2078

Evaluation of sewage sludge for agricultural purpose: case study of Madda Walabu University treatment plant

Research report

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Submitted to

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Declaration

Researchers: - we, the undersigned solemnly declare that this research report entitled **''Evaluation of sewage sludge for agricultural purpose: case study of Madda Walabu University treatment plant''** is our own original work submitted to Madda Walabu University RCETT Vice President office for a report of granted by MWU. We further declare that this research report does not contain any part of any research work which has been previously conducted or published at Madda Walabu University or anywhere else I/we am/are aware that I/we will be held accountable is I/we provide incorrect deceptive or mischievous information.

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Research Approval Sheet

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SUMMARY

Sewage sludge (SS) is a by-product of wastewater treatment plants that remains after municipal wastewater treatment process. Attention has been given toward recycling of organic waste as an alternative to chemical fertilizers and to promote environmentally sound waste disposal. Sewage sludge (SS) is widely used in agriculture in several countries around the world. However, scholars' research shows as the impact of successive applications of evaluated SS on soil and its risks on environment are neglected when compared with its benefit for agricultural use. The objective of this study is to investigate the quality of sewage sludge and to evaluate its suitability for agricultural use. To do this, dried sludge samples was collected from madda walabu university treatment and was summited to laboratory for investigation of its quality to use as alternative fertilizer to reduce budget require for chemical fertilizers for madda walabu farm area as well as to supply for surrounding community with low cost. To determine the quality of sewage sludge, physiochemical parameter such as pH, electrical conductivity, nutrients (exchangeable Na, ex.K, ex.Ca, and ex.Mg), cation exchange capacity (CEC), available phosphorous, available potassium, organic carbon, organic matter, total nitrogen, $CaCO_3$, and micronutrients (Fe, Mn,Cu,Zn) was done by using laboratory analysis. From the study result of physiochemical parameter; sewage sludge had high fertilizing values for essential macronutrients, micronutrients and organic matter which can be used as soil conditioner and alternative fertilizer. But researchers want to recommend a continues monitoring on the effect of using sludge on soil and crop.

Keywords: sewage sludge, Madda Walabu University, fertilizer, treatment plant

ACRONYMS

BS	bio-solid
dS/m	Decisiemen per meter
EC	Electrical Conductivity
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
MWU	Madda Walabu University
PH	Hydrogen ion concentration
WHO	World Health Organization
μS/cm	Microsiemen per centimeter
SS	Sludge Solid

Contents

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1. Background

Now days, attention has been given toward recycling of organic waste as an alternative to chemical fertilizers and to promote environmentally sound waste disposal (Nafez and Nikaeen, 2015). Sewage sludge (SS) is a by-product of wastewater treatment plants that remains after wastewater treatment (Singh and Agrawal, 2016). SS contains organic matters and can be used in agriculture as fertilizer or soil amendment (Rahmani *et al.*, 2014). Currently in Ethiopia, some industries adopted advanced wastewater treatment technologies composed of screening, equalization, up-flow anaerobic sludge blanket (UASB) process extended with aeration followed by final polishing unit to manage their liquid waste in an environmentally sustainable way (Alayu, Leta and Aragaw, 2018). Disposal of sludge requires about 50% of the operator's budget for wastewater treatment plant, besides causing environmental problems (Alayu, Leta and Aragaw, 2018). Among the different sludge disposal methods, landfilling is the common one Whereas, agricultural application is an alternative option to avoid the high landfill cost, available land space limitation as well as hygienic problems (Colón *et al.*, 2014; Alayu, Leta and Aragaw, 2018; Cesar *et al.*, 2020). One of the major concerns in land application of SS compost is the presence of high concentrations of numerous heavy metals, which may have hazardous effects for soils and crops and which may pose an indirect risk to human health due to the bioaccumulation and biomagnification properties (Rihani et al. 2010).

Therefore, disposal of sludge in a sustainable approach has got a global attention and has a great significance to local communities and authorities (Rahmani *et al.*, 2014). Most research investigation results showed that application of sludge from wastewater treatment plant for agricultural purposes is an ultimate disposal alternative option without any hazardous effect for soil conditioner (Mtshali, Tiruneh and Fadiran, 2014). However, sludges intended for agricultural use may contain toxic metals, persistent organic pollutants and pathogens that cause harmful effects to humans through transmission into the food chain (Mtshali, Tiruneh and Fadiran, 2014).

MWU wastewater treatment plant is generating more than 50 kuntal of sludge per a year and mostly stored into storage room. This present disposal practice couldn't be feasible option when land disposal space is scarce and may cause environmental problems in future. Therefore, it is important to investigate the quality of the sewage sludge in order to develop feasible and sustainable treatment technique for better management and provide baseline data on the physicochemical, and heavy metal contents in the sludge to the decision makers and local farmers who wants to start the practices of the sludge application for crop production. Accordingly, the objective of this study was to investigate the physical and chemical properties of sludge generated from MWU wastewater treatment plant in relative to Agricultural uses at least to substitute chemical fertilizers using by Madda Walabu University for wheat farm and vegetables and fruits fields in Madda Walabu University.

1.2. STATEMENT OF PROBLEM

Use of sludge without investigation of its quality and suitability for agriculture uses may bring to risk for crop yield, environment and human health. Use of sewage sludge for agriculture as alternative fertilizer is one way of sludge disposal manner and it is getting attention as a world. Investigation of sewage sludge before use in agriculture is limited in Ethiopia. The quality and content of sewage sludge applied to agricultural land has not been extensively researched in most part of Ethiopia. In similar way Sludge produced by MWU Treatment plant was used in small extent at some area in university without suitability test for agriculture. Hence, this research is aimed to investigate the quality and suitability of sewage sludge produced by MWU treatment plant for agricultural use as an alternative fertilizer.

1.3. The objective of the Study

1.3.1. General objective

The main objective of this study is to evaluate the suitability of sewage sludge for agricultural application.

1.3.2 Specific objectives

i) To investigate the quality of sewage sludge.

ii) To evaluate the suitability of sewage sludge for agricultural use as fertilizer

1.4. Research Questions

To address the above objectives, the following research questions are posed:

1. How the sewage sludge quality can be assessed?
2. Is the sewage sludge is suitable for agricultural use as fertilizer?

1.5. Significance of the Study

This study is the investigation of sewage sludge properties which produced from madda Walabu University treatment plant and its suitability for agricultural use. It will provide helpful information to various stakeholders as follows; the government institution of the study area will benefit from the study as a source of information on the quality of sludge producing from treatment plant which can be used for agricultural development as fertilizer and soil conditioner. The study will also solve the problem of storage room or area for storage of dried sludge by providing ultimate disposal alternative option.

This research will also full fills the primary function of Madda Walabu University, which is research and dissemination of knowledge and the application of that knowledge to advance the community by reducing the expenses of fertilizers. So, this research will provide options for replacing chemical fertilizers by organic fertilizer. Other researchers will also use the findings as a reference for further research on the suitability of sewage sludge for agricultural use.

2. Literature review

2.1. General

Fertilizers and soil amendments are materials added to soils to improve plant growth(Bo and Siemi, 2018). Their function can be seen in several ways (Crohn, 2004). For instance, they may change the pH of soil or supply nutrients. Fertilizers are primarily valued for their ability to supply nutrients (Crohn, 2004). Plants use these nutrients to make components for plant growth such as proteins and carbohydrate(Sohaili, Zaidi and Loon, 2012). Those nutrients also increases the amount of pore space and enhances air exchange, water movement, and root growth(Sohaili, Zaidi and Loon, 2012).

2.2. Characteristics of sewage sludge

The characteristics of sludge play an important role when considering the ultimate disposal of the processed sludge, especially in their use for agricultural uses(Iticescu *et al.*, 2018). Sludge characteristics can be broken down in three categories: (i) physical, (ii) chemical and (iii) biological(Hornick et al., 1984). The important physical characteristics are the solid content and the organic matter content. The total solids content affects the method of land application. Liquid or low-solids sewage sludge will generally be injected into soil to prevent vectors and provide better appearance. The organic matter is an important constituent of bio-solids and its use for land application enhances the organic content of soils. In sandy soils the organic matter increases the water-holding capacity, soil aggregation and other soil physical properties. It reduces the soil bulk density and increases the cation exchange capacity (a very important property for supplying plant nutrients). The positive effect of organic matter on the soil physical properties enhances the plant root environment. Therefore, plants are better able to withstand drought conditions, extract water, and utilize nutrients(Hornick et al., 1984). Chemical properties affect plant growth as well as the soil's chemical and physical properties. The important chemical characteristics are: (i) pH, (ii) soluble salts, (iii) plant nutrients (macro and micro), (iv) essential and non-essential trace elements to humans and animals and (v) organic chemicals. The pH of most bio-solids (whether liquid, semisolid, or solid) is generally in the range of 7–8, unless lime is added during the wastewater treatment process. Plant nutrients are among the most important chemical characteristics of bio-solids, the major plant nutrients are nitrogen (N), phosphorus (P) and potassium (K)(Alayu, Leta and Aragaw, 2018).

Other macronutrients are calcium (Ca), magnesium (Mg), and sulfur (S). The micronutrients essential to plant growth are boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn)(Norup and Åberg, 2015).

2.3. Types of fertilizers

There are many different types of fertilizers used in agriculture; artificial fertilizers, animal manure, digestate from biogas production and wastewater sludge are some of the most frequently used fertilizers on the market of today's world(Norup and Åberg, 2015).

2.3.1. 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(Norup and Åberg, 2015).

The artificial fertilizer is produced synthetically and nutrients within the fertilizer are extracted from natural resources. For instance; Phosphorous and potassium are mainly extracted from rocks whereas nitrogen mainly originates from nitrogen gas extraction from the air, with the input of energy and water(Norup and Åberg, 2015). The phosphate rocks do also contain heavy metals to some extent and it is therefore a risk that heavy metals and other hazardous substances follow the nutrient extraction. Cadmium is one example of a heavy metal that can be found in the rocks where phosphorus is extracted (Rahmani *et al.*, 2014).

2.3.2. Sewage sludge as 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(Rahmani, Rezaei and Rezaei, 2014).

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(Rahmani *et al.*, 2014). The nutrient value is another challenge when using sludge as fertilizer. Sludge is considered as a low-grade fertilizer in comparison to for artificial fertilizers, meaning that a larger amount of sludge must be spread to achieve the same required supply of nutrients(Norup and Åberg, 2015).

2.4. Benefits of using organic fertilizers in agriculture

Different researchers' shows that, organic fertilizer has an overriding importance, because it is not only supply the soil with nutrients, but improve the soil structure and induce useful microbiological processes (Singh and Agrawal, 2016). Therefore, every possible way of organic fertilizer has vital importance on the preservation of soil fertility. Organic fertilizer is the end product obtained by converting various organic wastes such as crop residue, urban wastes, poultry droppings, animal dung, etc., into a usable fertilizer by a modified aerobic and anaerobic process of composting. Sludge is one of the organic fertilizers used to increase the soil fertility. Sludge was also defined as an accumulation of solids removed from sewage during waste water treatment(Nafez and Nikaeen, 2015). Sludge also acts as a soil conditioner to facilitate nutrient transport, increase water retention and improve soil fertility(Singh and Agrawal, 2008). Sewage sludge/bio-solids are by-products of municipal and industrial wastewater treatment and a rich source of organic nutrients. Agricultural use of sewage sludge has a great incentive in view of its fertilizer and soil conditioning properties. it used for crop production in both the developed and developing countries as important organic fertilizer of the world. These bio-solids are rich in organic nutrients; therefore, bio-solids can be utilized as a soil conditioner to improve physical, chemical, and biological properties of soils, especially those degraded or disturbed soils(Colón *et al.*, 2014). In addition to that act as a food source for microorganisms, organic materials are the major binding agents for aggregate formation and stabilization. Sewage sludge characteristically contain high levels of the major plant nutrients such as nitrogen, phosphorus and potassium, contain valuable micro nutrients such as Fe, Mn, Cu, Zn, Mo and Cl and are often enriched in organic matter(Colón *et al.*, 2014). Agricultural application of the sewage sludge is becoming more popular due to the possibility of recycling valuable components such as organic matter, N, P and other plant nutrients(Alvarenga *et al.*, 2015). Due to population increase and urbanization, bio-solids production would be rise. To reuse this bio-solids or to minimize by product accumulation on environment, agricultural application is generally considered as the most economical and beneficial way of bio-solids disposal. The use of sewage sludge for soil amendment and land reclamation is not only to solve the final disposal problems but it also improves the soil physical properties and increases soil organic matter content. In general, the major benefits of sludge application are; increased supply of major plant nutrients; provision of some of the essential micronutrients (Zn, Cu, Mo, and Mn) and; improvement in the soil physical properties, i.e. better soil structure, increased water holding capacity, and improved soil water transmission characteristics(Alvarenga *et al.*, 2015). Therefore, the benefits of sewage sludge are always weighed up against the limitations before and even during sludge application(Alvarenga *et al.*, 2015).

2.5. Effect of sewage sludge on growth of plants

The major benefits of sludge application are; increased supply of major plant nutrients; provision of some of the essential micronutrients (Zn, Cu, Mo, and Mn) and; improvement in the soil physical properties, such as better soil structure, increased water holding capacity, and improved soil water transmission characteristics. According to Bhaskarrao et al., (2015) the average accumulative germination percentage with organic and inorganic fertilizer shows that the organic fertilizer showed high frequency of 92-96% germination when inorganic fertilizer show 80- 86%. (Dawari, and Sharma, 2014) also proved that as organic fertilizer maximizes seed germination. This suggests that wastewater sludge would be a positive input for yield increase in relation to poor soils. Concentrations of metals and toxic constituents' sludge can be a valuable resource if used as a fertilizer and soil conditioner. South African farmers using sewage sludge as a fertilizer amendment reported a 20% increase in the yield of cultivated maize and 40% saving on inorganic fertilizer. According to Ramya et al. (2015) the waste water sludge enhanced growth with increasing the proportions of sewage sludge. According to Driessen and Vereijken (2003) increase in sludge led to a significant increase in plant height and yield. Organic fertilizer is primarily responsible for the increase in biomass, the length of the shoot and root length increases with increasing rate of application. Increased leaf area and leaf length implies higher light interception and dry matter product which invariably promotes plant growth.

2.6. Effect of sewage sludge on Soil Physicochemical properties

It is possible to avoid the requirement for crops to be commercially fertilized by applying sewage sludge to agricultural soil (Singh 2007 and Agrawal, 2009). This allows nutrients to be recycled. Sludge application to the land is seen to be a better option than landfilling or burning. Using sludge for agricultural use is a good management strategy that can provide income. Most significant U.S. towns turn municipal sludge into agricultural fertilizers and soil conditioners due to the fact that dried biosolids in the country can be worth between $25 and $40 per ton, depending on quality (Jenifer, 2002). The chemical, biological, and physical elements of digestion can be evaluated (Metcalf and Eddy, 2003).

The presence of heavy metals and other inorganic pollutants, persistent organic pollutants, and nutrients (NPK) is related to the chemical components of digestive quality control. The hydrogen ion (H+) and hydroxyl ion (OH-) activities in a water solution can be determined by measuring the pH of the soil, which also measures its acidity and alkalinity. According to Garcia and Barco's (2000) investigation into the usage of wastewater and its effects on the physical and chemical characteristics of soil in greenhouse settings. The outcome demonstrated that as sewage sludge application rates were raised, the pH of the soil gradually declined. Also, according to study by other scientists (Nielson et al., 1998), the pH of the soil drops as wastewater sludge application rates are increased. To determine how salts are affecting plant growth, EC is a trustworthy method. The quantity and make-up of dissolved salts affect the EC of soil and water, respectively. A high EC value implies a high salinity level because salts make a solution more electrically conductible. The application rate of waste water sludge was increased without affecting electrical conductivity. The ability of the soil to store and exchange cations is known as cation exchange capacity. The kind and quantity of clay and organic matter in the soil affects the CEC. Depending on the soil's texture and the area's rainfall, organic carbon will differ. There will be less organic carbon in a soil with a reduced CEC. The CEC and nutrient retention capacity of some soils will rise with an increase in OC levels, increasing their productivity potential. More OC will typically be present in areas with more rainfall or finer texture. According to Orhue et al. (2005), the organic carbon content of the soil has increased after the waste water effluent was added. Ramya (2015) asserts that adding waste water sludge to soils greatly increased the organic carbon content of those soils, and that higher soil organic matter, higher cation exchange capacity, and other nutrients are all related to better soils' ability to retain water. One of the elements that is most prevalent in soil is potassium. The total K in the soil will depend on the parent material of the soil, the degree of weathering and leaching of soil minerals, the kind of clay minerals, the soil's texture, the presence of organic matter, and the previous use of K fertilizers. Because so much of the potassium that naturally occurs in soil is unavailable to plants and crops, soils with high levels of K can still respond well to K fertilizers. According to Ramya et al. (2015), the amount of potassium in the soil rises with the rate at which the sludge is produced. According to Kara (2000), organic soil matter and microbiological activity—which can take both organic and inorganic forms—are major contributors to nitrogen in soil. Organic nitrogen (N) is a substance that occurs naturally in soil and can take on a variety of forms, including plant and microbial proteins, amino acids, and nucleic acids. It also enters the soil as crop residue and amendments including manures, composts, and speciality products (Crohn 2004). Crops can only absorb ammonium (NH^{+4}) and nitrate (NO_3), the two main inorganic sources of nitrogen. As a result, in order for biological N to be absorbed, it must first be changed into inorganic forms (Dinnes 2000). More so than applications of inorganic fertilizers, organic amendments had a significant impact on 'N' uptake and crop productivity. According to Ramya et al. (2015), with varied soil types, the nitrogen content of the soil increased with increasing rates of waste water sludge application, however the concentration of phosphorous decreased with increased application rates of sludge.

2.7. Nutrients in sewage sludge

Sewage sludge has different levels of nutrients (such as nitrogen, phosphorus or potassium), depending on the degree of dewatering and origin(Singh and Agrawal, 2008). Nitrogen is an essential nutrient for plant growth. 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(Özyazıcı, 2013). Anaerobic digestion process increases the total nitrogen concentration of sewage sludge. This is due to volume reduction because of the conversion of organic matter to gases and the resulting concentration of the remaining solids of which nitrogen is a part. Only a small part of the total nitrogen is immediately available for plants after application of sewage sludge. The nutrient availability in sewage sludge is influenced by many factors. In the course of mineralization of sewage sludge, nitrogen is transformed into available forms. The amount of nitrogen mineralized is inversely proportional to the carbon to nitrogen (C/N ratio) (Nayak and Kalamdhad, 2014). Soils with large C/N ratio result in low quantities of mineralized nitrogen. Nitrate leaching to ground water as a result of sewage sludge application may be limited due to the limited nitrate form of nitrogen available and the loss of ammonia is mainly due to de nitrification and immobilization. Inorganic fertilizers by contrast increase the C/N ratio which increases organic matter mineralization and nitrate leaching. Phosphorous is an essential nutrient needed for plant growth and is required in large quantities by plants while it is relatively immobile in soils. Phosphorous availability can be as high as 50% in the year of sewage sludge application(Colón *et al.*, 2014). The binding form of the phosphorus contained in sewage sludge depends, amongst other things, on the type of phosphorus precipitation in the sewage treatment plant. The actual plant availability of phosphorus is influenced by several factors such as pH value, soil and fertiliser buffering, levels of iron and aluminium in the sewage sludge or the plants themselves. Therefore, biological P-precipitation during the wastewater treatment process is preferable to a chemical P-precipitation for sewage sludge that is to be utilised on soil. According to the applicable fertiliser legislation, phosphate may only be applied to soils containing more than 20 mg P_2O_5 per 100 g soil depending on the requirement. Fertiliser requirements for nitrogen and phosphorus must be established by means of compulsory fertiliser requirements in accordance with precisely defined specifications. To establish the requirements the expected yields and qualities, the nutrient levels available in the soil, the site-specific plant population and the nutrient replenishment must be taken into account(Aza and Mahmoud, 2013).

2.7.1. Hydrogen ion concentration

The pH of sewage sludge may vary between slightly acidic to neutral and alkaline ranges depending on the degree of treatment and application of sludge conditioners (EPA, 1995). Sludge application may reduce the pH of soils due to humic acid release and may increase the electrical conductivity of soils. However, acidic soils have been observed to experience increase in pH following sludge amendment. In addition, the pH of soils may increase due to the exchangeable calcium and other cations present in sewage sludge. Agricultural crops grow well when soil pH is between 6 and 7 because nutrients are available more at pH of around 6.5. It is commonly recommended that soil pH should be maintained above 6.5 for sludge amended soils (EPA, 1995).

2.7.2. Electrical conductivity

The electrical conductivity of soils amended with sludge (with or without lime) also increases mainly due to the high level of salts present in sewage sludge. High salinity is also a factor that can inhibit plant growth in soils (Alayu, Leta and Aragaw, 2018).

2.7.3. Organic maters

Organic matter which forms over half of the mass of sewage sludge also improves the physical condition of soils(Singh *et al.*, 2011). An increase in organic matter reduces the bulk density, increases aggregate stability, increases water holding capacity of soils 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 result of sludge application (Colón *et al.*, 2014). By contrast, the increased bulk density of fine textured soils without sludge amendment causes poor aeration which adversely affects plant growth(Colón *et al.*, 2014).

2.7.4. Macro nutrients

Macro elements are essential for plants and soil fauna (Alayu, Leta and Aragaw, 2018). Treated sewage sludge can enrich soil with macronutrients such as phosphorus, potassium, sulfur, calcium, magnesium and micro nutrients. For instance, a macro nutrient imbalance in the form of high exchangeable sodium percentage can cause nutritional disturbances in plants and impair the uptake of calcium. Sodic soils are also known to have deficiencies in zinc and manganese. Exchangeable calcium is the major reserve of soil calcium available to plant roots. Manganese deficiency occurs in some soils, due to oxidation of manganese when the pH is raised above 6.2. Manganese uptake in plants is, therefore, generally limited in alkaline soils. Acidic soils exhibit deficiencies in Ca, K, Mg, N, P, and S limit conditions for crop development(Singh and Agrawal, 2008).

2.7.5. Cation exchange capacity

Application of sewage sludge at higher rates also increases the cation exchange capacity, CEC, of soils (Uysal, Yilmazel and Demirer, 2010; Alayu, Leta and Aragaw, 2018). The increase in CEC provides adsorption sites for essential nutrients within the root zone. An increase in the cation exchange capacity also helps in restricting the bioavailability of toxic heavy metals (Alvarenga *et al.*, 2015).

2.7.6. Micronutrients (heavy metals) in sewage sludge

Due to their hydrophobic nature, heavy metals are primarily found in sewage sludge. According to Tiruneh et al. (2014), these components are connected to the wastewater's solids component. The Council Directive of June 12, 1986 (86/278/EEC) specifies the concentration limit values of heavy metals (Cd, Cr, Cu, Ni, Pb, Zn, and Hg) in sewage sludge for nations in the European Union. In addition, between 30 and

50 percent of sewage sludge is used in agriculture as a substitute for landfill disposal or cremation (Tyta 2019). While applying sewage sludge to land overcomes the issue of its final disposal, it also runs the danger of secondary heavy metal pollution of soil, surface and ground waters, and other ecosystems (Tyta 2020). The heavy metals in sewage sludge come from a variety of sources. The most frequent include home and industrial wastewaters, surface runoff from urbanized areas or highways, wastewater from the agro-industrial sector, corrosion of sewage systems, pharmaceuticals, body care and cleaning goods, and illegal wastewater discharges. Many experts examined the levels of heavy metals in dewatered sewage sludge from various WWTPs.

Iron (Fe)

Iron is an essential micronutrient for plant development. It plays a key role as it is involved in the synthesis of chlorophyll and in other enzymatic and metabolic processes without which plants cannot carry out their lifecycle. This is what provides the plant with a healthy green coloration and oxygen. This is the reason an iron deficiency in plants results in sickly yellow leaves. The availability of iron in soils dictates the distribution of plant species in natural ecosystems and limits yield and nutritional quality of crops. Iron levels are usually adequate in the soil even though it has low crop availability. Iron good levels should be between 50 and 100 ppm. Iron (Fe) is an essential microelement but is highly toxic when in excess. Classic symptoms of Fe toxicity are leaf discoloration (bronzing) and a stunted root system. Iron deficiency can dramatically weaken plants, but iron excess causes "stunted growth," which is when plants appear small and sick, and can also cause "bronzing of leaves," which is when leaves turn brownish-red. Fertilizers that are high in iron include iron sulfates, iron chelates (chelated iron), greensand, iron supplements, blood meal, compost, and manure. Some of these will affect soil pH, so keep this in mind when we apply them, and get a soil test before doing so. Iron availability is lowest between pH 7.5 and 8.5. It becomes more available as soil pH decreases.

Manganese (Mn)

Manganese (Mn) is an important micronutrient for plant growth and development and sustains metabolic roles within different plant cell compartments. The amount of available manganese is influenced by soil pH, organic matter content, moisture, and soil aeration. Manganese availability increases as soil pH decreases. Manganese toxicity is common in acid soils below pH 5.5. On the other hand, manganese deficiency is most common in soils with a pH above 6.5. Average manganese concentrations in sludge compost is 181.4 mg/kg. Comparing the W.H.O maximum allowable limit for manganese which is 2000 mg/kg with the results of samples tested for manganese, it shows that all the samples are below the W.H.O limit. Mn toxicity can trigger oxidative stress and disrupt photosynthesis, which may result in the generation of interveinal chlorosis in young leaves, necrotic dark spots on mature leaves, and crinkled leaf. Manganese sulfate (MnSO4) is the most common of the Mn fertilizer sources. It is highly water soluble and suited for soil or foliar application.

Cupper (Cu)

Copper (Cu) is one of eight essential plant micronutrients. Copper is required for many enzymatic activities in plants and for chlorophyll and seed production. Deficiency of copper can lead to increased susceptibility to diseases like ergot, which can cause significant yield loss in small grains. The copper content of soils ranges from 2 to 100 parts per million (ppm). Most of this is in unavailable mineral form. Copper toxicity to roots could occur when total Cu exceeds 50 ppm in sandy soils up to 150 ppm for silty-clay or clay soils. Soils higher in organic matter have a higher toxicity cutoff. The reason for the high Cu concentrations could have been caused probable by the corrosion of the water supply pipes, whose composition includes copper. the copper in sewage sludge may also came from the water supply connected to the household pipes (EPA,1995).

Zink (Zn)

Zinc is one of the essential micronutrients that acts as a catalyst for activating enzymes required for synthesis of plant proteins. The total amount of Zn in soils averages about 50 ppm, ranging from 10 to 300 ppm depending on the geochemical composition and weathering of the parent material. Zinc, like all plant nutrients, must be dissolved in water before it can be taken up by roots. Zinc is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops. Growth and development would stop if specific enzymes were not present in plant tissue. Carbohydrate, protein, and chlorophyll formation is significantly reduced in zinc-deficient plants. High concentrations of zinc can cause toxicity in plants. The general symptoms are stunting of shoot, curling and rolling of young leaves, death of leaf tips and chlorosis. The general critical levels of Zn deficiency in soils and crops falls in the range 0.6 – 1.0 mg/kg (DTPA-extractable) and 10- 20 mg/kg in dry matter, respectively but vary with soils and crops. Inorganic sources of Zinc include: zinc sulphate, zinc oxide, zinc carbonate, zinc nitrate, and zinc chloride. Zinc sulphate is the most commonly used zinc fertilizer worldwide and is available in both crystalline monohydrate and heptahydrate forms. Poor soil organic matter usually results in lower availability of zinc (Zn) micronutrients in plants. Such deficiency in Zn causes a significant decrease in the growth and yield of crops. Concentrations above 150 mg Zn/kg corresponded to severe stunting, whiles concentrations as high as 900 mg Zn/kg were measured in severely affected plants. The origin of Zn in the sludge may be due to the use of brass as a household cleaning material. Secondly Zn is a constituent of galvanized steel including water distribution pipes and the possibility is that its presence might be due to corrosion and the metal may find its way to the water treatment plant (Pawlowski et al., 2013).

2.8. Characterization and Classification of Sludge

2.8.1. Categories

Depending on the origin of the wastewater, the sludge produced within the process of wastewater treatment can be categorized in three categories:

Category A: Municipal sewage sludge, including comparable sludges (e.g. sludge from on-site sanitation facilities such as septic tanks or pit latrines).

Category B: Sludge from wastewater treatment plants treating municipal and industrial wastewater or treating exclusively wastewater from industries.

Category C: Sludge from wastewater treatment plants treating municipal and industrial wastewater or treating exclusively wastewater from industries belonging to the category of hazardous waste (ESA,2021).

Categorization of sludge mixture shall be according to below:

Category A + Category B = Category B

Category A + Category C = Category C

Category B + Category C = Category C

Category A + Category B + Category C = Category C

Depending on the classification of the sludges, different management options are permissible. In view of the protection of the environment in Ethiopia, it shall be forbidden to mix Category A sludge with Category C sludge.

Category A

The criteria for classifying sludge as category A are listed below:

(1) Sludge which gets produced in a wastewater treatment plant, treating only domestic wastewaters or urban wastewater shall be designated as municipal sludge and classified as category A.

(2) Sludge, which gets produced in wastewater treatment plants, treating wastewater, comparable to domestic wastewater or urban wastewater may be counted as municipal sludge and classified as category A.

Category B

The criteria for classifying sludge as category B are listed below:

(1) If the sludge cannot be classified as category A or category C it is automatically classified as category B.

Category C

The criteria for classifying sludge as category C are listed below: (1) sludge, which fulfils the criteria in which adapted from hazardous waste proclamation has to be counted as hazardous waste and classified as category C, unless the producer provides evidence that it does not possess any hazardous characteristics (2) sludge, which has at least one of the characteristics, as described in adapted from hazardous waste proclamation has to be counted as hazardous waste and classified as category C, unless the producer provides evidence that it does not possess any hazardous characteristics as described in proclamation of sludge draft guide. According to this guide the present sludge is category A sludge

3. MATERIALS AND METHODS

3.1. Description of the study area

The study area is situated in south-eastern Ethiopia in Bale zone around robe town as shown in figure 1. The study area is called as Madda walabu university sewage treatment plant which is found near Robe town the capital city of bale zone, Oromia regional state, Ethiopia in Madda Walabu University at a latitude of 7^{0}8'50'' N and longitude of 39^{0}59'55'' E. The annual average temperature of Bale Robe is 17.5°C. The maximum and minimum temperature is 25°C and 10°C respectively. The mean annual average rainfall is 875mm, whereas maximum 1200mm and 550mm minimum annual rainfall were recorded in the Robe town (NMSA, 2017). The study plant has a potential of producing five (5) ton of sludge per year.

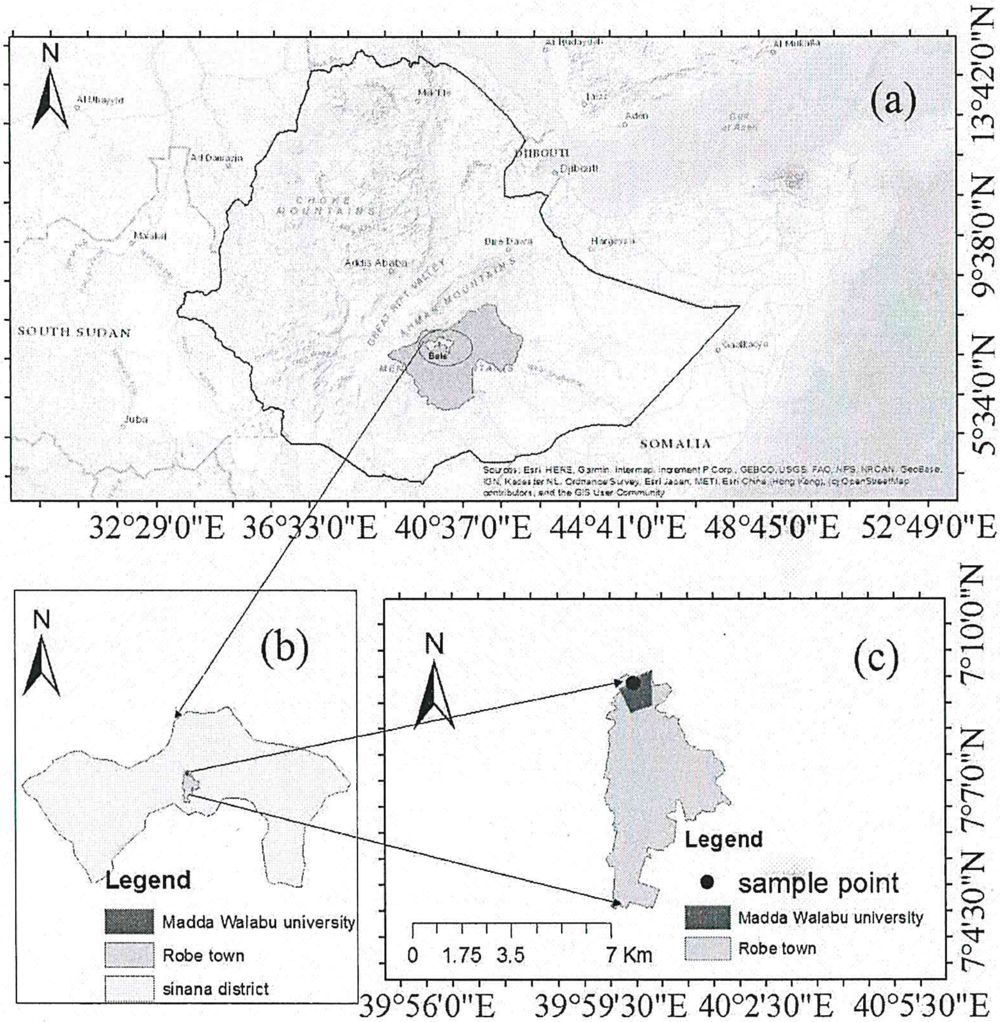


Figure 3.1: Location map of study area

3.2. Materials

Materials used during the study period includes Laboratory Equipment apparatus such as cylindrical glass, incubator, drying oven, furnace, Spectrophotometer, test tube, measuring cylinder, sieve and weighing scale throughout the experiment and stationary equipment such as pen, pencil, personal computer, paper, Photographic Camera, and plastic bag.

3.3. Methodology

The methodology adopted in this research was experimental. The research objective is to investigate the quality and to evaluate the suitability of sewage sludge for agricultural use as alternative fertilizer. Laboratory experiments were carried out for the determination of physico-chemical properties of sewage sludge that best describes the nutrient and agricultural potential of sewage sludge. In addition, heavy metal determination was carried out for a number of heavy metal elements that are known to have toxicity effects on humans, animals, plants and the soil ecological environment. For the purpose of determination of physico-chemical characteristics, sewage sludge samples were collected from Madda Walabu University sewage treatment plant and analysed in the laboratory of the Oromia Engineering Corporation (ECO) and Ethiopian Construction Design & Supervision Works Corporation. Now, dry season samples were submitted and we are waiting the for the test result and we will submit the wet season soon.

3.3.1. Sludge sampling and preparation

A sample is not suitable for direct analysis as collected and it must be prepared before analysis. The source of sludge sample was Madda Walabu University wastewater treatment plant, located in the oromia regional state, Ethiopia. Sludge sampling was performed based on the EPA procedure. The sludge was collected from the sedimentation tank and processed to obtain appropriate quality through air drying. A dried representative sludge sample was taken to laboratory for investigation of its physicochemical including heavy metals. A 1 Kg dried sludge sample was ground and sieved by passing through <2 mm stainless steel sieve and stored in the plastic bag at room temperature for further laboratory analysis by three replicate.



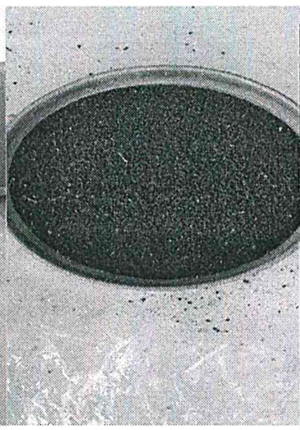



Figure 2: sample collection and preparation

3.3.2. Sample analysis

sample replicate from each of the prepared samples following the steps described in sample preparation above were taken for the determination of physico-chemical characteristics of sludge samples. The parameters determined included: pH, electrical conductivity, nutrients (exchangeable Na, ex.K, ex.Ca, and ex.Mg), cation exchange capacity (CEC), available phosphorous, available potassium, available sulfur, organic carbon, organic matter, total nitrogen, and micronutrients (such as Fe, Mn, Cu and Zn). pH and electrical conductivity were conducted by potentiometric method by H12211PH/ORP meter HNNA instrument. nutrients (exchangeable Na, ex.K, ex.Ca, and ex.Mg) was ammonium acetate PH7 extraction and reading by analytic jena, nova,400 AAS & LABCONCO distillation unit, 141102492T. Cation exchange capacity was determined using the NaCl replacement and then distillation or ammonium acetate extraction and instrumental. Available phosphorous was done by Olsen method by using Jenway 6400 spectrophotometer. Available potassium was done by morgan's solution method and reading by AAS analyses a.anovAA 400 or by using Ammonium acetate. Available sulfur was done by KH_2PO_4 Extraction turbidimetric, Organic carbon was determined by Walkey-Black, titration method by TITRE (2000). Organic matter (OM) content was estimated by multiplying total organic carbon content by the Van Bemmelen factor (1.724) (Wierzbowska, Kova and Bowszys, 2018). Total nitrogen was done by kjeldahal digestion method using Gerhardt, kt 40s. micronutrients (such as Fe, Mn, Cu and Zn) was tested by DTPA extraction and instrumental.

4. Results and Discussion

4.1. Physicochemical characteristics of sewage sludge

The results of the physicochemical analysis of sludge samples collected from madda walabu university treatment plant is presented in Table 1.

Table 1: physicochemical content of sewage sludge

S.N	Parameters	Test 1(from storage)	Test 2 (dry season)	Test 3 (wet season)	average
1	PH	6.4	6.34	6.06	6.27
2	EC (ds/m)	3.23	1.98	3.15	2.79
3	Ex.Na (cmol/kg)	0.84	2.11	3.23	2.06
4	Ex.K(cmol/kg)	1.24	2.97	2.85	2.35
5	Ex.Ca(cmol/kg)	29.94	38.5	42.74	37.06
6	Ex.Mg(cmol/kg)	7.98	9.63	11.77	9.79
7	CEC per kg	44.9	63.41	67.39	58.57
8	Base Saturation	89			89.00
9	Available phosphorous (ppm)	285	523.05	379.32	395.79
10	Available potassium (ppm)	48.3	1289.55	1253.22	863.69
11	Available sulfur		4565.96	8559.60	6562.78
12	Organic carbon (%)	22.03			22.03
13	Organic matter (%)	37.97			37.97
14	Total nitrogen (%)	1.98			1.98
15	C:N ratio	11			11.00
16	Fe (mg/kg)		264.63	234.79	249.71
17	Mn (mg/kg)		180.52	182.35	181.44
18	Cu (mg/kg)		10.2	3.4	6.80
19	Zn (mg/kg)		22.44	81.62	52.03

PH

The pH of sewage sludge may vary between slightly acidic to neutral and alkaline ranges depending on the degree of treatment and application of sludge conditioners (EPA, 1995). Agricultural crops grow well when soil pH is between 6 and 7 because nutrients are available more at pH of around 6.5. It is commonly recommended that soil pH should be maintained above 6.5 for sludge amended soils (EPA, 1995) and 6-8.5 according to permissible limit prescribed by USEPA (1995). But that of MWU treatment plant have average PH of 6.27 which is within recommended limit and can be used in Agriculture (Russell, 1973, Landon, 2014).

Electrical conductivity

The electrical conductivity of soils amended with sludge also increases mainly due to the high level of salts present in sewage sludge. High salinity is also a factor that can inhibit plant growth in soils (Alayu, Leta and Aragaw, 2018). Indeed, in previous study (Marchese et al., 2008), it has been reported that high EC values from 2.5-3.0 mS/cm is harmful for fruits and values between 4.5-5 mS/cm is harmful for the stems; which result into the low germination rate, withering of the plants. The allowable limit for using sewage sludge as prescribed by USEPA is <8 mS/cm. the present study sludge have average EC of 2.79 ds/m or ms/cm which may not harm any plant in short period of application and may harm fruits after long period application of sewage sludge. Continuous follow up is recommended during its uses for the fruit cultivation.

Exchangeable bases (Ex.Na, Ex.K, Ex.Ca, & Ex.Mg)

The levels of exchangeable cations in a soil are usually of more immediate value in advisory work than the CEC, because they not only indicate existing nutrient status, but can also be used to assess balances amongst cations. This is of great importance because many effects, for example on soil structure and on nutrient uptake by crops, are influenced by the relative concentrations of cations as well as by their absolute levels.

plant-available Ca are of little value, since the availability varies enormously from soil to soil, and is highly dependent on a number of other factors. Normally Ca deficiency as a plant nutrient occurs only in soils of low CEC at pH values of 5.5 or less (Landon, 2014). High values of exchangeable Ca can be taken as those above about 10 meq/100g soil (Landon, 2014). The present sludge has average exchangeable Ca of 37.06 cmol/kg which is high exchangeable Ca and very good for an acidic soil of PH less than 5.5.

The presence of Mg deficiency in a crop may not only be associated with low Mg content in the soil, but also with the presence of large amounts of other cations, particularly Ca and K. With increasing Ca:Mg ratios above about 5:1, the Mg may become progressively less available to plants, although soils can remain fertile over a very wide range of Ca:Mg ratios(Landon, 2014). high levels of Mg may be taken as those above 4.0 meq/100g (Landon, 2014). The average exchangeable Mg in the present sludge is 9.79 cmol/kg and Ca:Mg ratios is 3.79:1 which is very good and sufficient for application on soil of less exchangeable Mg (<0.5 cmol/kg).

Exchangeable K levels are of only limited value for predicting crop response since they give no direct indication of the capacity of the soil to release currently unavailable K over a period of time. Available K (meq/100 g soil) is high (> 0.5), medium (0.5-0.25), and low (< 0.25)(Landon, 2014). The present sludge has average Exchangeable K of 2.35 cmol/kg which is in the category of high potential and can be used on soil with low Exchangeable K.

Exchangeable Na is not an essential plant nutrient. Its absence, or presence in only very small quantities, is therefore not usually detrimental to plant nutrition. However, when Na is present in the soil in significant quantities, particularly in proportion to the other cations present, it can have an adverse effect, not only on many crops, but also on the physical conditions of the soil. A widely used measure of the effects of high sodium levels is the exchangeable sodium percentage (ESP), which is defined as:

ESP= Exchangeable Na/CEC

An ESP value of 15 is often regarded as the boundary between sodic and non-sodic soils. In general, soils with exchangeable Na > 1 meq/100 g should be regarded as potentially sodic. The present sludge has average exchangeable Na of 2.06 cmol/kg which is greater than 1 and have sodic property.

Cation exchangeable capacity (CEC)

Cation exchange capacity (CEC) is a measure of the total negative charges within the soil that adsorb plant nutrient cations such as calcium (Ca2+), magnesium (Mg2+) and potassium (K+). As such, the CEC is a property of a soil that describes its capacity to supply nutrient cations to the soil solution for plant uptake. The nutrient cations plants use in the largest amounts are potassium (K+), calcium (Ca2+) and magnesium (Mg2+). In general, the higher the CEC number the higher the soil fertility. The CEC can give insight into soil quality and site characteristics. Higher CEC likely indicates more clay, poor internal drainage, limited structure and soil compaction in high traffic areas. The average CEC in the present sludge is 58.57 cmol/kg. According to Landon (2014) this range is in the very high CEC (>40 cmol/kg) which is very good for agricultural lands.

Base saturation

Percent base saturation (BS) is the percentage of the CEC occupied by the basic cations Ca2+, Mg2+ and K+. Basic cations are distinguished from the acid cations H+ and Al^{3+}. At an approximate soil pH 5.4 or less, Al^{3+} is present in a significantly high concentration that hinders growth of most plant species, and the lower the soil pH, the greater the amount of toxic Al^{3+}. Therefore, soils with a high percent base saturation are generally more fertile. According Landon (2014), a soil of base saturation >60 is classified as high fertile. The present sludge has 89% of base saturation which is very good for plant growth. So, the sludge is very fertile and can be used as fertilizer.

Available phosphorous

Phosphorus in sludge comes from residues, microorganism cells formed during waste water treatment and phosphate- containing detergents and soap. After nitrogen, phosphorus is the 2nd most limiting nutrient. Bio-soil may have high amount of P (100 to 2500 kg total P/ha), although the assimilable quantity by plants is extremely low usually 0.1 – 1 kg/ha due to the high capacity of fixation by solids (precipitation and adsorption). According to Havlin et al. (1999): P < 3 mg/kg as very low, 4 to 7 mg/kg as low, 8 - 11 mg kg-1 as medium, and > 12 mg kg-1 as high. The present sludge has very high average available phosphorous content of 395.79 ppm which is very useful for plant growth.

Available potassium

Potassium, unlike nitrogen and phosphorus, is not associated to any great extent with organic matter. Total amounts of potassium in soil will vary from 0.3 to more than 2.5 percent. While total content of potassium is important, it is of little value in determining how well a given soil can supply potassium to growing plants. Readily available potassium is composed of exchangeable potassium and potassium in the soil solution. Exchangeable potassium is absorbed on the soil colloid surfaces and is available to plants. However, higher plants obtain most of the potassium from the soil solution phase. The available K for crop is insufficient for <50 mg/kg, low for 51-140mg/kg, sufficient for 141-370 mg/kg and high for >1000 mg/kg (FAO, 1990). The present sludge has average available potassium of 863.69 ppm or mg/kg which is sufficient for crop.

Available sulfur

Sulphur (S) is one of the essential plant nutrients, ranked as the fourth most important plant nutrient after nitrogen (N), phosphorus (P) and potassium (K). Sulfur is a key nutrient in agriculture. It is classified as a plant macronutrient and used by crops in about the same amounts as for phosphorus (P). It influences the metabolism of the plant itself, as well as crop yields and quality. Some soil sulfur inputs are required for proper crop production. Optimum supply of S can increase the nutritional value and yield, whereas S deficiency may cause an approximately 50% decrease in crop yield depend upon the crop. If the topsoil is found to have 15 parts per million (ppm) or more available sulfur, the field is predicted to have enough, and no sulfur fertilizer is recommended. However, when the topsoil layer has less than 15 ppm available sulfur, field corn will occasionally exhibit an economic response to sulfur fertilizer. Approximate critical levels are 200 mg/kg total S, or 6 - 12 mg/kg extractable S, below which S deficiency is likely in soils with a low organic matter content. High content of Sulfur in soil causes soil contamination and acidification. The present sludge compost has average available sulfur of 6562.78 mg/kg which is high content and can be replace sulfur fertilizer for agricultural uses.

Organic carbon

The OC content of soils are: Very low (< 2%), low (2- 4), medium (4 - 10), high (> 10), very high (> 10). But that of sludge is 22.03% which is high and good for plants. According to the standard level (8-50%) (Bina et al., 2004), the carbon was relatively medium in sludge samples and hence good for use in agriculture (Rahmani *et al.*, 2014).

Organic matter

It is well known that sludge's organic matter is the component key to its successful use sludge as organic amendment (Reuter 1993). Organic matter has an important role in soil such as increasing the stability of the formed aggregate, reducing the bulk density, and up holding better infiltrations of water (Roig et al. 2012). The obtained values of organic matters in the sludge is 37.97% which good for plant in range of (25-50%).

Total nitrogen

Nitrogen is the element with the highest economic value in bio-solids, and to which crops present the highest response. Nitrogen comes from the microbial biomass present in inorganic forms as nitrate and ammonia and organic forms as proteins. Total N content of present sample is 1.98 which is in the good range according to Landon (2014).

C:N ratio

A lower C/N ratio increases leaching and consequently loss of nitrogen and volatilization of ammonia. A higher C/N ratio indicates a limited mobilization of nitrogen; nevertheless, an availability for a later period of growth (Bhatt et al. 2015). The C/N ratio is too low, the resultant product will not help improve the soil structure (Parvaresh and Alidadi 2004). As for the C/N ratio, many authors have mentioned that it should be between 15 and 30 (Binh 2017). For the madda walabu treatment plant, the carbon to nitrogen ratio was lower at 11 (Table 1).

Iron (Fe)

Iron is an essential micronutrient for plant development. It plays a key role as it is involved in the synthesis of chlorophyll and in other enzymatic and metabolic processes without which plants cannot carry out their lifecycle. Iron good levels should be between 50 and 100 ppm. Iron availability is lowest between pH 7.5 and 8.5. It becomes more available as soil pH decreases. The present compost has average iron content of 249.71mg/kg which is above good level and enough to replace fertilizers containing iron.

Manganese (Mn)

Manganese (Mn) is an important micronutrient for plant growth and development and sustains metabolic roles within different plant cell compartments. The amount of available manganese is influenced by soil pH, organic matter content, moisture, and soil aeration. Manganese availability increases as soil pH decreases. Manganese toxicity is common in acid soils below pH 5.5. On the other hand, manganese deficiency is most common in soils with a pH above 6.5. Average manganese concentrations in sludge compost are 181.4 mg/kg. Comparing the W.H.O maximum allowable limit for manganese which is 2000 mg/kg with the results of samples tested for manganese, it shows that all the samples are below the W.H.O limit. So, the present compost can replace Mn fertilizers.

Cupper (Cu)

Copper (Cu) is one of eight essential plant micronutrients. Copper is required for many enzymatic activities in plants and for chlorophyll and seed production. Deficiency of copper can lead to increased susceptibility to diseases like ergot, which can cause significant yield loss in small grains. The copper content of soils ranges from 2 to 100 parts per million (ppm). Most of this is in unavailable mineral form. The reason for the high Cu concentrations could have been caused probable by the corrosion of the water supply pipes, whose composition includes copper. the copper in sewage sludge may also came from the water supply connected to the household pipes (EPA,1995). The present sludge has average Cu content of 6.8 mg/kg which is within allowable limit prescribed by EU 3rd Draft which is up to 1000 mg/Kg, Standard (USEPA) which is up to 1500 mg/kg and Ethiopian Standards Agency which is 800 mg/kg.

Zink (Zn)

Zinc is one of the essential micronutrients that acts as a catalyst for activating enzymes required for synthesis of plant proteins. The total amount of Zn in soils averages about 50 ppm, ranging from 10 to 300 ppm depending on the geochemical composition and weathering of the parent material. High concentrations of zinc can cause toxicity in plants. The origin of Zn in the sludge may be due to the use of brass as a household cleaning material. Secondly Zn is a constituent of galvanized steel including water distribution pipes and the possibility is that its presence might be due to corrosion and the metal may find its way to the water treatment plant (Pawlowski et al., 2013). The present sludge compost has average zinc content of 52.03 mg/kg which is within allowable limit prescribed by EU 3rd Draft which is up to 2500 mg/Kg and Standard (USEPA) which is up to 2800 mg/kg.

5. Conclusion and recommendation

5.1 Conclusion

Sewage sludge utilization as a means of waste disposal is gaining attention nowadays. However, characterization of sewage sludge is critical before any land application. Sewage sludge characterization helps determine the magnitude of nutrients for soil supplementation and enables the investigation of the presence of pollutants. In this study, a physicochemical characterization of the sludge generated from madda Walabu University was performed.

The results indicated that sewage sludge had high fertilizing values for essential macronutrients, micronutrients and organic matter which is in the guidelines on sludge reuse in thus do not restricting its use in agriculture. Further research is needed to explore the impact of using this sludge on soil and crops.

5.2 Recommendation

Based on the result of the study and conclusions reached, the following recommendations are forwarded as follow:

- continuous assessment of the effect of sludge used on agricultural field is recommended
- recommend to assess the yield of crops after uses of sludge
- recommend to test the content of remaining heavy metal in sludge such as Cd, Cr, As, Pb.

Reference

Alayu, E., Leta, S. and Aragaw, T. (2018) 'Advances in Recycling and Waste Management Characterization of the Physicochemical and Biological Properties of Kombolcha Brewery Wastewater Treatment Plant Bio-solid in Relative to Agricultural Uses', 3(1), pp. 1–7. doi: 10.4172/2475-7675.1000154.

Alvarenga, P. et al. (2015) 'Sewage sludge , compost and other representative organic wastes as agricultural soil amendments : Benefits versus limiting factors', WASTE MANAGEMENT, (276). doi: 10.1016/j.wasman.2015.01.027.

Aza, H. and Mahmoud, A. M. (2013) 'Effect of different sources of calcium , organic and inorganic nitrogen on sandy soil , peanut yield and components', 1(5), pp. 51–59.

Bhaskarrao Chinthapalli, DagneTafaDibar, D. S. VijayaChitra, MelakuBedasoLeta, (2015). A Comparative Study on the Effect of Organic and Inorganic Fertilizers on Agronomic Performance of Faba Bean (ViciafabaL.) and Pea (PisumsativumL.). Agriculture, Forestry and Fisheries. Vol. 4, pp. 263-268.

Bo, M. and Siemi, G. (2018) 'Characterization of composted sewage sludge during the maturation process : a pilot scale study', pp. 34332–34342.

Cesar, C. et al. (2020) 'Successive sewage sludge fertilization : Recycling for sustainable agriculture', Waste Management, 109, pp. 38–50. doi: 10.1016/j.wasman.2020.04.045.

Cohen, Y. and Ka, T. (2017) 'From agricultural use of sewage sludge to nutrient extraction : A soil science outlook', pp. 143–154. doi: 10.1007/s13280-016-0816-3.

Colón, J. et al. (2014) 'Chapter 14 Producing sludge for agricultural applications'.

Council Directive of 12th June 1986 on the Protection of the Environment, and in Particular of the Soil, When Sewage Sludge Is Used in Agriculture (86/278/EEC). Available online: https://eur-lex.europa.eu/legal.

Crohn, D. (2004) 'Nitrogen Mineralization and Its Importance in Organic', Soil Biology.

EPA (1995) 'Process Design Manual Land Application of Sewage Sludge and Domestic Septage', (September).

Ethiopian Standards Agency. ' Guideline for Sludge Management', First edition draft report, 2021

European Commission. Working document on sludge, 3rd Draft. Brussels, 27 April 2000.

Hornick et al., 1984 (1984) 'Utilization of Sewage Sludge Compost as a Soil Conditioner and Fertilizer for', p. 32.

Iticescu, C. et al. (2018) 'The characteristics of sewage sludge used on agricultural

lands', AIP Conference Proceedings, 2022, pp. 9–12. doi: 10.1063/1.5060681.

Kara E., (2000) Effects of Some Plant Residues on Nitrogen Mineralization and

Biological Activity in Soils.

Mtshali, J. S., Tiruneh, A. T. and Fadiran, A. O. (2014) 'Characterization of Sewage Sludge Generated from Wastewater Treatment Plants in Swaziland in Relation to Agricultural Uses', 4(4), pp. 190–199. doi: 10.5923/j.re.20140404.02.

Nafez, A. H. and Nikaeen, M. (2015) 'Sewage sludge composting : quality assessment for agricultural application'. doi: 10.1007/s10661-015-4940-5.

Nayak, A. K. and Kalamdhad, A. S. (2014) 'Feasibility of Composting Combinations of Sewage Sludge , Cattle Manure , and Sawdust in a Rotary Drum Reactor', 19(1), pp. 1–11.

Norup, J. and Åberg, E. (2015) 'Quality assessment of sludge from Glen Valley wastewater treatment plant and its potential as fertilizer by'.

Özyazıcı, M. A. (2013) 'Effects of sewage sludge on the yield of plants in the rotation system of wheat-white head cabbage-tomato', 2, pp. 35–44.

Pawlowski, B.; Krawczyk, J.; Bala, P. The premature deterioration of Zinc-coated steel pipes in water distribution system. Inter. J. Mater. Mech. Eng. 2013, 2, 43–47.

Rahmani, H. R. et al. (2014) 'Investigation of some properties of North-Isfahan sewage sludge for application on agricultural land – Isfahan .' doi: 10.15192/PSCP.AAB.2014.1.2.8488.

Rahmani, H. R., Rezaei, H. and Rezaei, M. (2014) 'Investigation some Properties of Shahin-Shahr Sewage Sludge For Land Application – Isfahan , Iran', 4(6), pp. 382–387.

Ramya N. Ramya T. Srinivas and K. Aruna Lakshmi (2015). Studies on effect of brewery waste water sludge (bws) on morphology and yield of chilly. Plant Vol. 6(1): pp 405-409.

Rihani, M., Malamis, D., Bihaoui, B., Etahiri, S., Loizidou, M., & Assobhei, O. (2010). In-vessel treatment of urban primary sludge by aerobic composting. Bioresource Technology, 101, 5988–5995.

Singh, R. P. et al. (2011) 'Land Application of Sewage Sludge : Physicochemical and Microbial Response Land Application of Sewage Sludge : Physicochemical and Microbial Response', (August). doi: 10.1007/978-1-4614-0668-6.

Singh, R. P. and Agrawal, M. (2008) 'Potential benefits and risks of land application of sewage sludge', 28, pp. 347–358. doi: 10.1016/j.wasman.2006.12.010.

Singh, R. P. and Agrawal, M. (2016) 'Use of sewage sludge as fertiliser supplement for Abelmoschus esculentus plants : Physiological , biochemical and growth responses Use of sewage sludge as fertiliser supplement for Abelmoschus esculentus plants : physiological , biochemical and growth res', (January 2009). doi: 10.1504/IJEWM.2009.024702.

Sohaili, J., Zaidi, N. S. and Loon, S. C. (2012) 'Nutrients Content of Sewage Sludge and Its Utilization towards Horticulture Plant Corresponding Author : Nur Syamimi Zaidi', 3(1), pp. 81–85.

Tiruneh AT, Fadiran AO, Mtshali JS (2014) Evaluation of the risk of heavy metals in sewage sludge intended for agricultural application in Swaziland. International Journal of Environmental Science and Technology 5: 197–216. http://doi: 10.6088/ijes.2014050100017

Tytła M (2019) Assessment of Heavy Metal Pollution and Potential Ecological Risk in Sewage Sludge from Municipal Wastewater Treatment Plant Located in the Most Industrialized Region in Poland - Case Study. International Journal of Environmental Research and Public Health 16:2430. https://doi.org/10.3390/ijerph16132430

Tytła (2020) Identification of the Chemical Forms of Heavy Metals in Municipal Sewage Sludge as a Critical Element of Ecological Risk Assessment in Terms of Its Agricultural or Natural Use. International Journal of Environmental Research and Public Health 17:4640. https://doi.org/10.3390/ijerph17134640

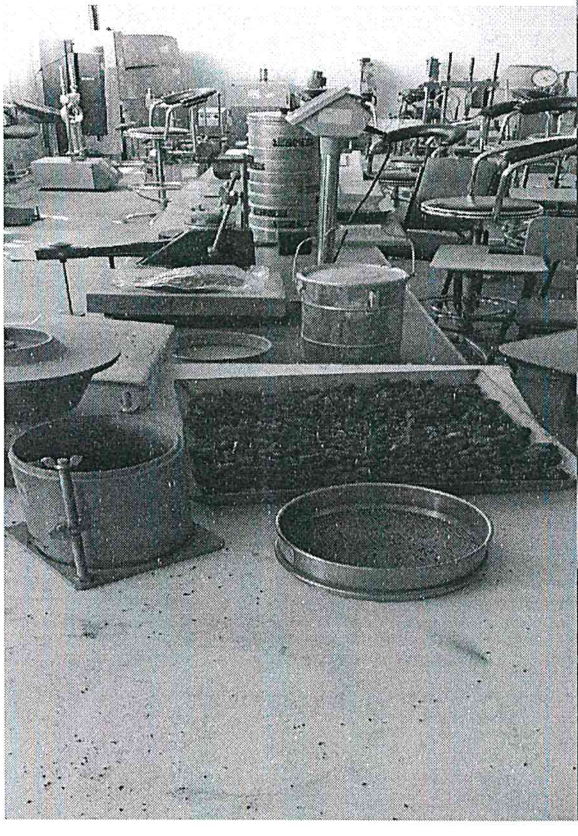
USEPA. (1995). A guide to the biosolids risk assessment for the EPA Part 503 Rule EPA. B32-B-93-005. Washington DC: United States Environmental Protection Agency Office of Wastewater Management.

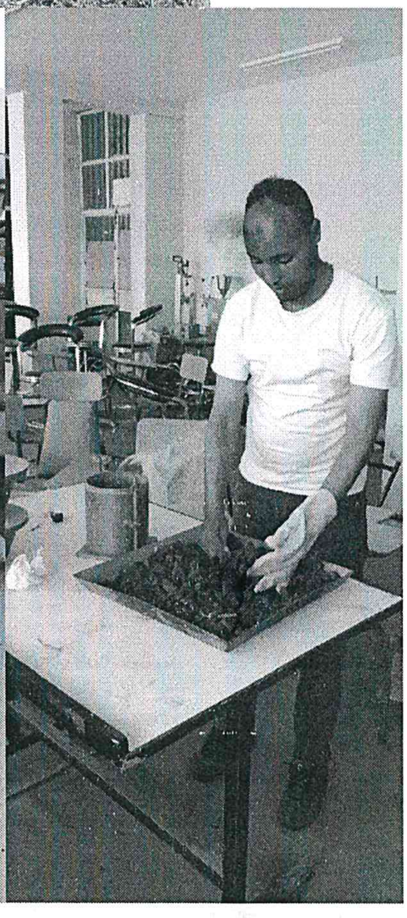
Uysal, A., Yilmazel, Y. D. and Demirer, G. N. (2010) 'The determination of fertilizer quality of the formed struvite from effluent of a sewage sludge anaerobic digester', Journal of Hazardous Materials, 181(1–3), pp. 248–254. doi: 10.1016/j.jhazmat.2010.05.004.

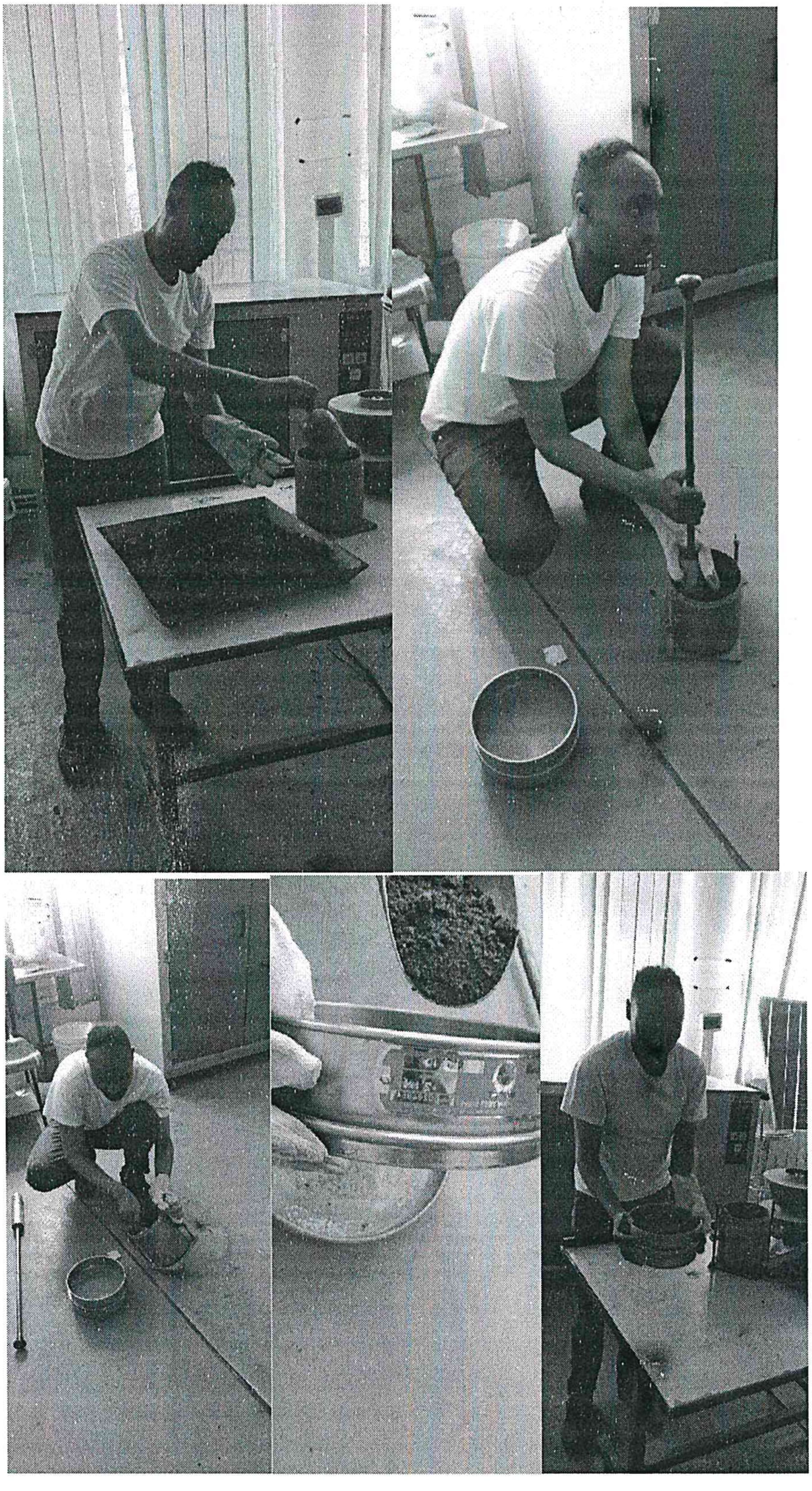
Wierzbowska, J., Kova, P. and Bowszys, T. (2018) 'Determination of heavy metals and their availability to plants in soil fertilized with different waste substances'.

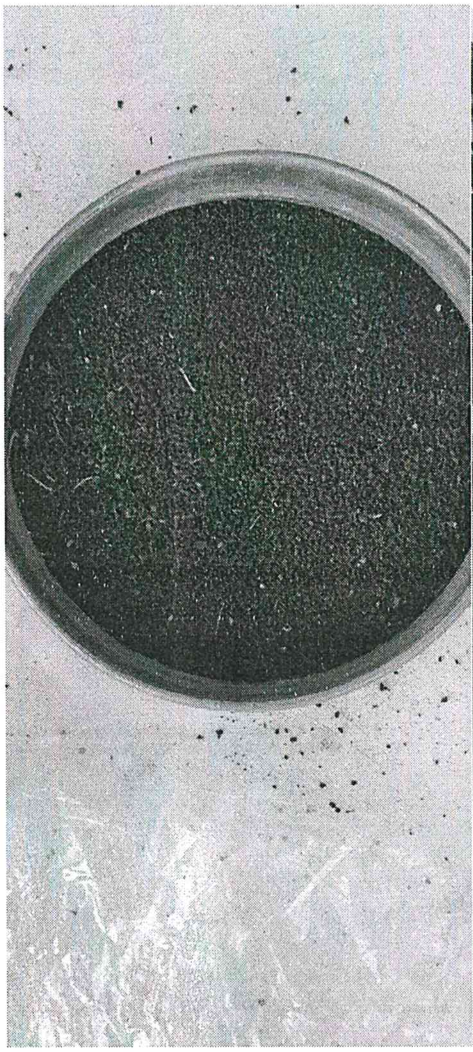
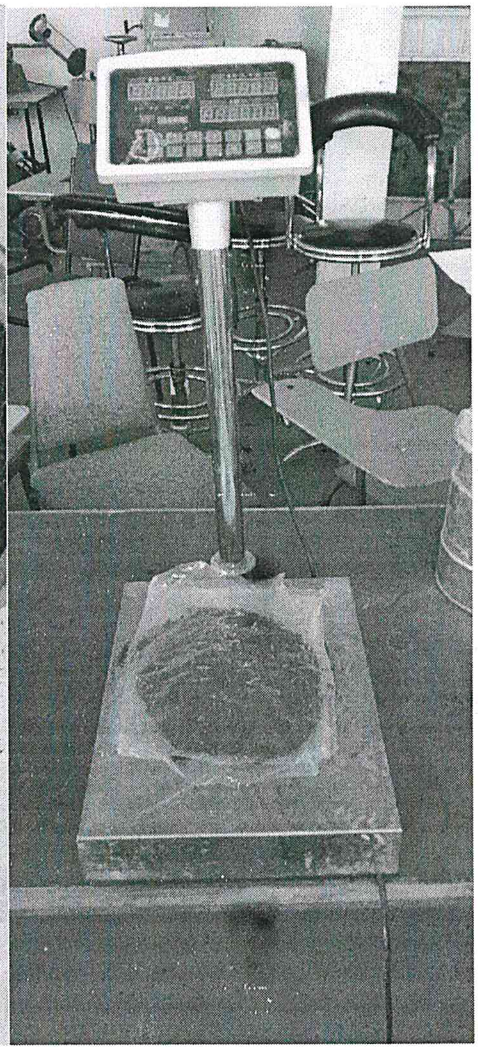
Appendix

A. Sample preparation

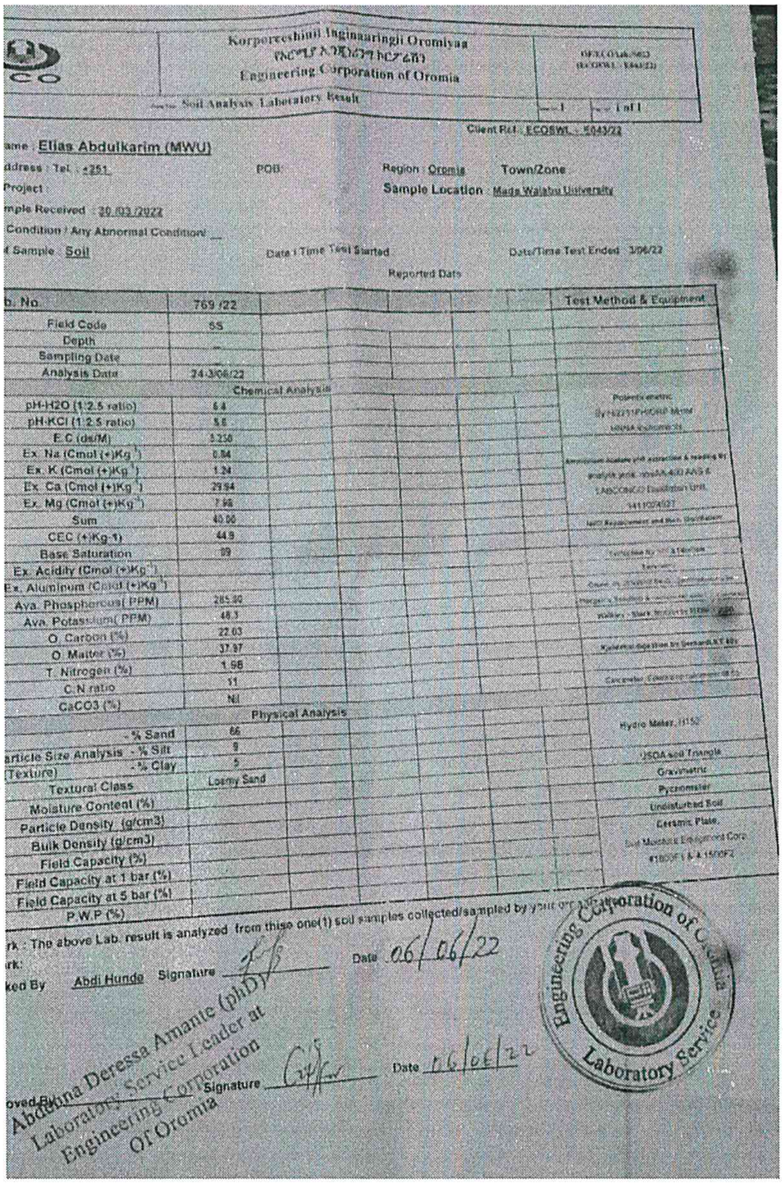






B. Laboratory result



Korporeeshinii Inginaaringii Oromiyaa

Engineering Corporation of Oromia

Soil Analysis Laboratory Result

1 of 1

Client Ref.: ECOSWL - 5043/22

ame : Elias Abdulkarim (MWU)

ddress : Tel. : +251 POB: Region : Oromia Town/Zone

Project : Sample Location : Mada Walabu University

mple Received : 20/03/2022

Condition / Any Abnormal Condition/ __

f Sample : Soil Date / Time Test Started Date/Time Test Ended 3/06/22

Reported Date

b. No.	769 /22	Test Method & Equipment
Field Code	55	
Depth	_	
Sampling Date		
Analysis Date	24-3/06/22	
Chemical Analysis		
pH-H2O (1:2.5 ratio)	6.4	Potentiometric
pH-KCl (1:2.5 ratio)	5.6	
E.C (ds/M)	5.258	
Ex. Na (Cmol (+)Kg^{-1})	0.84	
Ex. K (Cmol (+)Kg^{-1})	1.24	
Ex. Ca (Cmol (+)Kg^{-1})	29.94	
Ex. Mg (Cmol (+)Kg^{-1})	7.98	
Sum	40.00	
CEC (+)Kg-1)	44.9	
Base Saturation	89	
Ex. Acidity (Cmol (+)Kg^{-1})		
Ex. Aluminum (Cmol (+)Kg^{-1})		
Ava. Phosphorous(PPM)	285.90	
Ava. Potassium(PPM)	48.3	
O. Carbon (%)	22.03	Walkley - Black
O. Matter (%)	37.97	
T. Nitrogen (%)	1.98	Kjeldahl digestion
C:N ratio	11	
CaCO3 (%)	Nil	
Physical Analysis		
Particle Size Analysis (Texture) - % Sand	86	Hydro Meter, H152
- % Silt	9	
- % Clay	5	
Textural Class	Loamy Sand	USDA soil Triangle
Moisture Content (%)		Gravimetric
Particle Density (g/cm3)		Pycnometer
Bulk Density (g/cm3)		Undisturbed Soil
Field Capacity (%)		Ceramic Plate, Soil Moisture Equipment Corp.
Field Capacity at 1 bar (%)		
Field Capacity at 5 bar (%)		
P.W.P (%)		

rk : The above Lab. result is analyzed from thise one(1) soil samples collected/sampled by your organization

rk:

ked By Abdi Hunde Signature Date 06/06/22

oved By Abdeena Deressa Amante (phD) Laboratory Service Leader at Engineering Corporation Of Oromia Signature Date 06/06/22

Engineering Corporation of Oromia Laboratory Service

Company Name: **Ethiopian Construction Design & Supervision Works Corporation**

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ፖ.ሣ.ቁ P.O Box 2561 ኢሜል E-mail: info@ecdswco.com Alonge Megenagna Bole Road, Woreda 08 infront of Former Imperial Hotel, Addis Ababa Ethiopia

Title: Soil Fertility Test Report	Document No: OF/ECDSWC/0921	Issue No.2	Page No: 2 of 2

Client:-MEDEWOLABU University (Eliyas Abdulkerim)
Project:-Eliyas Abdulkerim (MWU)
Source of Sample:-
Location:-MWU
Contact Person:-Eliyas Abdulkerim
Contact Address:-0921-37-15-18
Date Sampled :- 31/12/2022
Client Ref:-Lab/SF/063/2022
Date received :-06/02/2023
Date of analysis :-07-23/02/2023
Date reported :-24/02/2023
Test Requested:-pH-H_2O,EC,Av.P,AV.K,AV.S,EX.Acidity,Micronutrients,CEC,Ex.Bases

Laboratory Number	2375/15	2376/15	Test Method
Profile Code	Sdry Pit 1	Swet Pit 2	
Exch.Na(meq/100gm of soil)	2.11	3.23	Ammonium Acetate Ext. and Instrumental
Exch.K(meq/100 gm of soil))	2.97	2.85	
Exch.Ca(meq/100 gm of soil)	38.50	42.74	
Exch.Mg(meq/100 gm of soil)	9.63	11.77	
CEC(meq/100 gm of soil)	63.41	67.39	
Sum of Cations (meq/100gm of soil)	53.20	60.59	
Exch. Acidity(Al+H) (meq/100gm of soil)	Trace	Trace	Volumetric
Exchangable Al (meq/100gm of soil)	Trace	Trace	
Exchangable H (meq/100gm of soil)	Trace	Trace	

REMARK: The Soil sample is collected and submitted to the laboratory by the client.
This test report is only for this specific Soil samples.
Reported by Tseganesh K. Lab Expert
Checked by Tseganesh K. Senior Soil Expert
Approved by Bethlehem B. Soil Fertility Lab S/P Manager Representative

Please make sure that this document is the correct version before use

Company Name: **Ethiopian Construction Design & Supervision Works Corporation**

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Test Requested:-pH-H_2O,EC,Av.P,AV.K,AV.S,EX.Acidity,Micronutrients,CEC,Ex.Bases

Laboratory Number	2375/15	2376/15	Test Method
Profile Code	Sdry Pit 1	Swet Pit 2	
pH-H_2O (1:2.5)	6.34	6.06	Potentiometric
EC(mS/cm) (1:2.5)	1.98	3.15	Conductivity Cell Potentiometric
Available Phosphorus (Av.p) (mg P_2O_5/kg soil)	323.05	379.32	Olsen
Available K (Av.K) (mg K_2O/Kg Soil)	1289.55	1253.22	Ammonium Acetate
Available Sulfur (Av.S) (mg/kg soil)	4565.96	8559.60	KH_2PO_4 Ext. Turbidimetric
Micronutrients			DTPA Ext. & Instrumental
Fe (mg/kg soil)	264.63	[illegible]	
Mn(mg/kg soil)	160.52	[illegible]	
Cu(mg/kg soil)	10.20	[illegible]	
Zn(mg/kg soil)	22.54	[illegible]	

REMARK: The Soil sample is collected and submitted to the laboratory by the client.
This test report is only for this specific Soil samples.
Reported by Tseganesh K. Lab Expert
Checked by Tseganesh K. Senior Soil Expert
Approved by Bethlehem B. Soil Fertility Lab S/P Manager Representative

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