PERFORMANCE OF PLANT GROWTH USING SLUDGE FROM TREATMENT PLANT AND COMPOST

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By

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Certificate

Certified that the contents and form of the thesis entitled "**Performance of plant growth using sludge from treatment plants**" submitted by Ms. Farhat Jabeen have been found satisfactory for the requirement of the degree of Master of Science in Environmental Science.

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Dedication

To my Parents, Hazrat Shah and Gul Haja

The reason of what I boom today thanks for your great support and continuous care


بسم الله الرحمن الرحيم

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Farhat Jabeen

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

CDM	Clean Development Mechanism
CIWMB	California Integrated Waste Management Board
DOC	Dissolved Organic Carbon
EC	Electrical Conductivity
EPA	Environmental Protection Agency
ICARDA	International Centre for Agriculture Research in Dry Areas
IUCN	International Union Conservation for Nature
OM	Organic Matter
P	Phosphorus
SWM	Solid Waste Management
WHO	World Health Organization
WB	World Bank
UV	Ultra Violet
XRF	X-Ray Florescence

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Composting of organic proportion of solid waste increases the efficiency of waste management and produces a product that can be used as a growth medium for plants. Similarly, sewage sludge also contain nutrients and makes sludge an effective soil amendment. Both these amendments increase productivity of crops because of micronutrients and organic constituents, which serve as a beneficial soil conditioner. Aim of this research was to study the nutritional values of solid waste compost and sewage sludge and compare the results to identify the best soil amendments for plant growth. White beans (*Phaseolus vulgaris*) were grew using different ratios of sewage sludge and compost in the pots. The sewage sludge/compost were added to the soil at the ratios of 25, 50, 75, and 100% and mixed thoroughly, keeping 250g in three replicates. Compost and sewage sludge properties were measured before and after the growth. The pH, electrical conductivity, moisture content and particle size fell in the optimum values except for the maturity indices of the compost and sludge that was 12.5 and 8.49 respectively, above the permissible limits. The germination rate was measured by counting the plants germinated each day and length was measured on a weekly bases to identify the uptake of nutrients. The leaves were tested after 30 days of sowing for measuring the chlorophyll content. After a period of two months, plants were uprooted and nutrient analysis was done. Root and shoot length were measured. Plant phosphorus were measured after harvesting the plants. Higher shoot length was observed in 100% sewage sludge and 25% compost was 23.81cm and 23.35cm respectively. Plants grew in 75% compost and sludge showed significantly distinct root length ($p<0.05$). Fresh and dry Biomass of plants were directly proportional to the concentration of compost while it showed an inverse relationship for sewage sludge ($p<0.05$). In 100% of compost and sewage sludge, compost had the lowest chlorophyll content, while opposite results were observed for sewage sludge. Phosphorus concentration increased with increasing sewage sludge whereas, it was decreased with increasing amount of compost. From the whole study it was concluded that plants were showed equally better growth in sewage sludge as well as compost.

CHAPTER 1

INTRODUCTION

1.1 Background

A large proportion of municipal waste is not properly disposed in many countries posing a potential environmental threat due to the presence of pathogens and toxic pollutants (Darby *et al.,* 2006). Landfilling is not a good practice as it causes pollution such as landfill gases and leachate, especially when the municipal solid waste possess higher moisture and organic matter (CIWMB, 2004).

Treated wastewater residual that can be used beneficially are called biosolids. Sewage sludge is the untreated left-overs of wastewater which can't be used as soil amendment unless they have been treated. Many researchers demonstrated that biosolids recycling is a safe practice and the crops grew in lands fertilized with sewage sludge were safe to eat.

Solid Waste generation in Pakistan is 65 thousand tons/day, 20 million tons per year (except 3% hazardous waste) per capita= 0.61 kg/ day (cities average) 0.23 kg/capita/day (avg. for rural and sub- urban areas) Growth rate= approximately 2.4% per year (Ministry of Environment, 2004). Methods for disposal is throwing in dumping site 28.6%, garbage thrown in open spaces 27.8%, dumped in or near water bodies/ drainage 16.3%, rubbish burned in the open 10.4%, collected recyclables 7.23%, composting (formal and informal) 5. 21%, and brought to a sanitary landfill in Lahore the only city of Pakistan is 4.20%. Almost 20-30 percent of solid waste is recycled and recycling is done informally and do not regulated in (EPA, 2005).

The only project of CDM in Lahore, Pakistan, is the composting of municipal solid waste who produce organic fertilizer from organic waste through aerobic windrow type composting technology (EPA, 2005).

Government of Pakistan have to work on development and implementation of standard solid waste management systems. Legislation of Environment are still not well developed in our country and the present rules and regulations dealing with solid waste management are poor and old-fashioned.

1.2.1 Solid waste compost

Solid waste compost represents organically decomposed leftovers. Leftovers are either vegetables or animals and are used for gardening and agricultural purposes. It takes more time to decompose the waste naturally so people generated a method of decomposition of organic remains called composting. Waste need proper environment, which contains Oxygen, Nitrogen, Carbon and water. In such conditions they can decompose generating the compost having all properties for soil enrichment (Stoffella *et al.*, 1996). In general, optimum conditions needed for composting are moisture content of 40 to 65%, suitable amount of oxygen for respiration of microbes, C: N ratio of 20:1 and 40:1, and particle size of 0.32 to 5cm (Rynk *et al.*, 1992).

Composition of compost is generally not stable and mineralization of soil organic matter is determined by different elements, for example; moisture content, soil properties, temperature and microbial populations therefore the prediction of nutrient supply at a specific time period is generally hard (Owen *et al.,* 2008). Compost is not a source of all nutrients necessary for best growth because of the slow decomposition of compost, but mostly supplies the micronutrients necessary for plant growth (Schoneweis, 2005).

When compost is incubated in clayey or sandy soil bulk density were reduced and it changed with the amount of compost added. Subsequently, structure of soil, retention capacity of moisture, and the rate of water infiltration of the soil were improved and crust was reduced.

Other advantages of composting are, suppression of pathogens and unwanted grass seeds, and improve handling characters of compost by lowering the weight and volume (Eghball and Power, 1999). It is the best among all soil amending growers which can increase the health and quality of soil. (Postma *et al.,* 2003). In addition, compost encourages benefits in porosity of soil, bulk density, Oxygen diffusion, water-filled pore space and shear vane strength (Carter *et al.*, 2004). Compost amendment significantly increases soil moisture by 7 to 10% (Edwards *et al.*, 2000) and water holding capacity (Lynch *et al.*, 2005). It also improve nutrient retention, organic matter content of soil, and also stabilize pH of soil. Moreover, composts are sources of macro and micronutrients, when compared to compost use in temperate climates, however, organic matter decomposition can be accelerated and the profits of compost can be reduced in humid and hot conditions (Stoffella *et al.*, 1996). In addition, production of compost from solid waste is a best method for solid waste disposal and decreasing the amount of water and other chemical fertilizer applied to crops (Ozores *et al.*, 1994).

High quality composts positively act on the structure of the ground (Abdelhamid *et al.*, 2004), its ventilation, its water holding capacity and the mineralization of the fertilizing elements (Porter *et al.*, 1999; Bailey and Lazarovits, 2003; Fuchs, 2003). The improvement of the structure of the ground allows a reduction of the erosion (Fuchs, 2003).

1.3 Sewage sludge

It is the suspended material left after the wastewater treatment (Fytili and Zabaniotou, 2008). The treatment of wastewater consists of a primary (physical and chemical treatment), secondary (biological treatment), and the last step is tertiary treatment (removal of nutrients). The composition of sewage sludge is highly variable and trace elements like Cu, Cd, Zn, and Pb may be high. Sewage sludge contains lower pollutants is, though, considered as a valuable plant fertilizer, due to its high nutrient content and good water-holding capacity (Tordoff *et al.*, 2000). Sewage sludge often called as “biosolids”, which is used for sludge low in pathogens, and which is considered as a suitable fertilizer and soil amendment. In re-stored industrial areas, like old mining sites, sewage sludge has commonly been used as an improving cover material (Sopper, 1993).

1.3.1 Importance of sewage sludge

Sewage sludge a by-product of sewage treatment process, consists of macronutrient which serves as best source of nutrients for plants and other organic compounds which are beneficial for soil conditioning (Logan and Harrison, 1995). pH of sewage sludge is neutral to considerably alkaline and the content of organic matter is generally high. It also contains high amount of Nitrogen, Phosphorus, calcium, Magnesium. Potassium is less in sewage sludge. Amendments of sludge may improve properties of soil such as bulk density, water holding capacity, porosity and aggregate stability (Singh & Agrawal, 2008).

Sewage generation is rapidly increasing due to urbanization and different organization in the world work for feasible and safe disposal of sewage. Different methods for waste disposal are incineration, dumping at land and sea, landfilling and field application for crops. Landfilling and incineration are not applicable because of environmental hazards and high cost. Therefor the best way to dispose that sludge is it application on fields for agricultural purposes as a source of plant nutrients and organic matter which is the most reasonable and useful method for its disposal.

Recycling of sewage sludge for agricultural use is a low cost method of disposal which preserves the organic matters and effect of fertilization (Özyazıcı, 2013).

1.4 Significance of study

Consumption of municipal solid waste compost in different modern nurseries for plant growth is a regular practice while sewage sludge is not that much commercialize for plant growth. This study reveal the utilization of sewage sludge as well as compost treated with soil for plant growth. The study demonstrated that if compost or sewage sludge is better for plant growth then at which concentration it is better for plants.

1.5 Hypothesis

A hypothesis has been proposed for the study was Compost and sewage sludge amendments increase the plant growth and finally enhance the yield.

1.6 Objectives of study

To prove the hypothesis different objectives were set for the research.

Objectives of the study were;

- Finding the nutritional values of domestic sewage sludge and compare it with solid waste compost
- Study plant growth performance by using sewage sludge and compare it with solid waste compost.

CHAPTER 2

LITERATURE REVIEW

2.1 Municipal solid waste

It is a type of waste collecting from family residential flats, hotel's waste, institutional and commercial areas, demolition waste, street refuse, dead animals, and so on (Bishop, 2000). Due to the improper planning, management and lack of finance, handling facilities is poor in developing and under developing countries which results into disposal of waste; it goes untreated in the environment (Anikwe, 2000). Therefore, storage of waste and least exposure to human and environment has been a fundamental rule of conventional landfills.

2.1.1 Composting

Methods to dispose of the waste include sanitary land filling, incineration, barging it out into the sea, composting by a bacterial agent (Garg, 1998). Landfills have been widely used for disposal of waste worldwide, because of the availability of land. Developing countries consider it trustworthy and economical method. The best method to dispose municipal solid waste is composting.

It is a biological process in which break down of organic waste occurs as a result nutrients and minerals are released (Pamela and Carolyn, 2007). It is much capable of destroying harmful pathogens and seeds of weeds in the compost. Mature compost smells like soil and colour become black or dark brown. Compost has no odor because organics that left after the process and become stable with lower rates of decomposition (Shiralipour *et al.*, 1992).

2.1.2 History of composting

Process of composting is always occurring in nature. If we go through the history it has been practiced in early Roman era. Composting was a large quantity of organic waste material and people let this material for a year or till the new planting season starts, at that time the waste material will ready to apply in soil. Chinese is the most ancient civilization to run through such practices to fertilize their rice fields (Hogg *et al.*, 2002).

Vegetable waste compost is used in many rural areas from ancient times. In India use of agricultural waste or food waste with cow dung as a fertilizer is an old practice, where different methods were applied for composting in different regions like, in the presence and absence of Oxygen, or using microbes and other organisms but mixing frequency of waste differs (Sharholy *et al*, 2008). In 1920s composting became a familiar method of organic waste disposal and modernized in Europe as a good way for organic farming (Bhide and Sundaresan, 1983).

2.1.3 Types of composting

There are three types of composting; aerobic composting, anaerobic composting and vermicomposting.

2.1.3.1 Aerobic composting

Aerobic composting is a process in which microorganism breaks organic materials into simpler material and extract energy from it through an exothermic reaction. The equation of aerobic composting is as follows;

2.1.3.2 Anaerobic composting

This process is carried out in the absence of Oxygen and use anaerobic microorganisms such as bacteria to convert organic material into stable compost. This equation describes the anaerobic decomposition of organic waste; (Insam *et al.*, 2002).

2.1.3.3 Vermicomposting

It is a process in which different worms utilize organic substances like, sludge from treatment plants, animal waste, yard waste, industrial waste and convert this into a stabilize and oxidized material. In the process of vermicomposting worms were fed by unstable organic waste which is then fragmented by worms and enhance the activity of microbes and the decomposition rate which leads to a humification or composting effect resulting in the formation of vermicompost and the end product obtained was the waste passed through the guts of worms quite different from original waste material. A study was conducted to determine the plant growth in horticultural container media and soil using composts and vermicompost. According to different researches it is demonstrated that vermicompost have considerable effects on plant growth, after using it as growth media for different plants. However, major differences were found between the effects of vermicompost and compost that were used when both are applied for growth. This differences were due to the parent waste material, vermicomposting and composting processes which use relatively different microbes, as a result of composting nitrogen releases in the form of ammonium whereas Nitrogen releases in the form of nitrates in vermicomposting, which is freely available for uptake of plants and according to this research both, composts and vermicomposts influence the growth of plant (Atiyeh *et al.*, 2000).

2.1.4 Compost characteristics

2.1.4.1 pH

Compost pH is the measure of the acidic and alkaline nature of compost. It ranges from 0 to 14; pH 7 indicates the neutral nature of compost. Compost mainly has a pH of 5-8.5. Different plant species need a specific pH for their growth. Addition of compost can affect the pH of soil or the growth media on the basis of the amount applied.

Compost pH can affect the pH of the soil or growing media after its application so pH of soil can be adjusted by using materials such as sulfur to lower the pH and lime to raise the pH. When such chemicals were used or already present in the parent material of compost it may not be applicable for usage due to difficulty in buffering (Nakasaki *et al.*, 1996).

2.1.4.2 Electrical conductivity

The amount of soluble ions present in a water and compost mixture. EC is the ability of a solution to conduct electric current, which estimates the ions present in the solution. The measuring unit for soluble ions is mmhos/cm or dS/m. Nutrients which are utilized by plants are mainly in salt form. Some particular salts like, sodium and chloride are harmful to plants and many types of compost don't hold such salts in adequate to be an alarm in land applications. Plant species have the ability to tolerate salinity at an optimum level if the soil crosses that level the soluble ions cause phytotoxicity. Compost takes part in compensating the soluble salt level in that soil. To reduce the soluble salt content in growing media thorough watering can be done during the time of planting. Permissible limits for electrical conductivity of soil are 1.0 to 10.0 dS/cm.

2.1.4.3 Nutrient content

The most essential nutrients utilized by plants in greater amounts are Nitrogen (N), Phosphorus (P) in the form of P_2O_5 and Potassium in the form of K_2O, that's why all types of fertilizers either commercial or retail contained these three nutrients. Each bag of fertilizer contained these nutrients in am measured quantity on the basis of its dry weight in the form of a percentage.

Nutrient content in compost is expressed on the basis of dry and wet weight. When we know the nutrient it will help us to add any complementary fertilizer for proper growth. Due to less amount of nutrient concentration in compost it is usually applied in greater rates as compared to other fertilizers.

Different types of compost have different amount of nutrients, for example, animal manure and biosolids usually contain more nutrients so use of such type of compost eliminate or reduce the need of fertilizer application during the first year of plants. Generally compost is in an organic form so it releases the nutrients slowly and decomposes compost.

2.1.4.4 Organic matter

It is the measure of carbon compound present in compost and expressed as a dry weight percentage. Organic matter in compost plays an important role in the availability of nutrients, structure of soil and water holding capacity of soil. If the organic content of the compost is known it is useful to estimate the properties and age of compost.

Different soil test kits are available to determine the organic matter content in recommended application rates. Compost has no ideal organic matter content; it may usually differ, ranging from 25% to 70% (Chanyasak, 1983).

2.1.4.5 Moisture content

Moisture content is the total amount of water present in compost and expressed in total eight percentages. Moisture content affects the density of compost causing the transportation and handling problems. The ideal moisture content of compost is often measured in 40 to 50%. Dry composts having moisture content of below 35% causes irritating and dusty effects during work while above 60% become clumpy and heavy making it difficult for application and delivery (Lopez and Babtista, 1996).

2.1.4.6 Maturity indices

The humic material content is a good indicator for the quality of compost produced and its efficacy in nutrient management, especially as a soil amendment to improve water retention and fertility. There exist a large number of studies on characterization of humic materials from composts (Christensen and Nielsen, 1983; Inbar *et al.*, 1993) investigated the molecular characteristics of humic substances extracted from composts at increasing stages of maturity.

Different techniques have been reported for the determination of compost stability (Wang *et al.,* 2004). Since stabilization indicates the formation of humic substances, humification indexes are usually recognized as a standard of stability, but the values of humification indexes of different materials vary greatly. Furthermore, their determination requires proper separation of the fulvic acid fraction and non-humic fraction because other compounds with similar structure to humic substances but different biological meaning can be extracted for example quinones, lignin residues, fats and polyphenols (Sa´nchez-Monedero *et al.*, 1999).

2.1.5 Compost for protection of soil structure

It is important for the environment to degrade waste and use that waste called compost for fortification of the structure of soil and provide nutrients to the crop. The composition of waste is important to know both physical and chemical quality and different processes taking place during composting to produce a valuable compost. The final product must have a constant chemical composition. Composting under favorable conditions must reduce pathogens and weeds to its least level. Composting destroys bad odors and reduces the need of more area for slurry. While applying compost on the field, it is important that it will distribute to sustain the ideal amount of Phosphorus and Potassium. Compost is distributed in the field to maintain the optimum amount of potassium and phosphorus for the crop.

During the process of decomposition, nitrogen compounds present if the waste converted into microbial proteins and ammonia. Proteins formed have to be mineralized before it is applied to plants. It depends on the microbial activity of soil and the relation between nitrogen compounds and easily decomposable compounds of carbon. If the amount of soluble carbon is higher as compared to nitrogen it causes a competition among plants and microbes for nitrogen and oxygen. If compost is applied on surface such harmful effects were reduced. Potassium has the higher fertilizing value as compare to phosphorus which has less values. To overcome this effect nitrification of compost has to done before its application on the soil (Jakobsen, 1995).

2.1.6 Effects of compost on soil properties

Application of compost improves soil fertility, control weed and suppress diseases, increase soil organic matter and conserve soil moisture.

2.1.6.1 Soil chemical properties

Vegetable waste and solid waste compost increase organic matter and total nitrogen content in soil (Hartl and Erhart, 2005). Hadas *et al*. (2004) showed that when MSW compost were applied at a rate of 43 Mg ha-1 it results in an increase of soil organic matter at a rate of 21% of the organic matter applied by the compost in 3 years. After the application of solid waste compost in both sandy and clay soils it increases the quantity and quality (humic acids) of soil organic matter (Weber et al., 2007, Melero *et al*., 2007). Solid waste and vegetable compost application can increase plant available P, K (Hartl and Erhart, 2003; Martínez *et al*., 2003) and Mg (Parkinson *et al*.,1999; Weber *et al.,* 2007) levels of soils. Due to the application of mixed green and animal waste compost it Increase the levels of soil EC (Stamatiadis *et al*., 1999; Madejón *et al.*, 2001). Although the increase of EC was not found capable of causing a sodium hazard to the soil, it indicates potential problems following the repeated application of compost to agricultural soil.

2.1.6.2 Effects on soil physical properties

Bio-waste and vegetable compost application to agricultural soil is shown to improve soil physical properties. This improvement is due to the organic matter addition to the soil by the compost application. Jakobsen (1995) after the application of solid waste compost he found the improvement of soil structure especially when compost was applied on surface of the soil. Soil surface was protected from compression effects of rain and rapid drying. Infiltration rates of soil were found to be higher. Opposite results were observed when compost application to silt clay loam soil after one year, the infiltration rates decreased (Stamatiadis *et al.,* 1999). Pandey & Shukla (2006) showed that compost addition to sandy soil resulted in higher retention of rainfall, if application levels are sufficiently high. Total porosity of soil (Guisquiani *et al*. 1995) and aggregate stability (Aggelides & Londra, 2000; Annabi *et al.*, 2007) was shown to increase when urban waste compost was applied to the soil. They also showed that compost application can reduce the penetration resistance of the soil.

2.1.6.3 Compost effects on biological properties of soil

Compost application to agricultural soil is shown to increase the number of micro-arthropods and earthworms and lower the parasitic nematodes (Leroy *et al.,* 2007). Peterson *et al*. (2003) demonstrated the stimulation of biological activity of soil and increase micro arthropod.

After the fourth year of application of compost on clay soils Melero *et al.*, (2007) showed a clear increase of enzymatic activities and microbial biomass. Composts have the potential to provide biological control of many soil-borne plant diseases (Hoitink *et al*., 1997; Noble & Coventry, 2005; Yogev *et al*., 2006). When compost mulch is used in the orchard ecosystem it was shown too beneficial for fungal, insect pest and weed management (Brown and Tworkoski, 2004). Gradual release of nitrogen from compost and manure over years has the positive effects on weed instead of crops (Blackshaw, 2005).

2.1.7 Compost effects on nutrient concentration

Solid waste compost and dairy manure application to the agricultural soil has significantly increase the Phosphorus and Nitrogen concentration and other nutrients in soil, even after several years of application (Butler *et al.*, 2008; Soumare *et al.*, 2003). However, increased microbial activity can also increase N mineralization and potential denitrification (Dambreville *et al.*, 2006) and may therefore increase N loss via leaching.

2.1.8 Effect of MSW compost on crop production

When 50Mgha^{-1} of bio-waste compost was applied, it increases the production of ryegrass under greenhouse conditions, but not as the same level as the chemical fertilizers (Iglesias-Jimenez and Alvarez 1993). According to Montemurro *et al.* (2005) application of less municipal solid waste compost to sunflower plants in Italy resulted in the same protein and oil production as the mineral fertilization. A study done by Clark *et al.* (2000) demonstrated that after a 3 year field experiments in Florida, when solid waste compost was incorporated into sandy soil under drip-irrigation it improved the yield and growth of vegetables. In a 4 year field work in Sweden showed that solid waste compost should be used in mixed form with mineral fertilizer for higher crop production, it should not be used as an individual fertilizer. But when applied in high rates it cause leaching and increase the loss of Nitrogen (Svensson *et al.*, 2004). According to Mamu *et al*. (1999) sufficient maize grain production was established when compost was applied in three consecutive years without any application of mineral fertilizer in a field study in

Minnesota. Solid waste compost application can also build the soil properties, thus improving the conditions for growth and yield of crops.

2.1.9 Effects of compost on plant growth

Improving the physical, chemical and biological properties of agricultural soil with the application of compost can improve the plant growth. Compost can increase the roots and shoots growth of tomatoes as compare to the amended soil (Levy and Taylor, 2003) and also the depth of roots of serpentine perennial grass (Elymus elymoides) (Curtis and Claassen, 2005). Compost also increases the weight of cotton seed (Khalilian *et al.*, 2002) yield of barley, fresh weight of parsley, marketable weight of Chinese cabbage and all these positive effects on plant growth were due to the improved soil structure, increased water content in soil and nutrient supply (Wang *et al*., 2010).

2.1.10 Compost application to soil for agriculture

Composting is a process which help in use of compost and optimization of nutrient management on land contribute to combat the decline of organic matters and soil erosion. The compost utilization to land is considered as a best way to maintain or restore the soil quality, importantly due to fertilizing and improving properties in the organic content present in compost. Additionally, it may help in carbon sequestration and partially replace fertilizers and peat (Smith *et al.*, 2001). Its application to land needs to be carried out in a way that ensures sustainable development. By ensuring the protection of environmental quality, management systems have to be developed to enable to maximize agronomics benefit. (Amlinger *et al.,* 2003).

2.1.11 Phosphorus in compost

Phosphorus is a vital element for growth of plants and its contribution has long been accepted as essential nutrient to keep economically sustainable levels of crop production. In agricultural systems Phosphorus is necessary for the growth and release of energy related with cellular metabolism, root and seed formation, quality of crops and strength of straw in cereals and crop maturation. In natural systems, Phosphorus is recycled to soil in litter, animal remains and plant residues (Brogan *et al.*, 2001). Its addition to soil in organic form or crop residues, represents a vital source of Phosphorus for plant growth. Fresh plant remains may rapidly release Phosphorus into the soil, whereas organic matter (such as composts) generally act as long term and slow release sources of Phosphorus.

2.2 Wastewater

Estimates exposed the fact that Pakistan had declined from 5000m^3 per capita of fresh or less than 1,000m^3 per capita to be declared as water stressed country (PSCEA, 2006). The water table is dropping at the rate of 3 meters per year in Kirthar. The groundwater table is also dropping all over the country. The collection level is no more than 50% nationally (less than 20% in rural), however, only 10% of collected Wastewater is effectively treated (WHO, 2006).

2.2.1 Wastewater treatment plants

Treatment of wastewater produces two types of products: treated effluent and sewage sludge. Sewage sludge produces by the removal of sludge from the influent wastewater and suspended solids and the treated effluent is discharged to waterway. Treatment of wastewater can be a complicated process; several different designs are used, utilizing mechanical, biological, and chemical methods, in various combinations (Rhyner *et al.* 1995). The difference between facilities depends mostly on the extent of water purification and disposal method used for sludge. In its simplest form the treatment process can be seen as including up to three levels or stages of treatments: primary, secondary, and tertiary.

In primary treatment all the floating and sink waste is removed through screening which firstly remove the fragments from the raw water, but organic waste left in the sewage as solution and suspension. After this screening, most of the organic waste is left in the settling tank and removed from it. From here it is removed into a sludge treatment tank. In secondary treatment, the activity of microorganisms occurred naturally is encouraged the digestion of carbon containing residues in aerobic and anaerobic environments. This result in the flocculation of solids produced by the microbial activity, which are removed from the wastewater process in the sludge treatment process. Tertiary treatment of wastewater consists of physical that is Filtration and the addition of lime, iron or aluminum compounds that is chemical treatment to flocculate solids and precipitate nutrients (Smith 1996).

After initial thickening of sludge, biological activity is supported for an extended time, mostly to reduce bulk and make the sludge more manageable. During stabilization the odor potential and number of pathogenic organisms is reduced, and some mineralization of plant nutrients occurs (Ministry of health, Ministry of Environment and Ministry of agriculture and food., 1986).

2.2.2 Wastewater treatment methods

Industrial, domestic and agricultural wastewater treatment has an important role in solving the global problems of water pollution. Wastewater treatment plants use physical and biochemical procedures to minimize the organic matter, eliminate pathogenic organisms and enhance water quality, so that water can be reused or discharged into the environment with nominal concerns.

Various wastewater treatments were carried out such as flocculation, membrane separation, coagulation, reverse osmosis, ultrafiltration etc. Use of activated carbon produces different secondary pollutants, whereas biological treatment is not a proper way to treatment wastewater to the problem because some dyes have the biological resistance (Arslan et al., 2000). However, it can remove above 90% of the Biological Oxygen Demand (BOD) in wastewater (Sheng et al., 2008).

Aerated lagoons are among widely used wastewater treatment processes because of their low capital and maintenance cost, less sludge production and integration of the environment. The process works on the decay and consumption of organic material by microbes under aerobic conditions. The key players in the transformation of complex organic compounds are prokaryotes in wastewater treatment plant. The studies of the microbial performance concluded that changes in the diversity of communities can comprise the whole process (Foster et al., 2002).

2.2.3 Activated sludge process

It is a process of biological treatment systems that is employed in the sewage wastewater treatment or a secondary treatment option in the industrial wastewater treatment. Aerobic digestion is utilized in various processes ranging from conventional to auto thermal (Riley and Foster. 2002). Most of the biological wastewater treatment plants work on the principle of activated sludge process which converts organic substances into microbial biomass (Ritchelita et al., 1998). Suspended bacteria produce effluent within legal standards by oxidizing the carbon and nitrogen compounds ensuring minimal environmental impacts.

2.2.3.1 Components of sewage sludge

Sewage sludge has been used as nutrient source for decades (Kirkham 1982). When material is evaluated for its fertilizer value, total quantity of plant nutrients is of interest, as well as chemical forms and subsequent plant availability (Terman and Engelstad 1971).

Sewage sludge is the insoluble part of wastewater left after its anaerobic and anaerobic digestion process of wastewater. It consists of resistant components that are, Nitrogen (3%), Phosphorus as P_2O_5 (2%), organic matters (65%), and other macronutrients (0.5% Potassium oxide and Magnesium Oxide 1.5%) and some micronutrients and trace elements, microorganisms, eggs of parasites and organic micro pollutants (Ahmed, Fawy, & Abdel-Hady, 2010).

2.2.4 Land application of sewage sludge

Land application of material of organic origin is an ancient method of recycling nutrients and beneficial factors for plants and soils. Before urbanization of the world this was possible without problems, but increasingly denser population created problems by offsetting the balance between number of people and available arable land. Further this development created favourable conditions for pathogens which led to major epidemics for centuries. One major reason for the construction of sewage systems was the need to reduce the risk of epidernics of that kind. As cities grew in size, the need to treat sewage to a higher level became more important as pollution of water systems and aquatic ecosysterns became increasingly severe.

In some areas industrialization was also a major source of pollution from sewage effluent. The sludge generated by sewage treatment reflects the nature of the raw sewage entering WWTP.

2.2.5 Phosphorus in sewage sludge

Crop requirements of phosphorus are usually 1/10 to 1/5 that of N, but the quantity of P in sewage sludge is often closer to being half of the N content. Because of foreseeable stricter rules for P removal from wastewater, the amount of P in sludge is Iikely to increase (Smith 1996). Therefore, the potential danger of applying phosphorus in excess of crop needs has become a concern (McCoy et al. 1986; Smith 1996). This may lead to accumulation of P in soils and potentially create an environmental hazard if P becomes mobile through changes in environmental factors, such as precipitation, temperature, and pH (Rydin and Otabbong 1997; Rydin 1996). All of these factors are known to affect the availability and mobility of P in soils. Excess P in soi1 can block uptake and lead to micronutrient deficiency in plants of copper, iron, and zinc (Kirkham 1982).

2.3 Interaction of soil and sludge

Soil properties, such as EC, organic matter content, pH, texture, redox potential and presence of other elements affect solubility, plant uptake, and mobility of metals from sewage sludge (Soon, 1981; Zwarich and Mills, 1979; Street et al., 1977; CAST, 1976; MacLean et a/., 1969). All metals not react similarly to changes in the soil properties. For example, decrease in soil pH levels decrease the metal cations availability to plants but increase the microorganism availability (LaHann, 1976).

Dowdy and Larson (1975) mixed the sewage sludge into two different soil structure with different pH levels of 5.9 and 7.9. After incubating the sludge-soil samples for one growing-degree season, the researchers grew barley to measure the amounts of plant-available toxic metals. Soil pH, Incubation and sludge application rates affected metal accumulation within the roots and tops of barley seedlings. As the rates of sludge application increased, an increase in the removal of Cr, Ni, Zn, and Pb occurred when barley was grown on the acid soil.

2.4 Effects of sewage sludge on microorganisms

Municipal sewage waste affects the duration of survival of microorganisms like; bacteria and viruses when it is applied as a liquid effluent or solid sludge (Van Donsel and Larkin, 1977). They observed a 90 percent decrease of Mycobacterium eight days after its application to soils and 11 days after effluent application. In sewage sludge the death rate of microbes as compare to the effluent was faster.

2.5 Effects of sewage sludge on plant growth

Sludge disposal in soil is an attractive option due to its macro nutrients, micro nutrients and organic matter. Nitrogen is the most important nutrient in sludge. Alternative way of waste disposal is using the sewage sludge as an organic fertilizer. To minimize the environmental pollution and best yield different types of waste can be recycled. A study has been done to determine the sewage sludge uses in agriculture and its effects on plants and soil. Barley plants were grown in amended soil, pH were became lowered and electrical conductivity rose with the addition of sewage sludge. It was also observed that higher the yield the higher the nutrient content level in soil mainly Nitrogen and Phosphorus (Ahmed et al., 2010).

2.6 Sewage sludge as Nitrogen source for *Phaseolus vulgaris*

After vermicomposting sewage sludge is used as an organic fertilizer. Fernández-Luqueño et al in 2010 study the effects of different nitrogen based fertilizers on bean plants and yield was examined in sandy loamy soil under greenhouse conditions. Beans were fertilized with urea, sewage sludge or grown in amended soil. During the period yield and plant characteristics were observed. Plants grown in amended soil with urea and unamended soil were lower than those cultivated in wastewater sludge. It was found that application of organic waste products improved the yield and growth of bean as compared to those plants amended with inorganic fertilizer.

CHAPTER 3

MATERIALS AND METHOD

This chapter reveals the procedure and experiments performed in the whole research. First part of the chapter belongs to the characteristics of compost and sewage sludge used in the study. Second part shows the experimental design and conducting of experiments in lab scale. Whole procedure was shown in the below flow Chart.

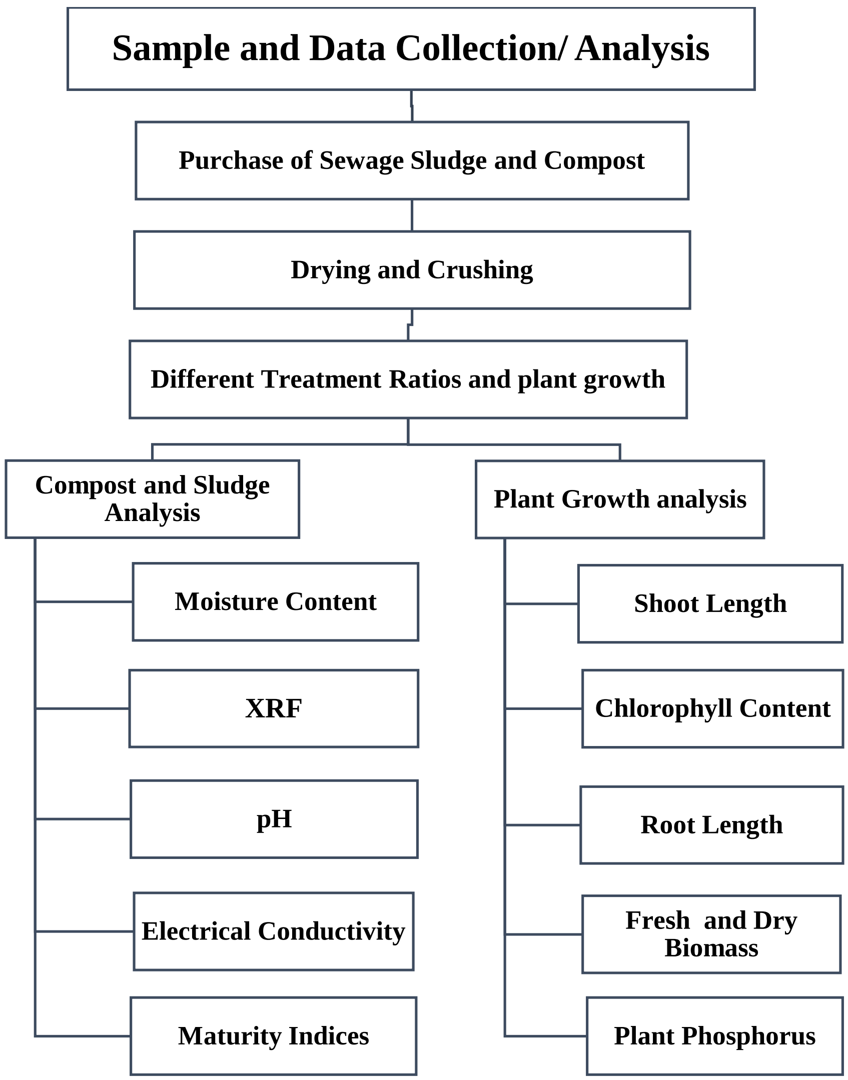

Figure No.3.1 Flow chart showing the steps in the study

3.2 purchase and preparation of samples

Sewage sludge and compost were obtained from I-9 municipal wastewater treatment plant and a modern plant Nursery in H-9 respectively. Air dried the soil, sewage sludge and compost for two days and crushed to pass through 2mm sieve made different ratio of compost/sewage sludge and soil.

Table 3.1 Sample preparation for plant growth

Amendments	Treatments (Sludge/Compost: Soil) %			
	A	B	C	D
Compost	25:75	50:50	75:25	100:0
Sewage Sludge	25:75	50:50	75:25	100:0

Pots contained 300g of soil to compost and sewage sludge 75g, 150g, 225g and 300g in A, B, C and D respectively. Experiment were done in laboratory. Pots were placed in front of window to ensure the availability of sufficient sun light. Methodology applied was discussed in detail below.

3.3 Characteristics of compost and sewage sludge

To ensure the stability of sludge and compost moisture content, pH, electrical conductivity, XRF and maturity indices were measured. After uprooting the plants a post analysis of all the samples has also been done to ensure the uptake of ions by plants.

3.3.1 Moisture content

The moisture content was measured in all samples and control group before sowing of seed. For this purpose, firstly china dish was weighed. Weigh the samples and put them in oven for 24 hours at temperature of 105^oC. After 24 hours, cooled the samples in a desiccator and weigh the samples again. Measured the moisture content using the following formula: (Eaton et al., 2005).

$$Moisture\ Content\ (\%) = \left(W1 - \frac{W2}{W2}\right) X100 \ldots\ldots\ldots..1$$

Where

W1= wet weight

W2= dry weight

3.3.2 X-ray fluorescence spectroscopy

XRF of the samples has been done for the elemental analysis compost and sewage sludge. XRF is working on the basis of light and other forms of electromagnetic radiations. It provides a mean of identification of an element, by measurement of its characteristic X-remission length or energy. This method allows the quantification of a given element by first measuring the emitted characteristic line intensity and then relating this intensity to elemental concentration.

Properly ground the sample to form a fine powder and made a pallet by pressing hydraulically to ensure the uniform density and better reproducibility.

3.3.3 pH and electrical conductivity

To determined pH and EC a mixture of 20g sludge /compost in 100ml distilled water were made, left for an hour and filter the mixture. pH was measured using a HI2211 pH/ORP meter at room temperature. Electrical conductivity was analyzed using a conductivity meter (HACH) (Janakiramn et al. 2010). Measurements have been done at room temperature. Total dissolved solids were measured manually in laboratory. Same procedure was followed to measure the pH and EC of control group (McLean, 1982).

3.3.4 Maturity indices

To determine how much the compost and sewage sludge were mature at the time of utilization the following procedure was used.

Weighed one gram of compost and sewage sludge sample into a 250-ml conical flask and made an extract with 50 ml of 0.5MNaOH and put on the shaker for 2 hours. The flask was left overnight and the suspension was centrifuged at 3000rpm for 25 minutes on the next day and the absorbance of that supernatant was measured in three different wavelengths that were 280nm, 472nm and 664nm (Sapek and Sapek, 1999). The following absorbance ratios indicating the degree of humification were calculated: A/B, A/C and B/C. The A/B reflects the percentage between the Lignins and other materials at the start of humification, and the material content at the beginning of conversion. The A/C denotes the relation between strongly humified and non-humified material. The B/C is called the humification index and is the most calculated ratio. Typical values of the B/C ratio for humified material are usually <5 (Gieguzynska et al., 1998).

3.4 Plant analysis

3.4.1 Physical parameters (Root and Shoot, Chlorophyll content and fresh and dry biomass)

Length of the shoots was determined on weekly basis for two months and measured average length of plants for each pot. Roots length were measured after uprooting the plant for further experiment. Weighed the whole plants for fresh biomass and oven dried to measure the dry biomass of plants.

3.4.2 Chlorophyll content

Leaves were sampled after 30 days of sowing for measuring chlorophyll content. It was measured two times in the whole period of growing. Chlorophyll content was measured using a portable chlorophyll content meter (CCM-200), which is defined as the ratio of percentage of transmission a 935 nm to 635 nm through leaf tissues. Calibration was done before each measurement (Richardson et al., 2002).

3.4.2.1 Data analysis

For this process arithmetic mean of the CC and conversion of CCI to $mgcm^{-2}$ a calibration equation was used (Richardson et al., 2002).

$$Y = 5.2e^{-04} + 4.04e^{-04} * X + 1.25e^{-05} * X^2 \ldots\ldots\ldots\ldots 2$$

Where;

Y= Total chlorophyll content

X= Chlorophyll meter value

3.4.3 Phosphorus analysis

Plant phosphorus analysis has been done by using the standard method of ICARDA (International Center for Agriculture Research in the Dry Areas).

3.4.3.1 Washing of plant samples

After a period of two months plants were ready for nutrient content analysis, for this purpose whole plant were uprooted, dipped the plant in water several times to remove or adhere the soil, washed the samples with about 0.2 percent detergent solution to remove the waxy/greasy coating on the leaf surface, after washing with detergent washed with 0.1M HCl followed by thorough washing with plenty of water and had given a final wash with distilled water, soaked to dry with tissue paper than air-dry the samples on a perfectly clean surface at room temperature for at least 2–3 days in a dust-free atmosphere after two days samples were oven dried for 2 days at 70^{o}C. After proper drying ground the samples in a marble pistol and mortar and screened using a 0.5-mm sieve. Cleaned the pistol and mortar before each sample and put them back in the oven, and dry again for constant weight then stored in well-stoppered plastic bags for analysis.

3.4.3.2 Wet digestion

For plant sample digestion a mixture of nitric acid (HNO_3) and Perchloric acid ($HClO_4$) is used in a ratio of 2:1. It is called di-acid digestion. It is used for measuring Phosphorus, Potassium, Calcium, magnesium, sulfur, Iron, Manganese, Zink, and Copper whereas tri-acid digestion is used for Phosphorus and Potassium Perchloric acid is used to increase the oxidation process as it dissociate into Oxygen and chlorine at high temperature and increase the process of sample digestion. Sometimes, when Perchloric acid cause explosion when it come into contact with plant sample directly. Thus it is desirable to digest $HClO_4$ firstly with nitric acid to overcome such effects.

In general, for the digestion process 100mg of ground plant sample has taken and placed in a 50ml volumetric flask. Then, 5ml of mixture of acids has poured and mixed by swirling. Heated the flask at a staring temperature of 80 to 90^{o}C and raised the temperature up to 150 to 200^{o}C placing it on hotplate in the fumehood. Heating the sample until red fumes of NO2 produces and the sample volume left were 3-4ml and become colorless but it must not be dried. After that, cooled the sample and made the volume of sample up to 100ml with distilled water and filtered with the help of No. 1 filter paper. This would be the final solution for nutrient content analysis.

3.4.3.4 Measurements

1. Pipetted out 10 mL clear filter into a 50mL volumetric flask.
2. Added 10 mL Ammonium-vanadomolybdate reagent, and diluted the solution up to the volume with distilled water.
3. Made a blank with 10 mL Ammonium-vanadomolybdate reagent, and preceded the similar procedure for the samples.
4. Read the absorbance of the standards, blank and samples after 1 hour on the UV-Visible spectrophotometer at 430-nm wavelength.
5. Prepared a calibration curve for standards, plotted absorbance against the respective P concentrations.
6. Read Phosphorus concentration for the unknown samples from the plotted calibration curve. At last determine the plant Phosphorus Concentration with the help of calibration curve.

3.5 Statistical Analysis

The statistical analysis of results has been done using Two Tailed t-test (mean analysis) and standard deviation. Statistically significant differences were described when the probability of the result assuming the null hypothesis ($p < 0.05$).

CHAPTER 4

RESULTS AND DISCUSSIONS

Different compost and sewage sludge parameters were measured to understand the stability. These parameters were Maturity indices, pH, Electrical conductivity, Total Dissolved Solids and Phosphates. Pre-analysis and Post-analysis of compost and sewage sludge were analyzed. Plant (Phaseolus Vulgaris) growth performance has been examined using these compost and sludge.

4.1 Stability parameters

4.1.1 Moisture content

Moisture content values for compost and sewage sludge were 17.50% and 19.97% respectively. This was optimum for proper plant growth. Composts with <35% moisture content are optimum for handling, transporting, and applying. Composts with high moisture content concentrations increase transportation cost and become more massive to application in fields whereas low moisture content composts become dust and can be have less water holding capacity. So compost and sewage sludge which were used for experimentation have the optimum moisture content.

4.1.2 Maturity indices

The A/B reflects the amount of lignin and different other materials at the start of humification, and the material content at the beginning of conversion. The ratio of A/C shows the relationship between strongly humic material and non-humic material. The ratio of B/C is usually called the humification index and the most calculated ratio. The optimum values for B/C ratio for humified material are usually <5 (Gieguzy_nska et al., 1998).

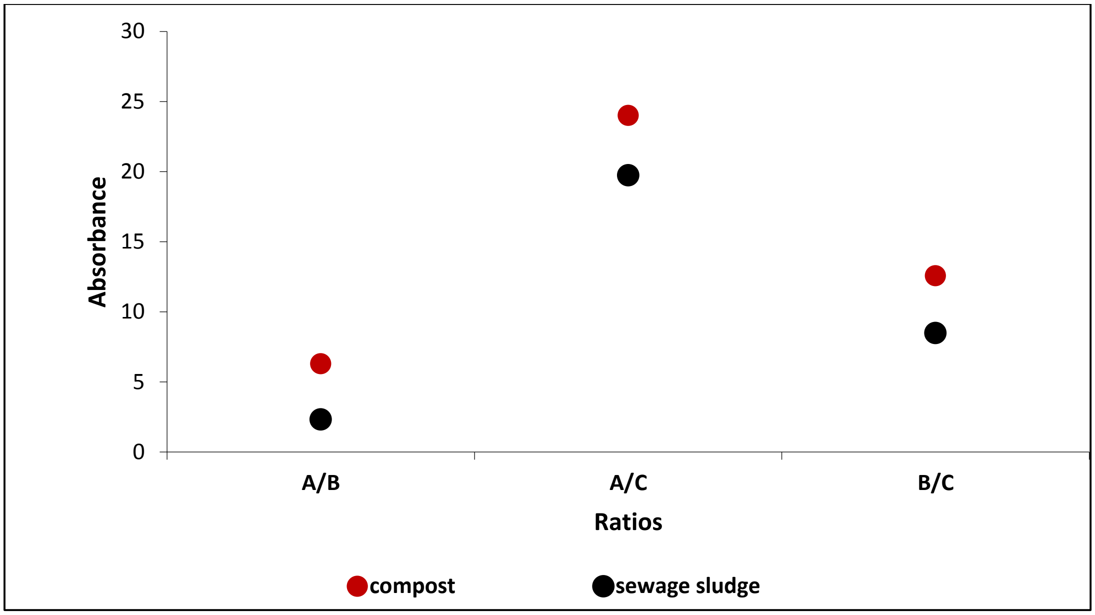

Figure 4.1: Showing maturity indices of compost and sewage sludge

Results in the Figure No. 4.1 depicted the humification index of compost and sewage sludge. Humification index value for compost was 8 while for sewage sludge it was 12.57. Which shows that sewage sludge used for plant growth is not properly matured. While compost used for growth is near to perfect maturation.

4.1.3 Compost and sewage sludge effects on soil pH

The stability measurement of the soil pH was analyzed in the increasing concentrations of sewage sludge and compost that are (0, 25, 50, 75 and 100%). Figure 4.2 showed that the pH undergoes a little increase regardless of the dose of compost/ sewage sludge applied. Thus, in the soils amended with 25, 50, 75 and 100% of compost, the pH of the soil was 7.62, 7.8, 7.9 and 7.95 respectively and for sewage sludge pH values decreases slightly despite of the dose applied. Values for pH in 0, 25, 50, 75, and 100% were 7.6, 8.1, 8, 7.78 and 7.47 respectively. Based upon these results it was found that the sewage sludge and compost used in the study did not adversely affect the stability of the soil pH even at high concentrations (100%). A study has emphasized that the harmful effects of heavy metals on plants depended on the dose of compost and soil properties, particularly the pH, which directly affects their solubility (Costa et al. 1991). Same results were observed in a study on maize and lettuce by using household compost (Mrabet.et al., 2012).

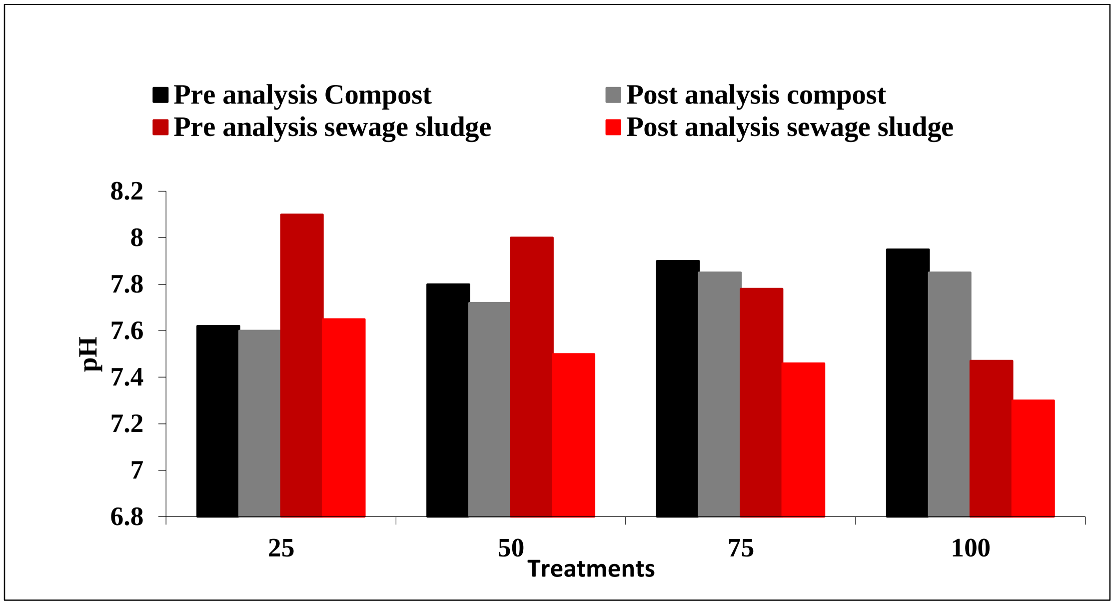

Figure 4.2: Showing the pre and post pH values of compost and sewage sludge

4.1.4 Electrical conductivity effects on soil

The results shown in Figure No. 4.3 expressed the effects of sewage sludge and compost on the salinity of soil. The analysis of these results showed that Electrical conductivity was increased slowly with the increase in the amount of compost and sewage sludge. The observed values were increased from 1.56- 3.58dS/m in compost and 1.4-2.7dS/m in sewage sludge. Muhammad and Athamneh, (2004) used SS of same electrical conductivity to study plant nutrient and heavy metal uptake from sewage sludge. Permissible limits for electrical conductivity of soil is 1.0 to 10.0 dS/m or 1000-10,000 µS/cm. So the electrical conductivity of all the doses falls in the permissible limits. Plant species have the ability to tolerate salinity at an optimum level if the soil crosses that level the soluble ions cause phytotoxicity. Compost take part in compensate the soluble salt level in that soil.

To reduce the soluble salt content in growing media thorough watering can be done during the time of planting. Post measurement of Electrical conductivity show less values as compare to pre measurements. It means that different soluble ions of salts were taken up by plants.

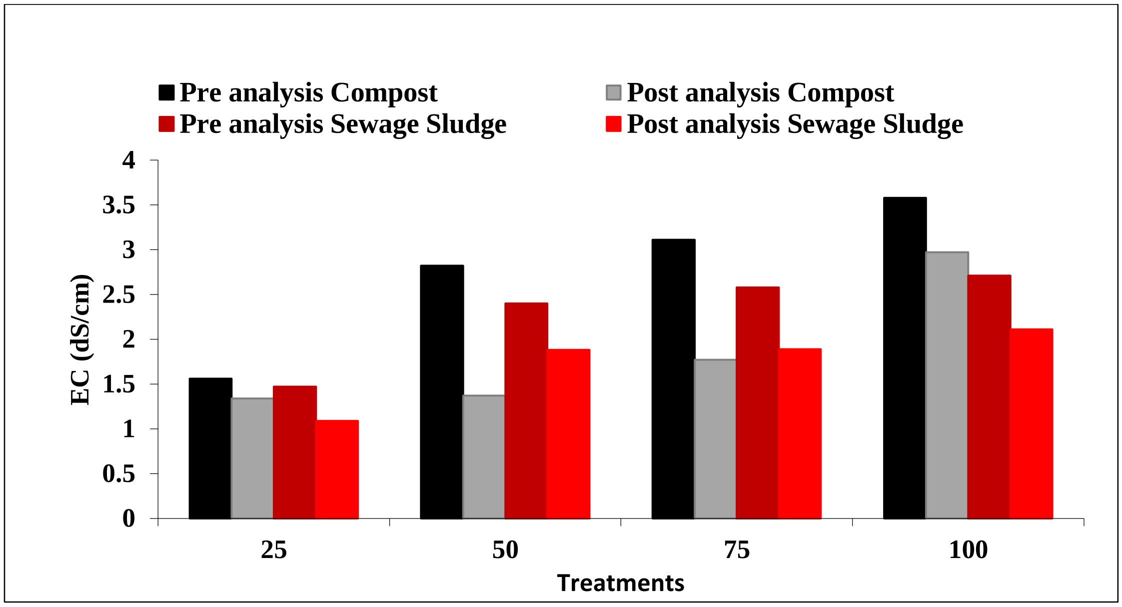

Figure 4.3: Electrical conductivity values for compost and Sewage sludge

4.1.5 NPK Values of compost and sewage sludge

NPK values of sewage sludge and compost were shown in table No. 4.1. Values were calculated in percent. Same results were observed when Mehmet 2013 studied the effects of sewage sludge on yield of plants in the rotation system of wheat, White head cabbage and tomato. Compost showed les NPK values as compared to sewage sludge.

Table 4.1 Nutritional values of Compost and sewage sludge

Soil Amendments	N Nitrogen (%)	Phosphorus (%)	Potassium (%)
Compost	0.9	0.62	1.41
Sewage Sludge	5.9	3.5	0.67

4.1.6 X Ray Florescence Spectroscopy

After elemental analysis it has be observed that the different macro as well as micro nutrients were present in the compost and sludge used. Table No 4.2 showed the elements present in compost and sewage sludge.

Table 4.2 Macro and micronutrients in compost and sewage sludge

S/No	Elements	Compost (ms %)	Sewage Sludge (ms %)
1	Calcium	26.6	39.05
2	Carbon	11	26
3	Silicon	38	18.76
4	Iron	11.4	30.5
5	Zinc	0.11	3.6
7	Sulfur	4.93	-

4.2 Plant analysis

4.2.1 Germination rate and time

Seed in all the pots except for WWC and CD were germinated in 4 days while in WWC and CD seed were germinated in 5 days. All the seeds sowed were germinated but due to the small size of pot plants were thinned to three in each pot. Results for plant growth parameters were shown as follow;

4.2.2 Shoot length of bean plants

Figure No. 4.4 illustrated the shoot length of *Phaseolus vulgaris*. Plants that grew in 25% compost with 75% soil reveals the better growth while in sewage sludge the results were totally reversed. Significant increase in shoot length were observed in 25% of compost and 100% of sewage sludge, 23.35cm length has observed in 25% compost and lowest values shown by 75% were 18.7cm. While in sewage sludge higher length observed were 23.81cm and the trend of length was gradually increase with the increase in the amount of sludge. The bars on the figure showed the standard deviation of three replicates.

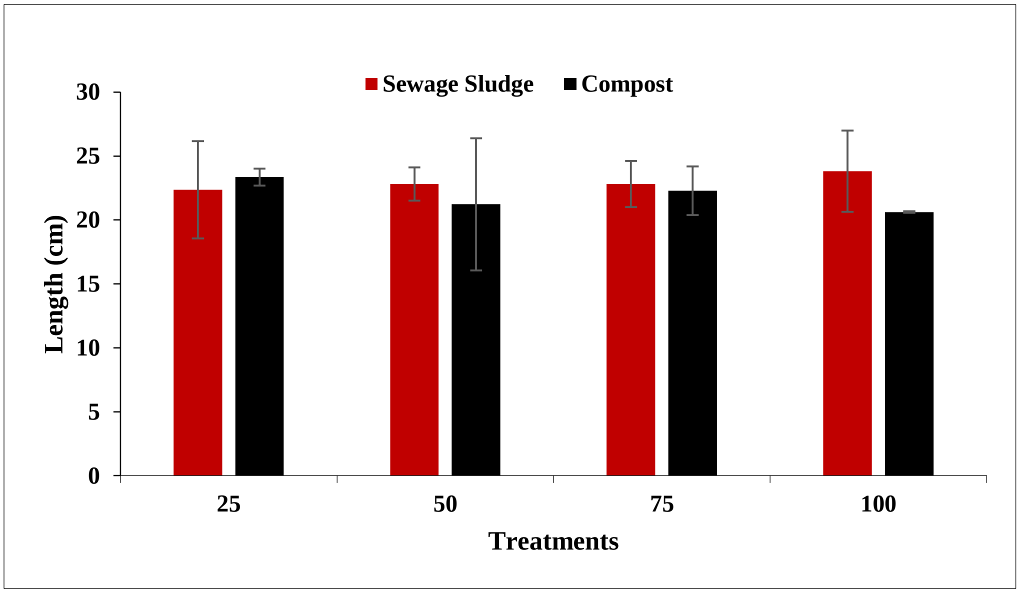

Figure 4.4: Shoot length of plants grown in compost and sewage sludge

4.2.3 Root length

Figure 4.5 showed the bean plants grown in 100% compost as well as sludge showed the higher root length of 6cm in both. While lowest root length were observed in 50% compost to soil as well as sludge to soil ratios that were 4.58cm and 4.54cm respectively. Statistically significant difference has been observed in 75% of compost and sewage sludge ($p<0.05$).

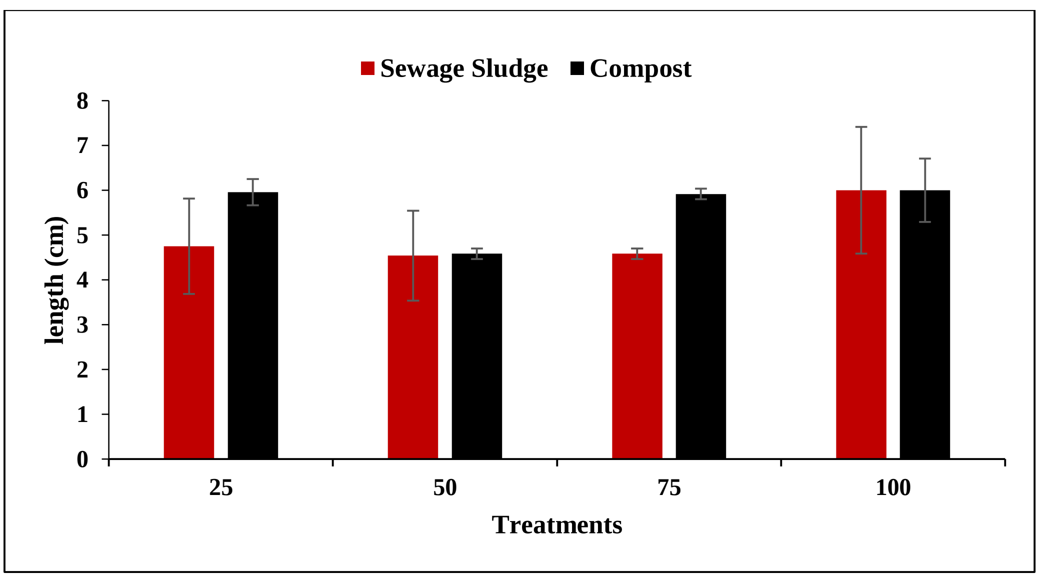

Figure 4.5: Root length of Phaseolus Vulgaris in response to compost and sewage sludge

4.2.4 Chlorophyll (Photosynthetic pigment)

Plant photosynthetic capacity is usually reflected by leaf chlorophyll content. Figure. 4.6 showed the chlorophyll content of white beans at different doses of compost and sewage sludge mixed with soil. Chlorophyll content increased as the ratio of compost increase from 25%-100%. Highest chlorophyll content measured in 100% compost was 6.45mgcm^{-2} and lowest Chl content observed in 25% compost was 5.92mgcm^{-2}. While in sewage sludge higher chlorophyll content was observed in 75% sewage sludge and lowest values were shown by 100% compost. Total chlorophyll content is correlated with fresh weight of plant which shows that chlorophyll content of plant took part in photosynthesis as a result plant grow more. But in our case plants having higher chlorophyll content shows less growth and vice versa for example, in 100% of compost the chlorophyll content and plant length were 6.45mgcm^{-2}CCI and 20.62cm respectively and in 25% compost 5.92mgcm^{-2} and 23.35cm chlorophyll content and plant length respectively. In sewage sludge plants having chlorophyll content of 5.27mgcm^{-2} was 23.81cm long in the ratio of 100% sewage sludge.

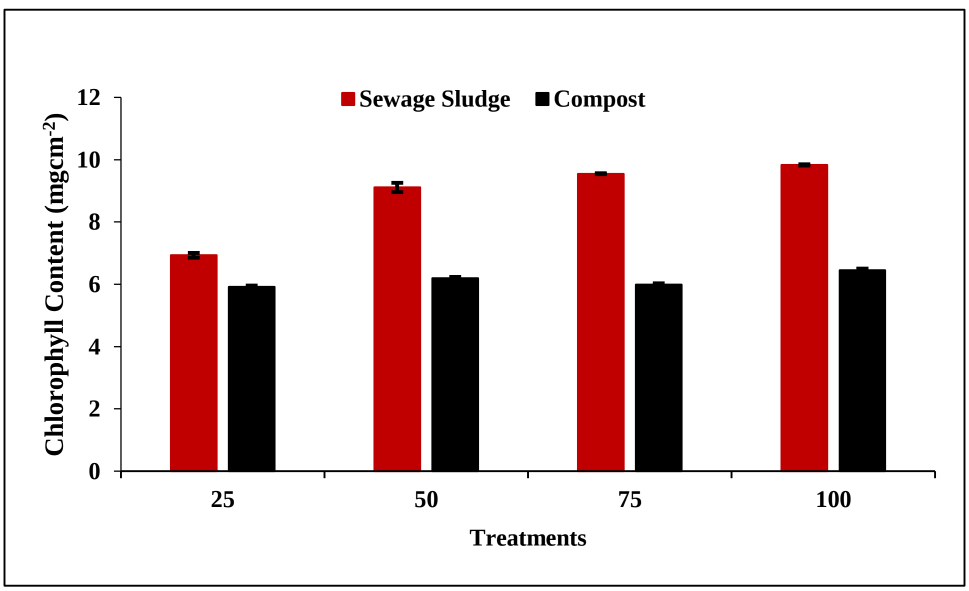

Figure 4.6: Values of Chlorophyll content in plants grown in compost and Sludge

4.2.5 Fresh and dry biomass of white beans

Figure. 4.7 And 4.8 depicts that fresh and dry biomass of bean plants. It was decreased with the increasing compost concentration till 75% but 100% concentration shows higher biomass. The trend was totally opposite in plants gown in sewage sludge. They showed the increasing trend with increase in concentration of sludge. Plants grew in 25% compost concentration were show highest values for fresh biomass whereas in case of sewage sludge highest values were shown by plants grew in 100% sewage sludge. All the treatments presented the statistically significant growth ($P<0.05$).

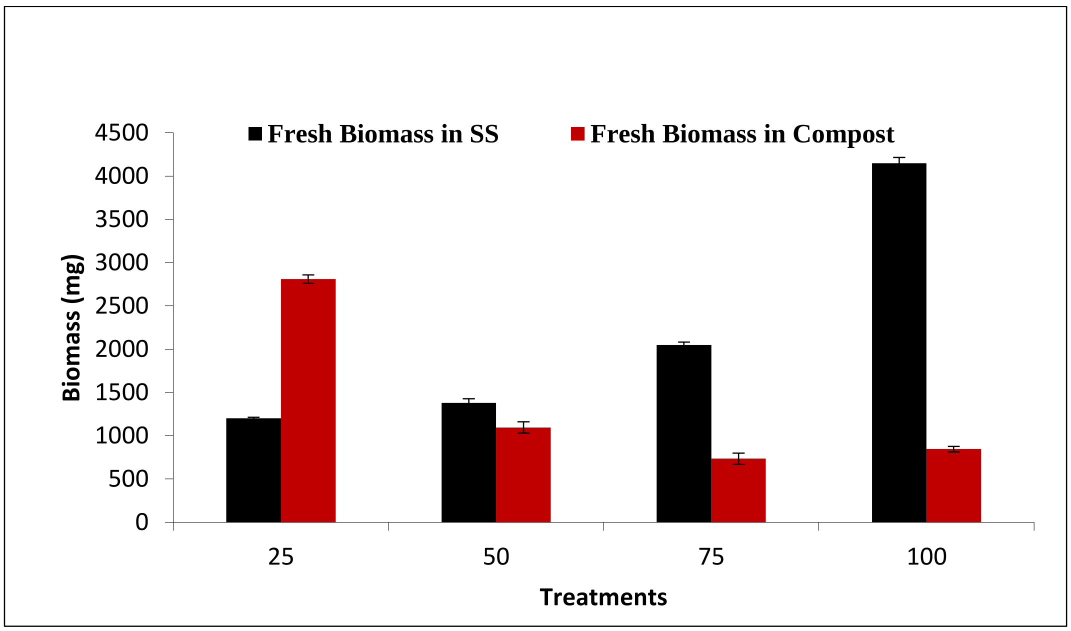

Figure 4.7 Fresh Biomass of common Bean

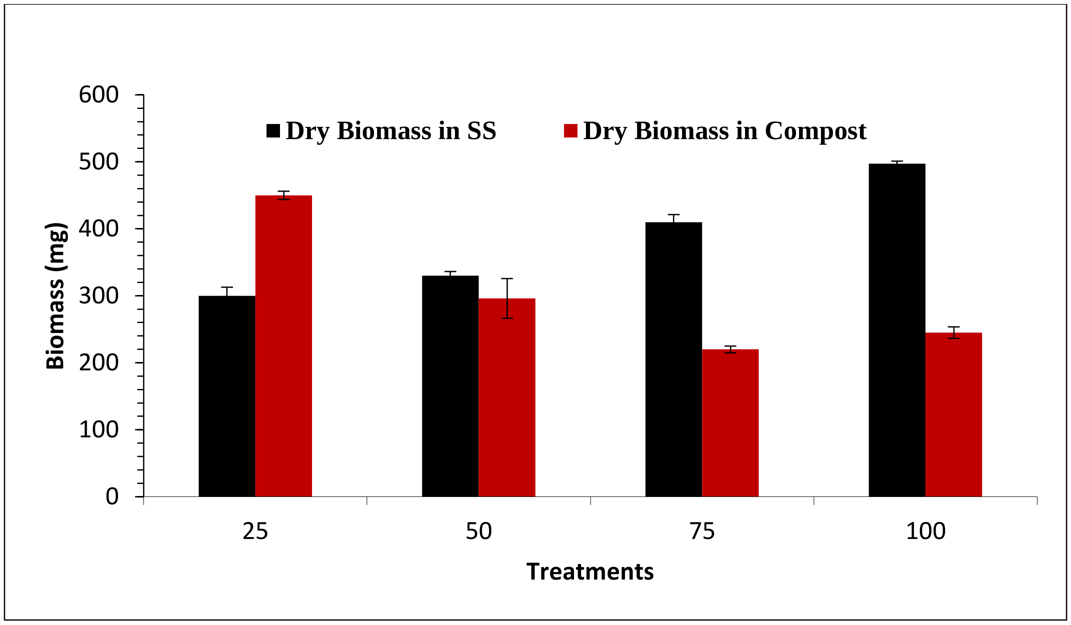

Figure 4.8: Fresh and dry biomass of white beans

4.2.6 Phosphorus concentration in plants

Phosphorus is used in some energy transfer compounds used for plants growth. A very important function for Phosphorus is its role in nucleic acids, the building blocks for the genetic code material in plant cells. Phosphorus concentration in response to compost was decreased with increasing amount of compost but concentration was increased in 100% of compost. Lowest Phosphorus concentration was observed in 50% sewage sludge was 2759mgkg^{-1} and highest was 4242mgkg^{-1} in 75% sludge. Phosphorus concentration in bean plants increased with increasing the concentration of sewage sludge. It increased from 2759mg^{-Kg} to 4416mg^{-Kg}. Same trend were observed in a study in which the changes in soil fertility and plant uptake of nutrients and heavy metals in response to sewage sludge application to calcareous soils was studied (Muhammad and Athamneh., 2004).

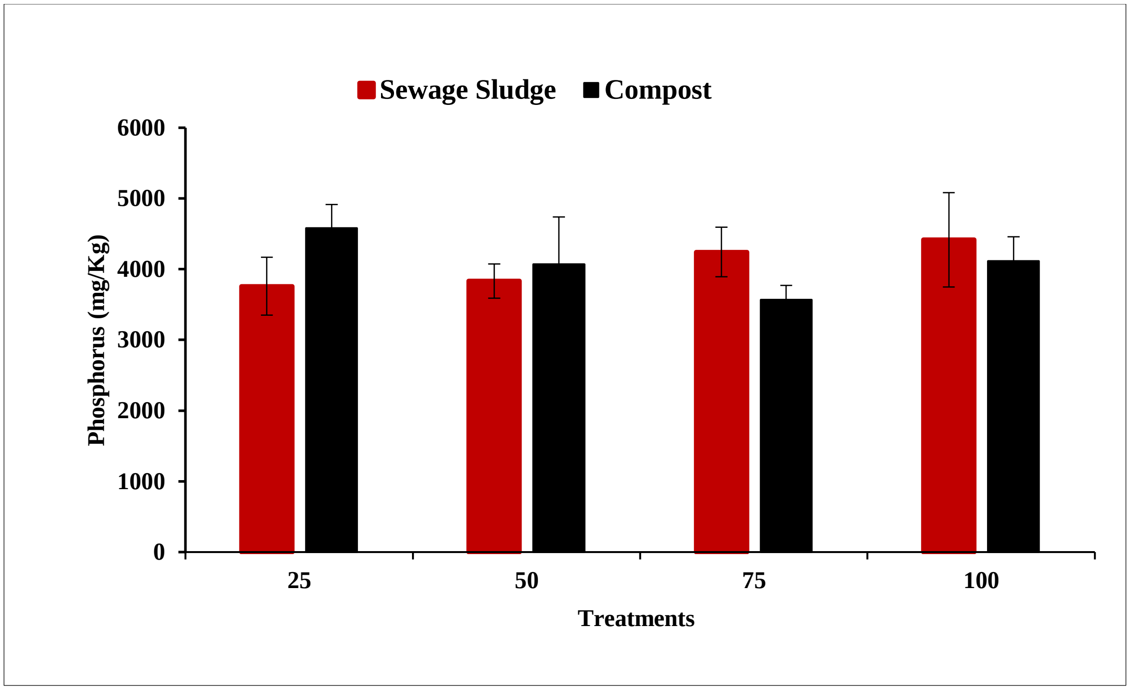

Figure 4.9: P concentration in Phaseolus Vulgaris in response to compost and sewage sludge. Bars represent standard errors

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Present study indicates that the utilization of sewage sludge and compost does not play a role in causing Environmental risk, but a best solution for the final disposal of organic waste mostly in developing countries like Pakistan. Addition of such material in soil cannot cause toxicity but it must increase the crop production. From the recent study it was concluded that compost and sewage sludge used for growth of Phaseolus Vulgaris is good for plant growth. All the stability parameters that are pH, EC, moisture content and particle size of the compost and sewage sludge values fall in the optimum values except the maturity indices of the compost and sludge. Its values were fall above the optimum values for fully mature compost. Compost and sewage sludge were equally good for plant growth. Fresh and dry Biomass of compost and sewage sludge have ($p<0.05$). If we observed the treatments in which better growth were observed were 25% compost and 100% sewage sludge it means that sewage sludge contain soil due to which 100% showed better results. If we go through the economical values sewage sludge is cheaper than compost

5.2 Recommendations

Some recommendations for future research are;

- Studies may be conduct to find accumulation of Heavy metals in plants
- Sewage sludge can be used for crop yield on commercial scale
- Possibilities of using dairy sludge can be explored using treatment technologies

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