteristics of the sludge and solids that produced by domestic wastewater. Wastewater treatment has different stages and it is very important to know about these different stages and what are the characteristics of the solids and sludge produced during wastewater treatment at each stage.

Especially organic and inorganic materials, fecal contaminants, chemical composition at different stages of wastewater treatment should be considered [4]. Nowadays most of the countries in the world have motivated to use wastewater treatment plant sludge as a fertilizer. In Sri Lankan there is no proper plan to use sludge as fertilizer.

1.1. Significance of the research

Disposal of wastewater treatment plant sludge is one of the huge problems. To overcome this issue, it is good solution that uses the sludge as fertilizer. Through this research it will be able to find the fertilizer potential of domestic biological wastewater treatment plant sludge.

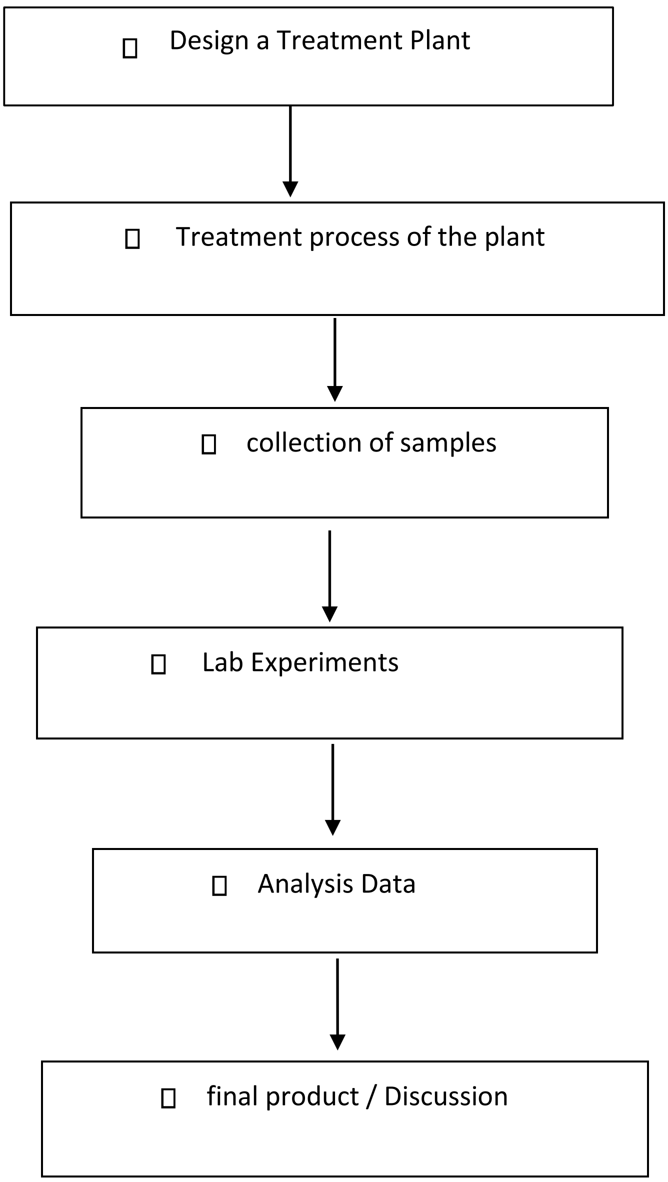
1.2 Scope of the study

In Sri Lanka, most of the wastewater treatment plant sludge is used as a backfill material or building material. There is a potential of this sludge being used as a supplement to fertilizer. Therefore, it is necessary to check the fertilizer potential of wastewater sludge. It will be able to identify the fertilizer potentials according to the NPK ratios of different stages of wastewater sludge.

1.3. Aims and Objectives of the research

1. Identification of heavy metal contamination level of the selected plant wastewater sludge.
2. Develop a method to remove above contaminants.
3. Identification of NPK ratios of selected wastewater treatment plant sludge at different stages.
4. Comparison of NPK ratios between selected fertilizers and Wastewater treatment plant sludge.
5. Investigation of plantations which can use this sludge without any harm.

2. Methodology



2.1. Design a Treatment Plant

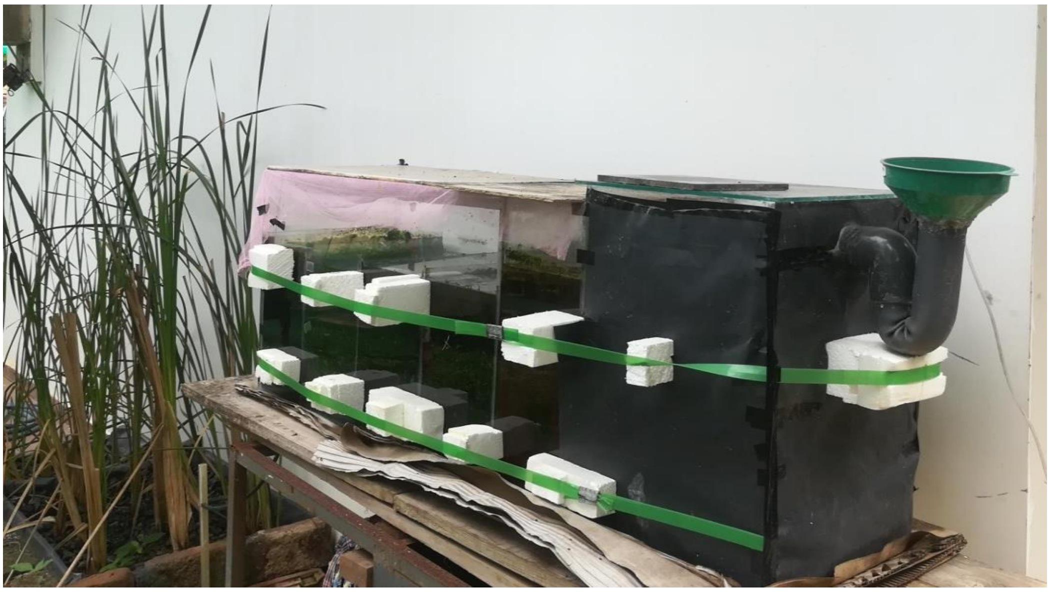


Figure 1-Treatment Plant

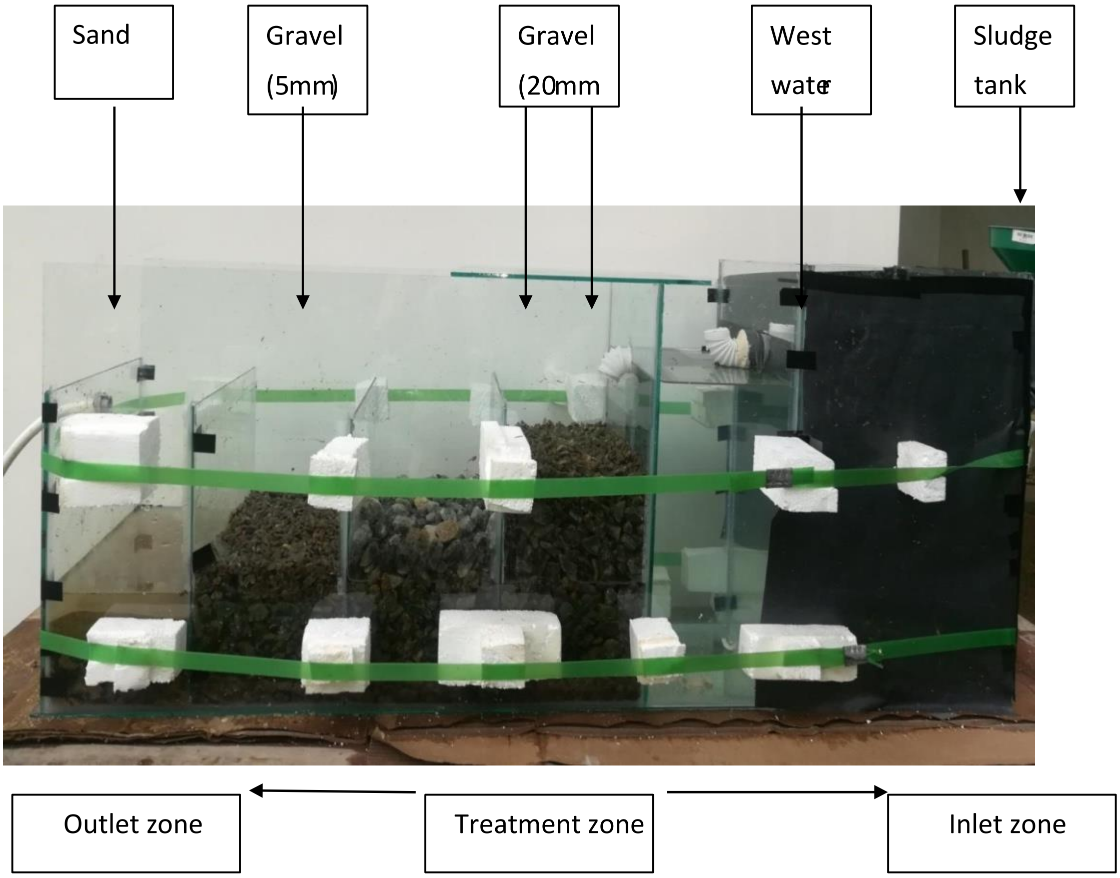


Figure 2- Treatment process of the plant

Figure 3-Water flow system

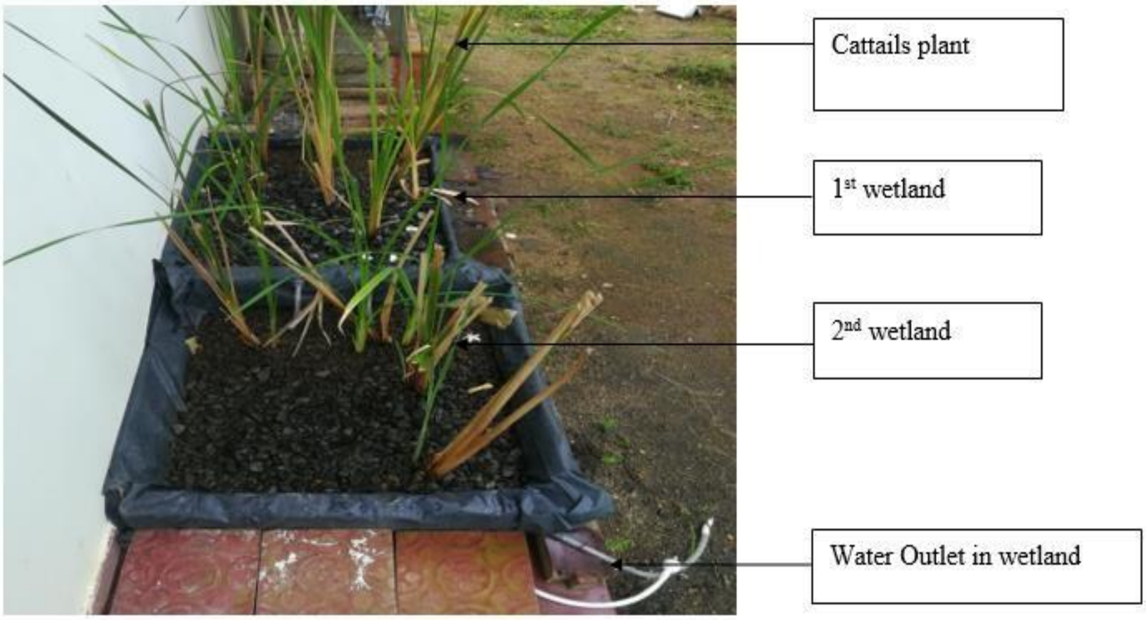


Figure 4: Wetland processes

Constructed wetland is an innovative and emerging ecological technology for wastewater treatment. This study was conducted to investigate the effectiveness of a pilot scale sub-surface flow constructed wetland unit comprising of 2 cells treatment system of 1800mm x 900 x 900 mm. Two wetland cells were utilized, with two cells planted Typha. The wetland cells were fed with treatment tank runoff wastewater were collected for analyses at 5 day interval for a retention period of 10 days. One of the most common plants in wetlands the cattail (Typha) in removing heavy metals from simulated wastewater**.**

2.2. Sludge sampling

In order to determine the quality of sludge from wastewater treatment plant, sludge from different stages along the process chain was sampled, see Table 1. The sludge was sampled from a total of two sampling points.

Table 1: *Parameters which need to check*

Parameter	
Macronutrients	Tot-N, Tot-P, NO3-N, K
Metals	Cr, Cu, Ni, Pb, Zn
Physiochemical parameters	TS, pH, Temperature, Conductivity

2.2.1 Sampling procedure

The sludge from each sampling point was collected in 5x1.0 L plastic boxes which directly after sampling were stored in a cooler box at the site. The samples were then stored in a refrigerator (4°C) until the day of analysis.

2.3 Laboratory work

The laboratory work was done in order to determine the physiochemical parameters, nutrient content and heavy metal content of the sludge.

2.4 Physiochemical parameters

The physiochemical parameters (pH, temperature, electronic conductivity, total solids). See methodology for the above mentioned parameters below.

2.4.1 Electronic conductivity, PH and temperature

At the time of sampling, PH, temperature and electronic conductivity were measured only for the wet types of sludge (primary and secondary sludge). The PH was measured with ELE International 370 pH meter, the temperature with ELE International micro thermal 2 digital thermometers and the electronic conductivity with ELE International 470 Conductivity meter.

2.4.2 Total solids (TS)

The amount of total solids in the sludge was determined by using oven ELE International heated to 105°C. A known volume of sludge was put into a beaker with a known weight. The beaker with sludge was then inserted in the 105°C oven for 24 hours. The beakers with sludge were thereafter scaled and the weight after oven is the amount of total solids. The difference between the weight before and after oven is the amount of water that the sample contained.

2.4.3 Nutrients

The nutrients measured were nitrogen, phosphorous, potassium. See methodology for the mentioned elements below.

2.4.4 Nitrogen

Sample preparation: After collection, the sludge was air-dried for five days to let water evaporate from the sample. After drying the samples were crushed with a mortar and sieved to a size of 150 µm. The sieved samples were thereafter stored in sealed bottles in room temperature until the day of analysis.

2.4.5 Phosphorous

Sample preparation*:* After collection, the sludge was air-dried for five days to let water evaporate from the sample. After drying the samples were crushed with a mortar and sieved to a particle size of 150µm. The samples were thereafter stored in sealed bottles in room temperature until the day of analysis.

2.4.6 Potassium

Sample preparation*:* The collected samples were first air-dried for five days and thereafter dried in oven ELE International of 105°C for one day. After drying, samples were crushed with a mortar and sieved to a particle size of 150 µm. 0.5 g of each sample were then put in crucibles together with 100 ml of distilled de-ionized water and 12 ml of concentrated HNO3 in order for digestion to occur. The samples were then heated on heating plates until the volume of the solution was approximately 0.5 ml. Thereafter the samples were air-cooled and then filtered through a Whatman No. 42 filer paper and quantitatively transferred to a calibrated flask and diluted with de-ionized water until 25 ml.

2.4.7 Heavy metals

Sample preparation: The collected samples were first air-dried for five days and thereafter dried in oven ELE International of 105°C for one day. After the drying, samples were crushed with a mortar and sieved to a particle size of 150 µm. 0.5 g of each sample were then put in a crucible together with 100 ml of distilled de-ionized water and 12 ml of concentrated HNO3 in order to digest the sample. The samples were then heated on heating plates until the volume of the solution was approximately 0.5 ml. Thereafter the samples were air-cooled and then filtered through a Whatman No. 42 filer paper and quantitatively transferred to a calibrated flask and diluted with de-ionized water until 25 ml.

Wastewater and sludge treatment

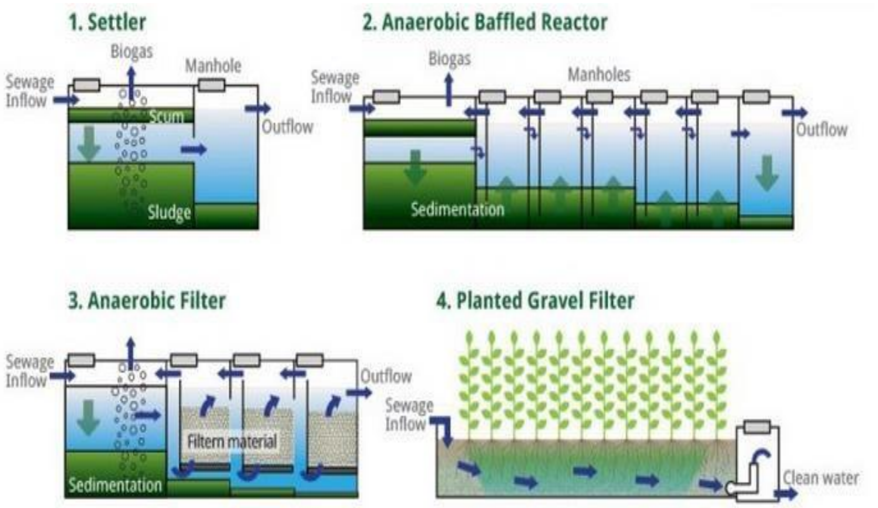


Figure 5: *Wastewater and sludge treatment process*

1. Pre-treatment done in a Settle tank – a tank that separates the liquid from the solid.
2. First treatment takes place in an Anaerobic Baffled Reactor – a tank with several identical chambers through which the effluent moves from top to bottom.
3. Second treatment happens in an Anaerobic Filter – a tank filled with a filter material (cinder), through which the effluent moves from top to bottom.
4. Third treatment takes place in a Planted Gravel Filter – a structure filled with gravel material and planted with water-resistant Cattail plants, Biological Removal Processes. A constructed wetland is a complex assemblage of wastewater, substrate, vegetation and an array of microorganism (most important bacteria). Vegetation plays in the wetland as they provide surface and s suitable environmental for microbial growth and filtration. Pollutant are removed with in the wetland by several complex physical (sedimentation, filtration, absorption and volatilization) chemical (precipitation, absorption hydrolysis, oxidation/reduction) and biological (bacterial metabolism, plant metabolism, plant absorption, natural die- off processes as depicted in Figure 6.

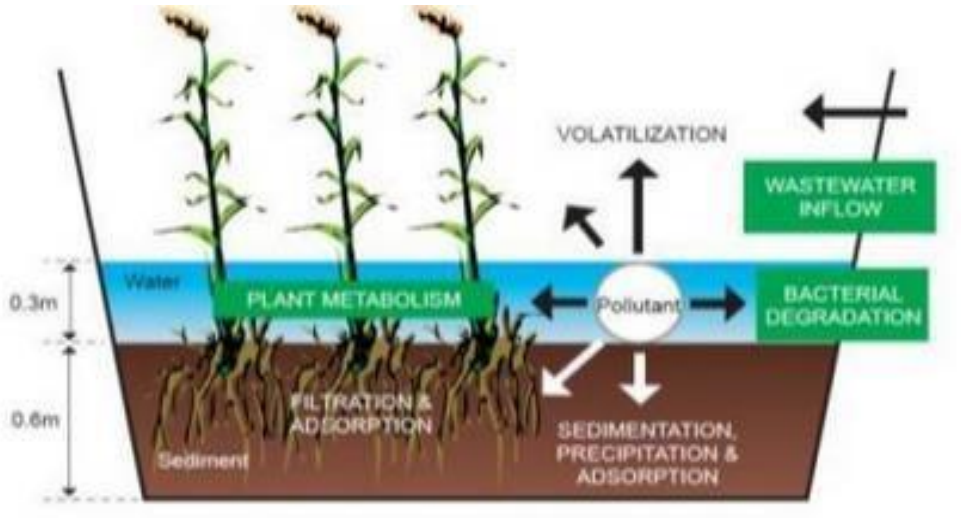


Figure 6: *The pollutant removes mechanism in construction wetland*

Biological removal is perhaps the most important pathway for contaminant removal in wetlands. Probably the most widely recognized biological process for contaminant removal in wetlands is plant uptake. Contaminants that are also forms of essential plant nutrients, such as nitrate, Potassium and phosphate, are readily taken up by wetland plants during wastewater treatment in wetlands. However, many wetland plant species are also capable of uptake and even significant accumulation of, certain toxic metals such as cadmium and lead [6]. The rate of contaminant removal by plants varies widely, depending on plant growth rate and concentration of the contaminant in plant tissue.

2.5 Chemical Removal Processes

In addition to physical and biological processes, a wide range of chemical processes are involved in the removal of contaminants in cattail wetlands. The most important chemical removal process in wetland soils is sorption, which results in short-term retention or long-term immobilization of several classes of contaminants. Sorption is a broadly defined term for the transfer of ions (Molecules with positive or negative charges) from the solution phase (water) to the solid phase (soil). Sorption actually describes a group of processes, which includes adsorption and precipitation reactions [6].

Adsorption refers to the attachment of ions to soil particles, by either caption exchange or chemisorption. Caption exchange involves the physical attachment of captions (positively charged ions) to the surfaces of clay and organic matter particles in the soil. This a much weaker attachment than chemical bonding, therefore the captions are not permanently immobilized in the soil. Many constituents of wastewater and runoff exist as captions, including ammonium (NH_4^+) and most trace metals, such as Cu, Zn, Pb, Cr, Ni. The capacity of soils for retention of captions, expressed as caption exchange capacity, generally increases with increasing clay and organic matter content. Chemisorption represents a stronger and more permanent form of bonding than caption exchange. A number of metals and organic compounds can be immobilized in the soil via chemisorption with clays, iron (Fe) and aluminum (Al) oxides, and organic matter.

Phosphate can also bind with clays and Fe and Al oxides through chemisorption [6].

2.6. Fertilizers

The use of fertilizers in agriculture has for a long time improved the life situation for many people all over the world due to the consequence of increased crop growth. But as the population increases, the demand for fertilizers will also be greater.

Fertilizers are used in order to supply the soil with nutrients in order to favor plant growth. This extra input of nutrients is especially needed at fields where crops and plants are harvested due to the fact that nutrients are lost when crops are removed from the soil. If the plant was degraded instead, the natural supply and recycling of nutrients to the soil would occur. Even if crops are efficiently cultivated with high productivity, fertilizers are often needed in order to avoid depletion of the soil. Furthermore a large portion of the soil in the world would not be fertile enough for crop production if not fertilizers were added.

2.6.1 Fertilizer requirements

There are several requirements for the use of fertilizers in agriculture. A fertilizer should have a high nutrient value and have nutrients in accessible form for plant uptake, but it should also improve the soil structure and be easy to handle. In addition to this, a fertilizer should not contain any hazardous substances. These demands and requirements are described more in detail below.

2.6.2 Fertilizer’s Nutrient value

Except from sunlight, water and carbon dioxide, the availability of nutrients and minerals in the soil is essential for plant growth. The most important nutrients for a plant to grow are the macronutrients nitrogen (N), phosphorus (P) and potassium (K). Other nutrients needed are calcium (Ca), sulphur (SO_4), sodium (Na) and magnesium (Mg) as well as micronutrients like boron (Bo), chloride (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn). These lastly mentioned nutrients are essential but only required in very small quantities. Nutrients are available in both organic and inorganic form but it is the inorganic form that is available for plant uptake. For nitrogen, there are three major inorganic forms: nitrate (NO_3^-), nitrite (NO_2^-) and ammonium (NH_4^+).

2.6.3 Heavy metal content

Plants are not only able to assimilate nutrients but also heavy metals from the soil. It is therefore important to regulate and control the heavy metal content in fertilizers so that it won’t cause harm to the environment or human health.

There are several factors influencing the metal uptake by crops; concentration of metals in the soil, pH and organic matter content, crop type and crop age are just some important parameters. According to the most affecting factor for the plant uptake of heavy metals is the concentration of metals in the soil together with the pH. With low pH-value in the soil, the metal uptake is high, and if the concentration of metals in the soil is high, the plant uptake of metals will also be high.

Additionally the configuration of the plant is of importance for the heavy metal uptake. The leafy part of the crop seems to accumulate higher concentrations of metals than roots, grains or fruits. In order to measure the supply of heavy metals when fertilizing, the heavy metal content in fertilizers is often presented in comparison with the content of nutrient (mg metal/kg nutrient). The reason why this unit is chosen is that differences in heavy metal input by different fertilizer alternatives and sludge types will be clearer if it is presented in relation to the supply of nutrients.

2.6.4 Types of fertilizers

There are many different types of fertilizers used in agriculture; artificial fertilizers, animal manure, dig estate from biogas production and wastewater sludge are some of the most frequently used fertilizers on the market today. These are described more in detail below.

2.6.5 Artificial fertilizers

An artificial fertilizer is a synthetically produced product which consists of inorganic minerals and nutrients extracted from the nature in order to nourish and meet the requirements of specific crops.

2.6.6 Manure and digestate fertilizer

Animal manure or digestate from biogas production is another possible fertilizer alternative since it contains macronutrients like nitrogen, phosphorous and potassium but also micronutrients and organic matter. The nutrient content in the manure can however vary depending on animal, feeding, bedding material, other supplements but also treatment and management of the manure. Manure can consist of both urine and/or feces from animals like cows, pigs and chickens. Digestate is the solid by-product from biogas plants that is left after the biogas production. This product is rich in nutrients and is therefore also a suitable alternative for fertilization purposes an example of nutrient value in cow manure and co-digestate (mixture of digesting-substrates) is shown in Table 2.

2.6.7 Sewage sludge fertilizer

Sewage sludge is another product that can be used as fertilizer. The use of sludge in agriculture contributes to recycling of nutrients and organic matter to the soil, but it also improves the properties of the soil in terms of structure, humus content, and water holding and transmission capacity. Additionally, sludge is also usually a cheap alternative in comparison to other fertilizers .There are also some challenges linked to the use of sludge in agriculture. Considering the fact that it has been seen that heavy metals and hazardous compounds in sludge can accumulate in the crops and be transferred to humans, the acceptance of spreading sewage-based fertilizer on farmland is not total. The nutrient value is another challenge when using sludge as fertilizer. Sludge is considered as a low-grade fertilizer in comparison to for example artificial fertilizers, meaning that a larger amount of sludge must be spread to achieve the same required supply of nutrients.

3. Result/ Analysis and Discussion

The result from the laboratory work is discussed and analyzed in the result analysis. The fertilizer potential of the sludge is discussed in terms of agriculture demand and in comparison to other fertilizer types.

Table 2: *Nutrient content of fertilizers [7]*

Parameter	Artificial fertilizer (mg/l	Compost fertilizer (mg/l)	Farmyard manures fertilizer (mg/l)
Tot-P	36	31.6	9
NO_2—N } NO_3—N Tot-N	130 } 79 209	170	30
K	66	51.2	28

Table 3: *PH, Total solid, EC, and Temperature Data [7]*

Parameter	Artificial fertilizer	Compost fertilizer	Farmyard manures fertilizer
PH	5.5	7.1	6.7
Total solid(mgl1○)	715	1625	1334
EC(µs)	915	625	723
Temperature(°C)	30.1	30	31

Table 4: *Heavy metal Content [7]*

Metals	Artificial fertilizer (mg/l	Compost fertilizer (mg/l)	Farmyard manures fertilizer(mg/l)
Cr	66	1.8	2.8
Ni	11	0.9	3
Cu	125	13	31
Pb	120	1.3	0.69
Zn	210	82	170

3.1. Identification of NPK ratios of wastewater treatment plant at different stages

Table 5: *NPK value of different stages in treatment plant*

Sample No/ Parameter	Nitrate (mgl1○)	Nitrite (mgl1○)	Phosphate (mgl1○)	Potassium (mgl1○)
Sand tank	8.5	3.70	31.10	10.85
Sludge tank	9.02	5.42	34.08	11.76

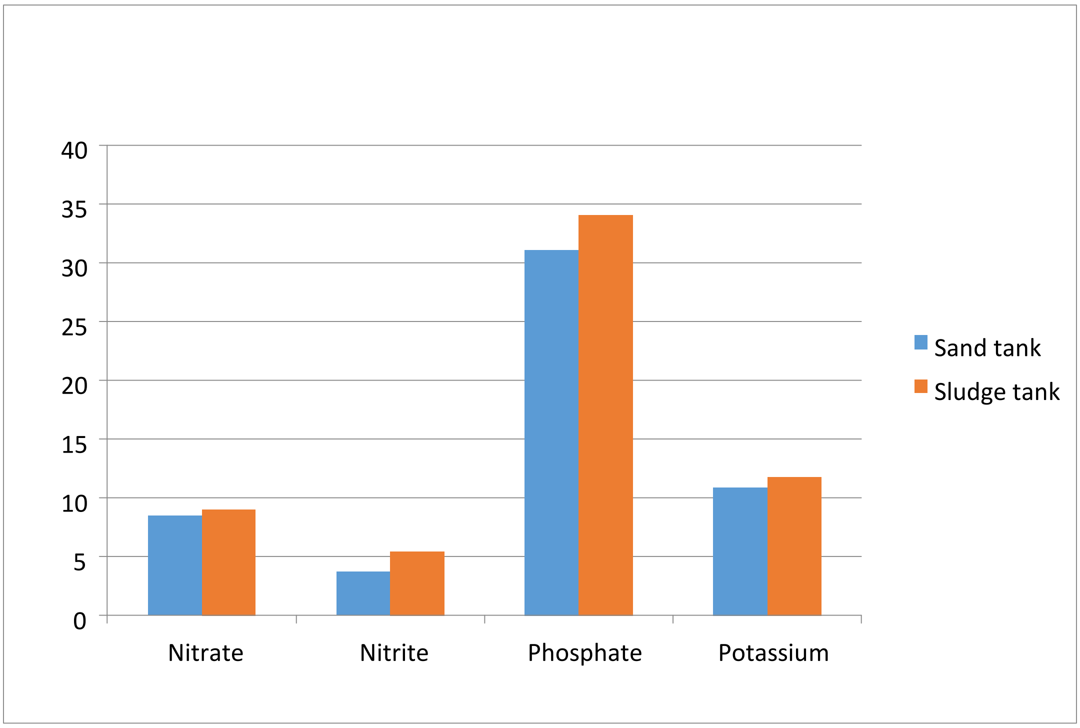


Figure 7: *NPK value of different stages in treatment plant*

NPK values of the sludge collecting tank of the sludge treatment plant and the end stage of purification tank were separately calculated. These two values showed that end stage purification tank NPK value is less than the sludge collecting tank NPK value as the percentage.

- Nitrogen - 5.76%
- Phosphate- 31.43%
- Potassium-7.73%

This revealed that the heavy metal in a treatment plant (Cr, Ni, Cu, Pb, Zn) react with NPK and sediment. As Nitrates & Phosphate.

Table 6: *Laboratory test result average values*

Sample No/ Parameter	Total solid (mgl1◌)	PH	Nitrate (mgl1◌)	Nitrite (mgl1◌)	Phosphate (mgl1◌)	Potassium (mgl1◌)	EC (µs)	Temperature (°C)
01 (1^{st}week)	1106	6.5	8.5	3.70	31.10	10.85	896	30.1
02 (2^{nd}week)	1183	6.3	9.25	4.98	34.32	10.75	810	31.1
Average	**1144.5**	**6.4**	**8.87**	**4.34**	**32.71**	**10.80**	**853**	**30.6**
			Total N-13.21					

3.2 Comparison of Ph Value of different fertilizers

Table 7: *Different fertilizer's Ph values*

Type of Fertilizer	PH
Artificial fertilizer	5.5
Compost fertilizer	7.1
Farmyard manures fertilizer	6.7
Sludge fertilizer	6.4

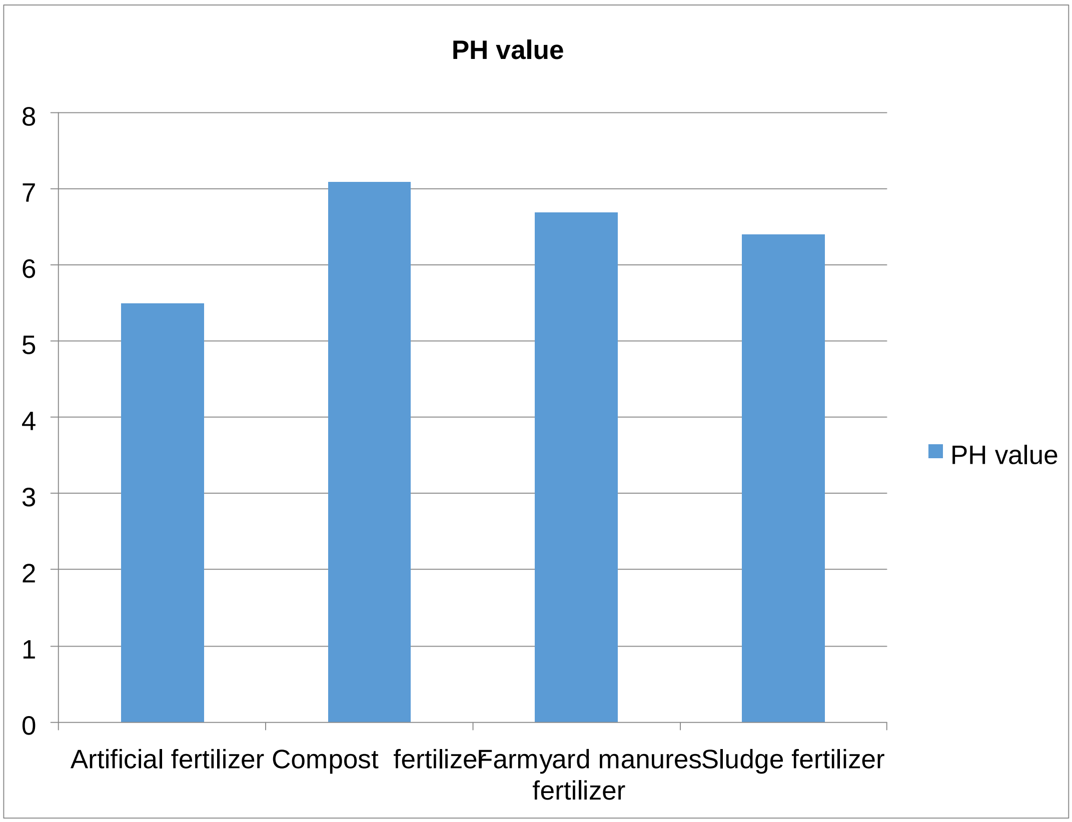


Figure 8*: Different fertilizer's Ph values comparison*

In the next step, pH values of the purified sludge fertilizer and other fertilizer were compared. According to these values the pH value of the sludge fertilizer and the other pH values are almost the same. So it does not affect for the pH value of the soil when it contaminated with the soil.
Also compare to artificial fertilizer, sludge fertilizer more safer.

3.3 Comparison of NPK Value of different fertilizers

Table 8: *Different fertilizer's NPK values*

Type of Fertilizer	Nitrogen (mgl1◌)	Phosphate(mgl1◌)	Potassium(mgl1◌)
Artificial fertilizer	209	36	66
Compost fertilizer	170	31.6	51.2
Farmyard manures fertilizer	30	9	28
Sludge fertilizer	13.21	32.71	10.80

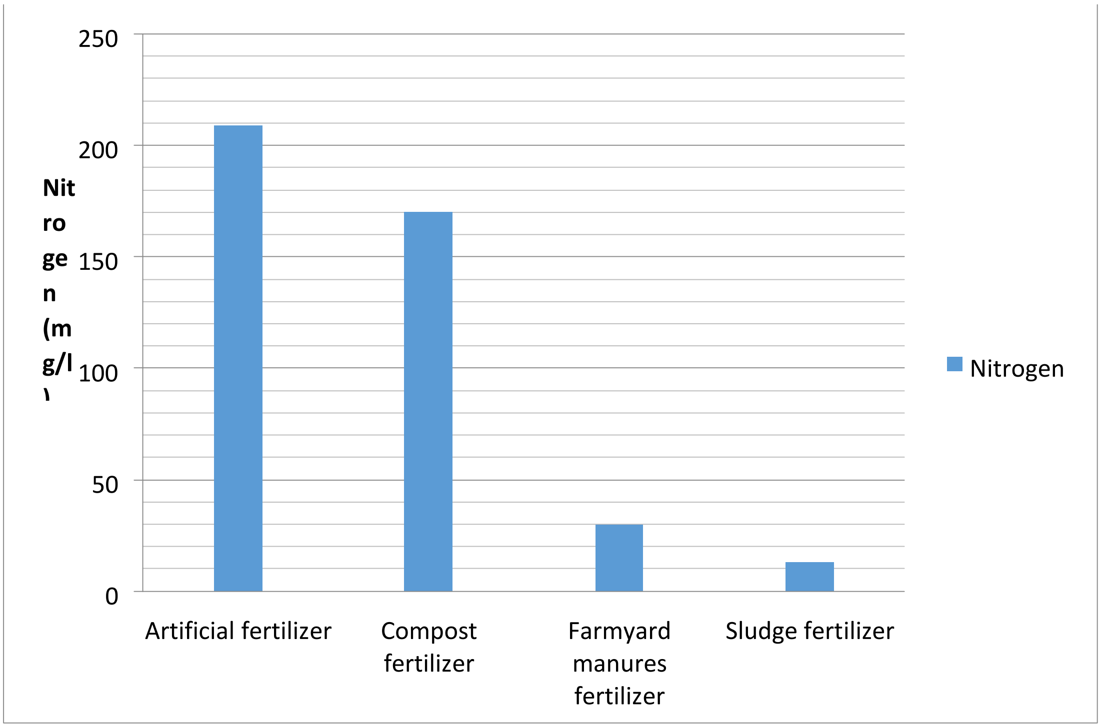


***Figure 9:** Different fertilizer's Nitrogen value comparison*

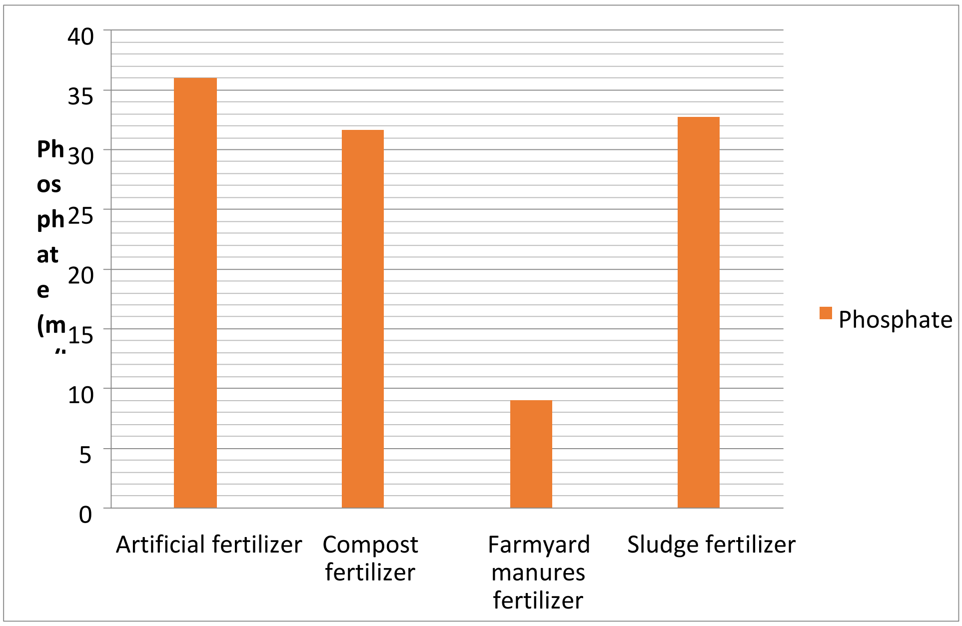


***Figure 10:** Different fertilizer's Phosphate value*

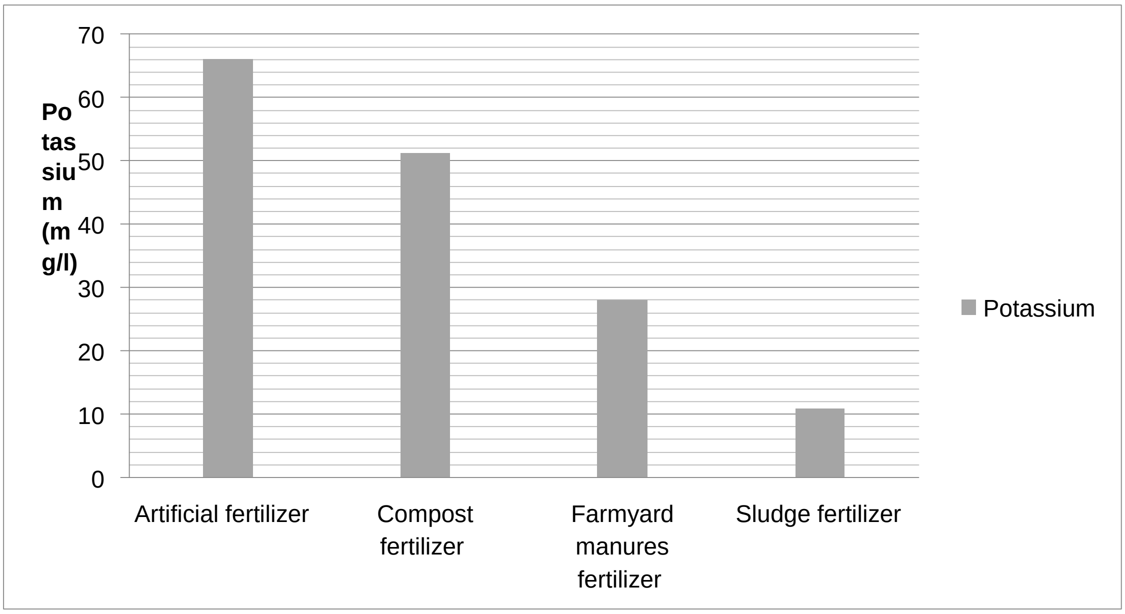


Figure 11: *Different fertilizer's Potassium value comparison*

When compare to purified sludge fertilizer and the other fertilizer's NPK values,

Comparison to Artificial fertilizer N%	Sludge (N%)	93.76% was reduced
Comparison to Compost fertilizer N%	Sludge (N%)	92.22% was reduced
Comparison to Farmyard fertilizer N%	Sludge (N%)	55.96% was reduced
Comparison to Artificial fertilizer P%	Sludge (P%)	9% was reduced
Comparison to Compost fertilizer P%	Sludge (P%)	72.48% was increased
Comparison to Farmyard fertilizer P%	Sludge (P%)	3% was increased
Comparison to Artificial fertilizer K%	Sludge (K%)	83.63% was reduced
Comparison to Compost fertilizer K%	Sludge (K%)	78.90% was reduced
Comparison to Farmyard fertilizer K%	Sludge (K%)	61.42% was reduced

3.4. Comparison of PH value & NPK value of Sludge different Stage

Table 9: *NPK values and PH value of wastewater treatment plant at different stages.*

	PH value	Nitrate mg/l	Nitrite mg/l	Phosphate mg/l	Potassium mg/l
Sand tank	6.5	8.5	3.7	31.1	10.85
Unpurified Sludge tank	4.8	10.02	6.02	37.18	12.36

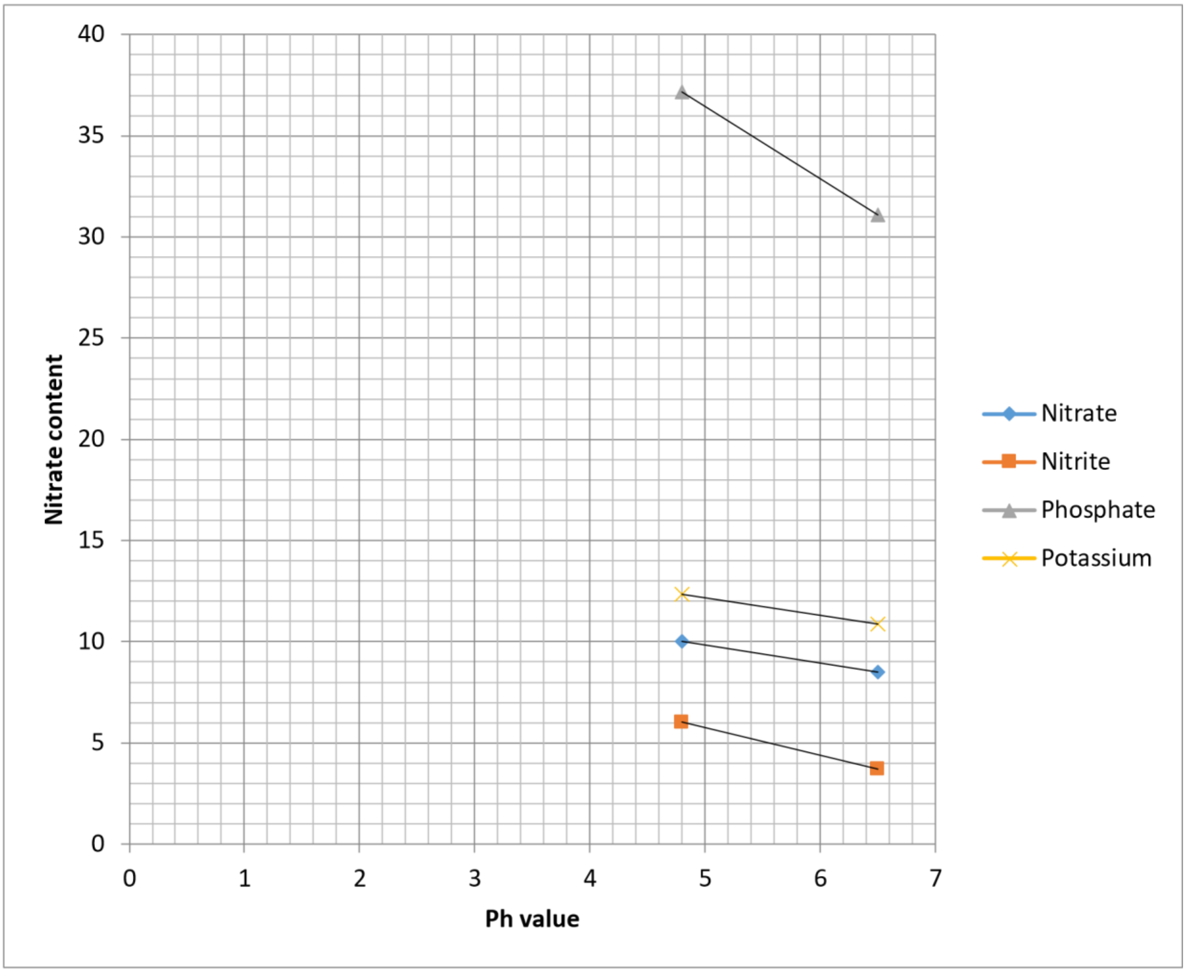


Figure 12: *The way of changing NPK values with the PH values*

When comparison the NPK values and the pH values of the non-purified water in the sludge treatment plant and the purified water in the sludge treatment plant,
In non-purified water pH value low and NPK value high and in purified water pH value high and NPK value low.

So as conclusion, Acidity is directly proportionate to NPK value.
So that the sludge, not suitable to contaminate with the soil without purification and it will leads to increase the acidity of the soil.

3.5. Comparison of heavy metal content of Sludge different Stage

Table 10: *Heavy metal content of wastewater treatment plant at different stages*

Sample No/ Parameter	Heavy metal (mgl1○)				
	Pb	Zn	Cr	Cu	Ni
Treatment tank	27.84	271.16	27.61	40.05	9.04
wetland	8.29	171.35	8.28	12.05	2.71

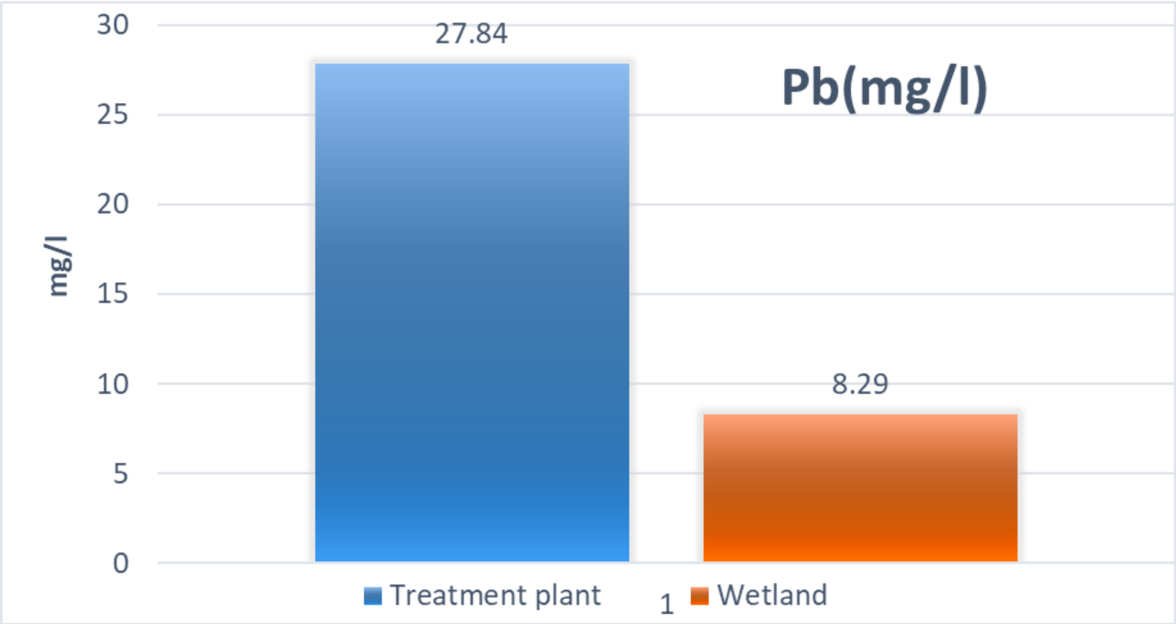


Figure 13: *Lead (pb) content of wastewater treatment plant at different stages*

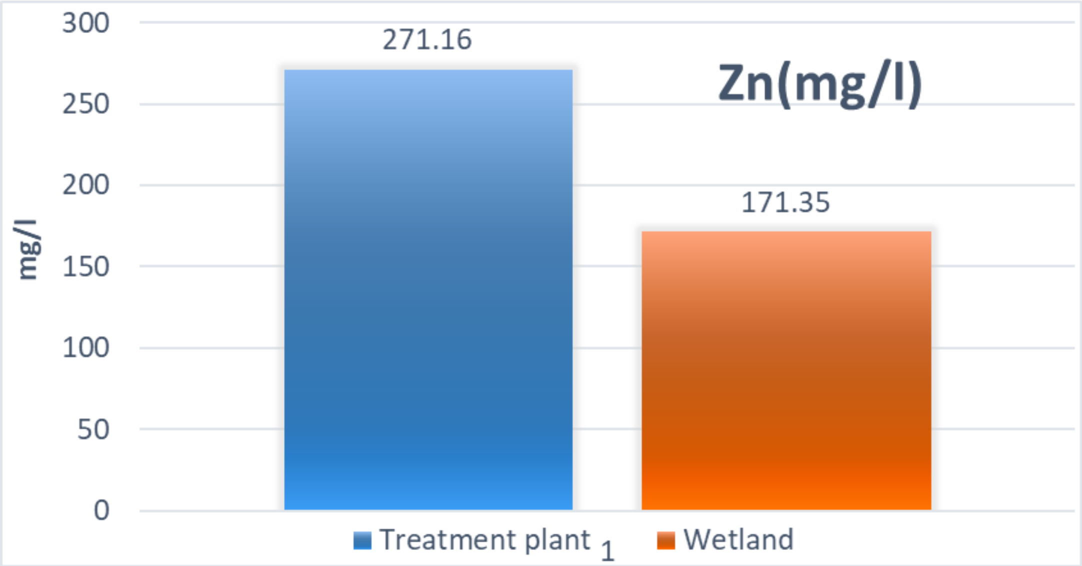


Figure 14: *Zinc (Zn) content of wastewater treatment plant at different stages*

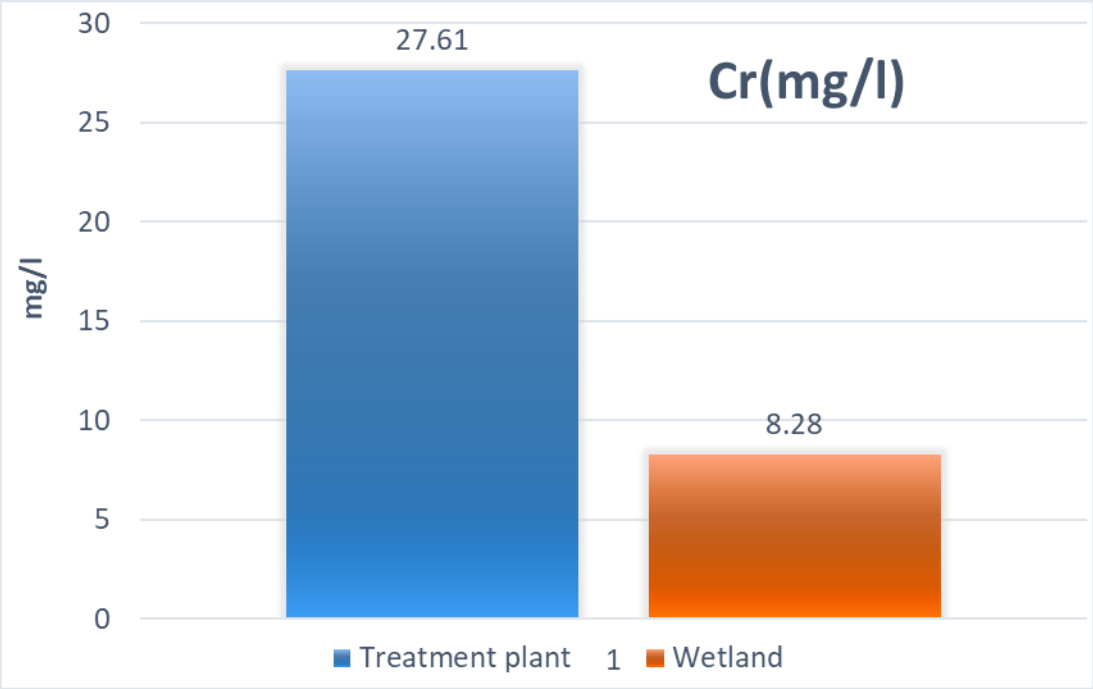


Figure 15: *Chromium (Cr) content of wastewater treatment plant at different stages*

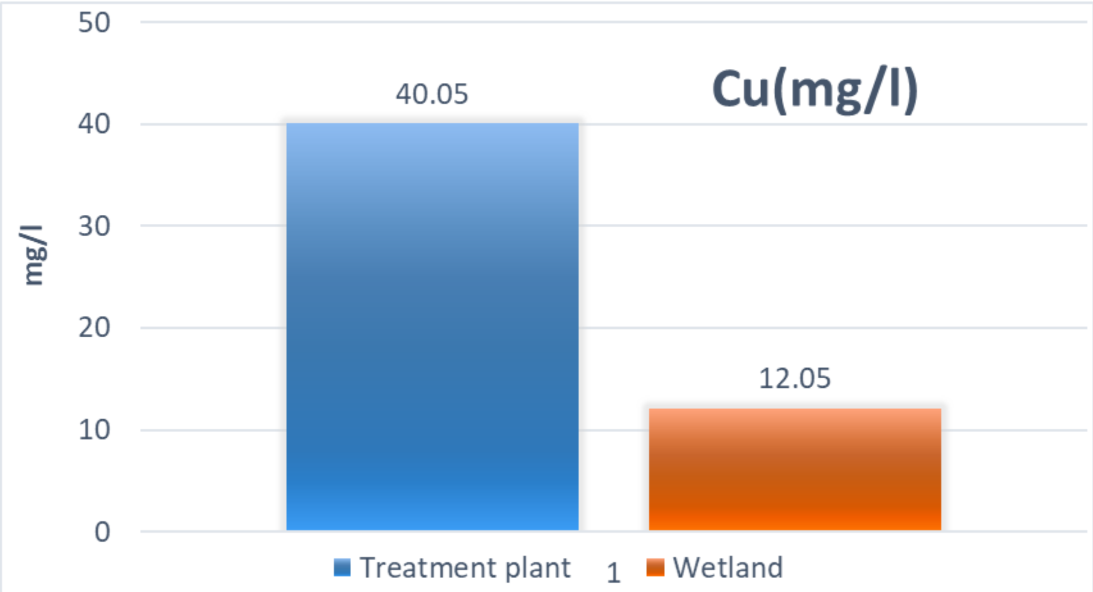


Figure 16: *Cupper (Cu) content of wastewater treatment plant at different stages*

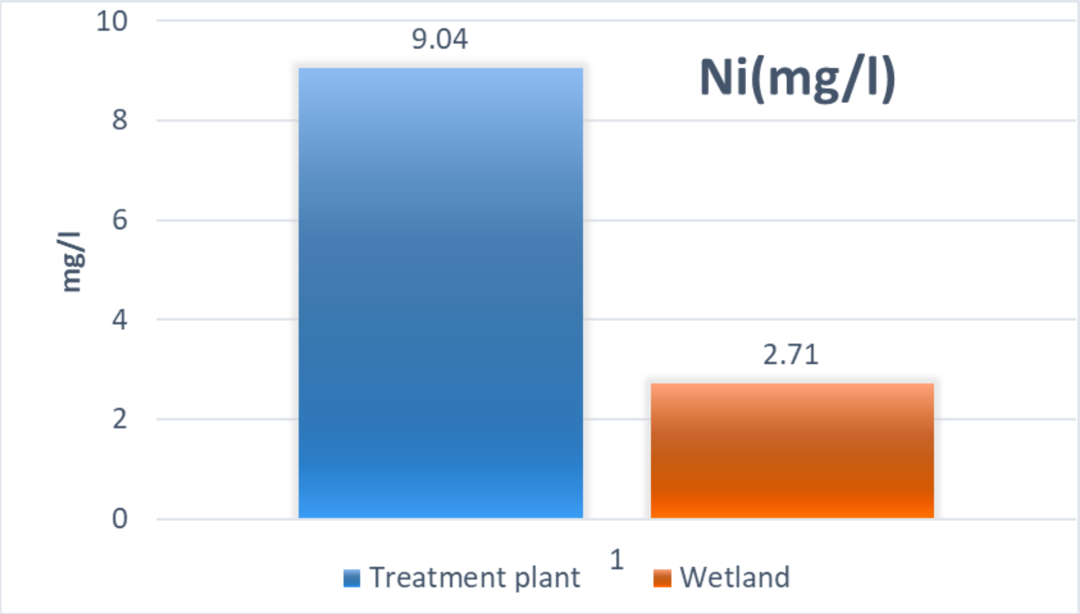


Figure 17: *Nickel (Ni) content of wastewater treatment plant at different stages*

The main purpose of the sludge treatment plant is removing the heavy metal from the water. Water which was purified from the wetland tank and the sludge had been investigated for heavy metal concentration such as Pb, Zn, Cr, Cu, Ni.

By that we are able to identify that the Cattail plant of the wetland was absorbed most of these heavy metals from the water.

As a percentage

Pb-29.77%

Zn-63.42%

Cr-38.31%

Cu-30.08%

Ni-29.86%

So by letting the water to drain through purified sludge that leads to reduce the heavy metal concentration in the water.

Heavy metals in waste water in the wetland were absorbed by the cattail plants. Thus there is no harm though that water contaminates the soil.

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3.6 Comparison of heavy metal content of different fertilizers

Table 10: *Different fertilizer's Heavy metal Content*

Type of Fertilizer	Artificial fertilizer (mgl1ꟹ)	Compost fertilizer (mgl1ꟹ)	Farmyard manures fertilizer (mgl1ꟹ)	Sludge fertilizer (mgl1ꟹ)
Cr	66	1.8	2.8	8.28
Ni	11	0.9	3	2.71
Cu	125	13	31	12.05
Pb	120	1.3	0.69	8.29
Zn	210	82	170	171.35

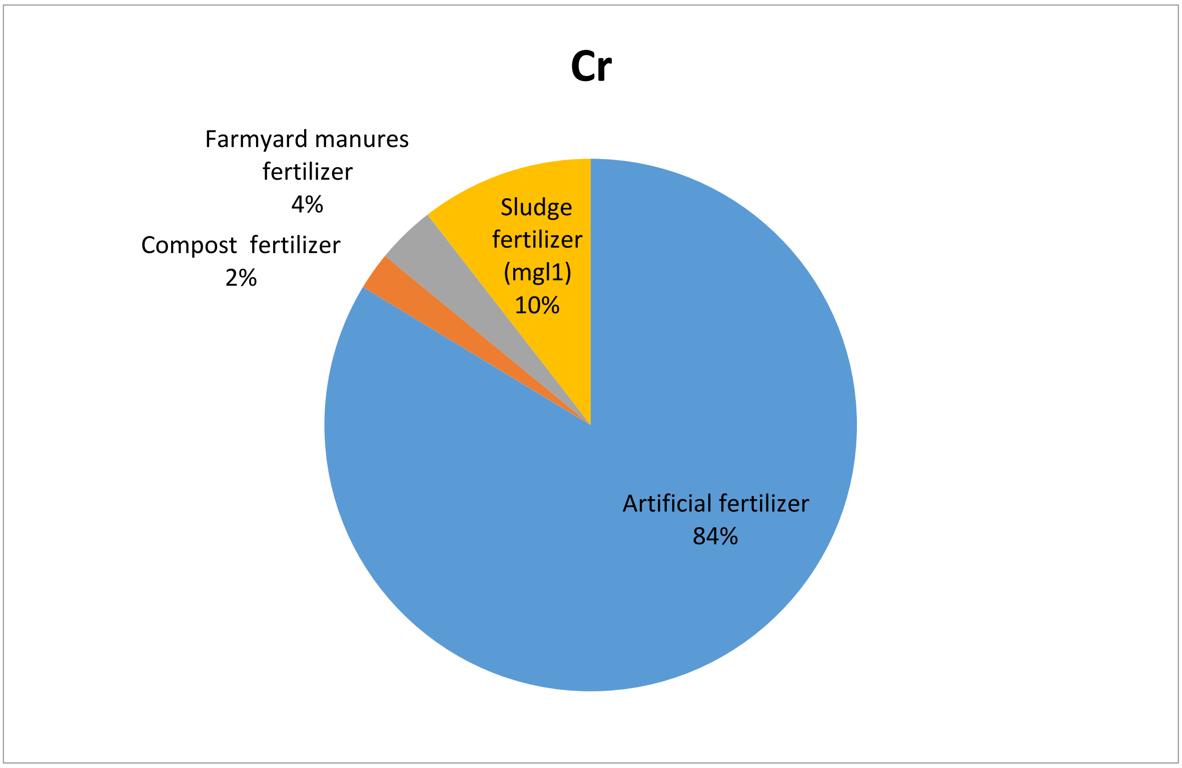

Figure 18: *Different fertilizer's Chromium (Cr) Content*

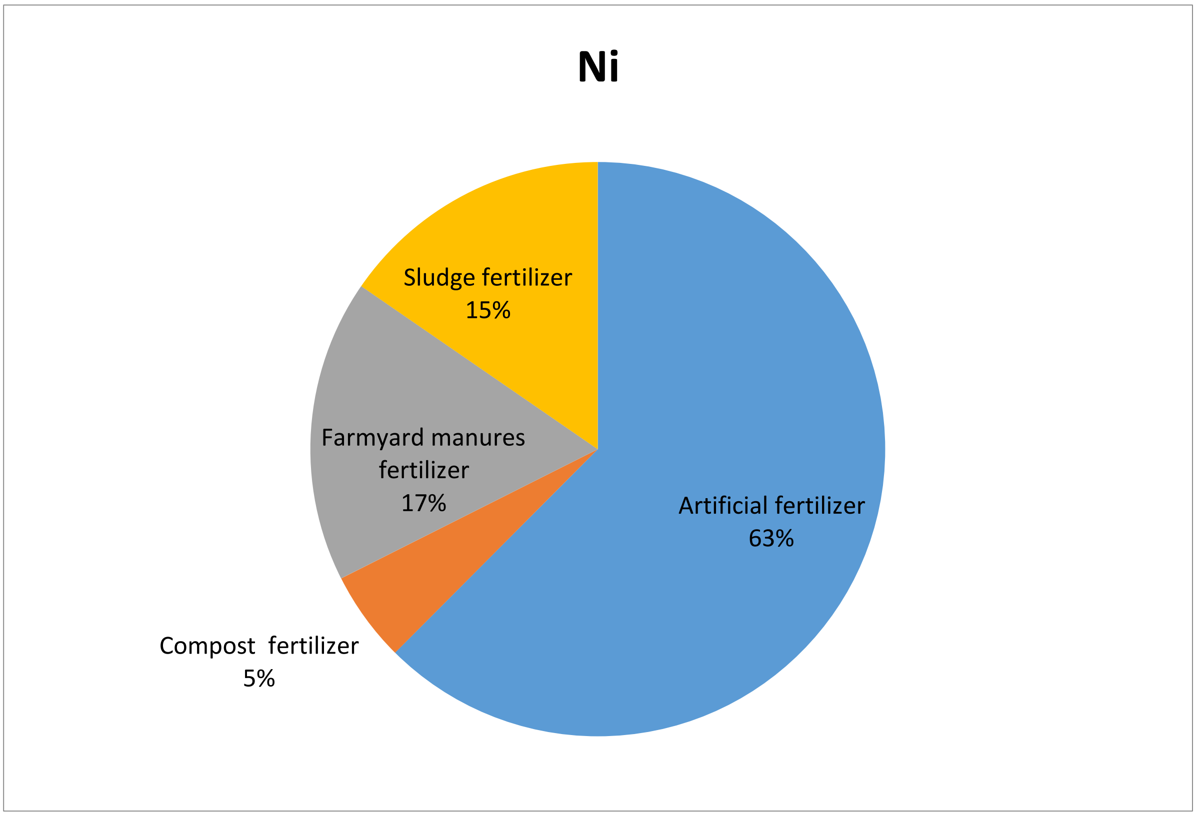

Figure 19: *Different fertilizer's Nickel (Ni) Content*

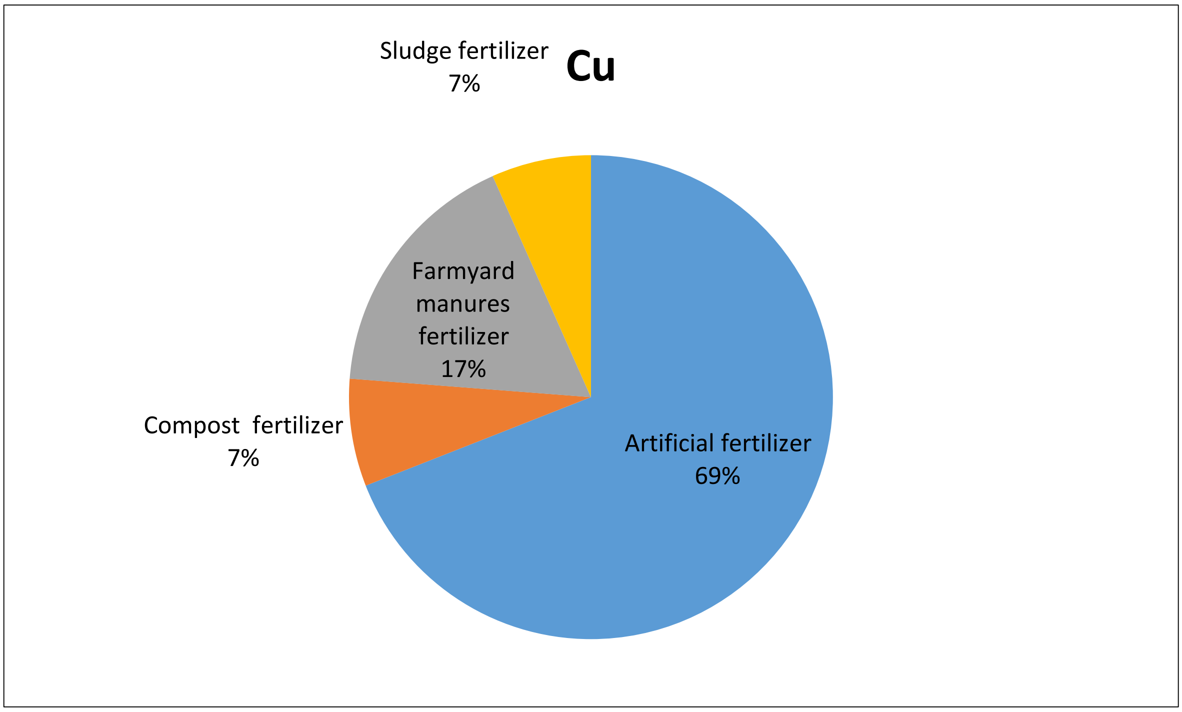

Figure 20: *Different fertilizer's Cupper (Cu) Content*

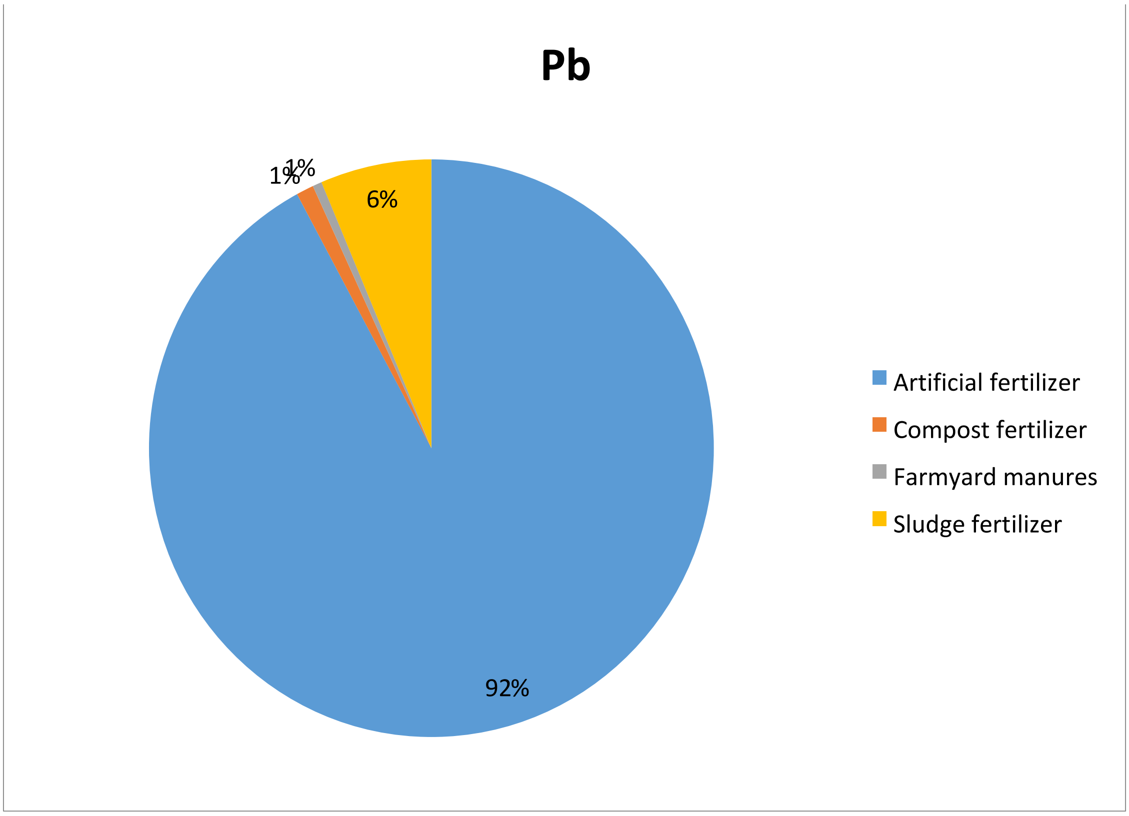

Figure 21: *Different fertilizer's Lead (Pb) Content*

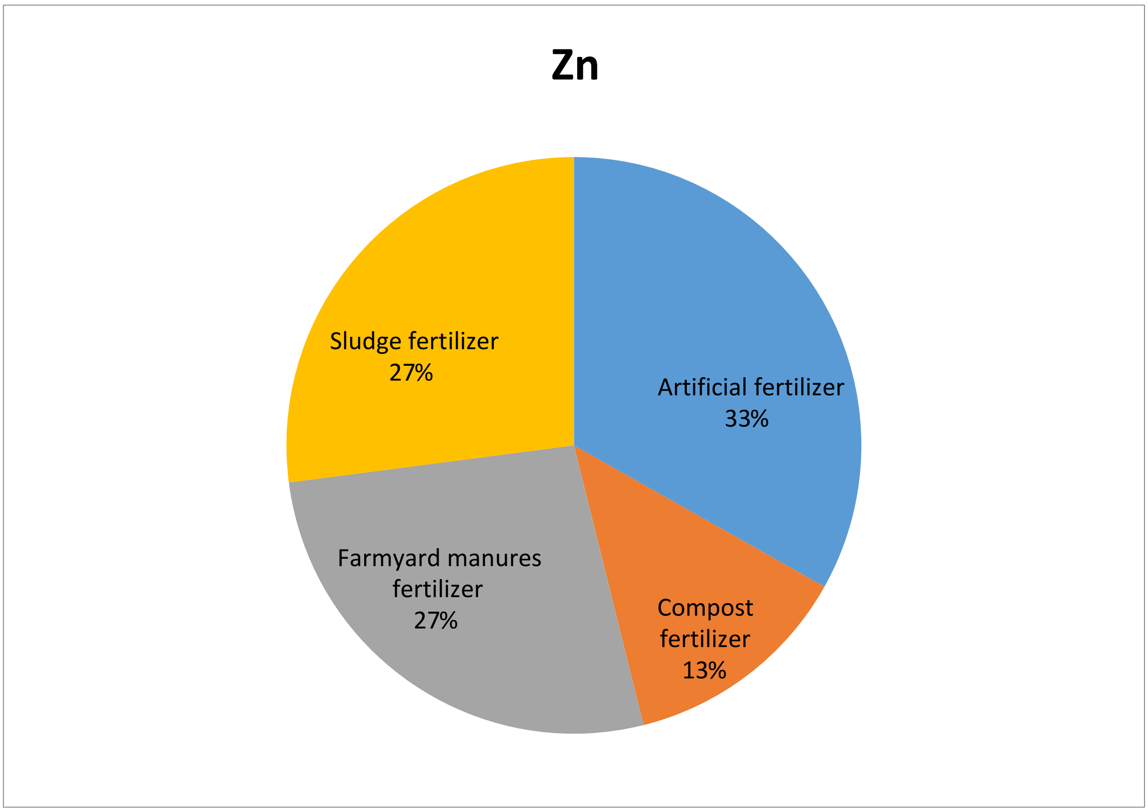

Figure 22: *Different fertilizer's Zink (Zn) Content*

5. Conclusion

The quality of sludge from wastewater treatment plant has been examined and analyzed in terms of fertilizer potential. Possible improvements for increasing the sludge quality have also been discussed. Following conclusions can be made about the current fertilizer potential:

- In comparison to selected examples of fertilizers and other sludge types, the sampled sludge from indicates a relatively low nutrient value. The heavy metal content in the sludge varies depending on analysis method used but in a worst case scenario, content of arsenic, copper, lead and zinc in the sludge does not meet the for sludge use in agriculture. From the results of this thesis it can also be seen that the secondary sludge from indicates lower heavy metal content than the primary sludge.

There are several actions that could be made to increase the fertilizer potential of the sludge. These actions are concluded below.

- A treatment process optimized for phosphorous removal, e.g. Chemical precipitation or enhanced biological phosphorous removal may increase the phosphorous content in sludge.

- The treatment process in the seems to have an influence on the sludge quality, both in terms of nutrient and heavy metal content. Lower heavy metal and higher nutrient content `in the sludge may therefore be gained if only using the secondary sludge from as fertilizer.

- A more nitrogen-rich sludge can be obtained if the sludge is kept in a closed storage instead of open air. This with reservation for methane gas production and a sludge product with more water and larger volume.

- The work with source tracking in Botswana may most likely contribute to a reduction of the heavy metal content in the sludge. However, more emphasizes must be put on getting industries to join the Trade Effluent agreement and in the future lower the limits according to the local problems seen.

Overall, the result from only one sampling occasion is not enough to estimate the quality of the sewage sludge. More continuous and frequent laboratory analysis of the sludge from design treatment plant is needed to determine the fertilizer potential. This may also contribute to better operational prerequisites of the plant, but also a better assurance to the customers on the sludge status.

The analysis method is also of great importance for the sludge quality results. The choice of the analysis method must therefore be reviewed for future sludge analyzed.

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