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OPTIMIZING THE USE OF SMDS BIOSLUDGE COMPOST AS A SOIL FERTILIZER - CONDITIONER : NUTRIENT UPTAKE STUDIES

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This project is submitted in partial fulfillment of the requirements for the degree of
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DECLARATION

No portion of the work referred to in this dissertation has been submitted in support of an application for another degree of qualification of this or any other university or institution of higher learning.

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8721

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Specially dedicated to my beloved father and mother;
To my big bros;
To my sisters;
And to my youngest bro;

Who were my hopes and my greatest strength

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Wassalam...

TABLE OF CONTENT

LIST OF FIGURES

Page

FIGURE

LIST OF TABLES

Page

TABLE

Optimizing the use of SMDS biosludge compost as a soil fertilizer-conditioner:

Nutrient uptake studies

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ABSTRACT

This study was carried out to examine the uptake of essential nutrients and heavy metals by *Zea mays* L. from soil that had been treated with SMDS biosludge compost. Six treatments containing 0%, 5%, 10%, 20%, 30%, and 50% compost by volume in soil compost mixtures were used. Growth was evaluated in terms of weekly measurements of height of plants, number of leaves and the total dry matter after 4 weeks from seedling emergence. Treatment with 50% and 30% indicated the best growth performance in terms of height but there was no significant difference between the treatments in term of number of leaves emerged. Treatment with 50% of biosludge compost showed the highest total of dry matter yield. Macronutrient elements (N, P, K, Ca and Mg) and heavy metal elements (Zn, Cu and Pb) were analyzed. Treatment with 50% of biosludge compost indicated the highest total nutrient uptake of N, P, K, Ca, Mg, and Zn. Control and treatment with 10% of biosludge compost indicated the highest total of Pb uptake. All treatment indicated the highest uptake of Cu except treatment with 20% of biosludge. Further studies on the application of SMDS biosludge compost should be conducted due to its high potential as a soil fertilizer-conditioner.

Key words: Biosludge compost; macronutrient; heavy metals; nutrient uptake; *Zea mays* L.

ABSTRAK

Kajian ini dilakukan untuk mengkaji pengambilan nutrien penting dan logam berat oleh Zea mays L. dengan menggunakan tanah yang dirawat dengan kompos SMDS "biosludge". Enam rawatan yang berbeza peratusan campuran kompos "biosludge" per isipadu tanah iaitu 0%,5%, 10%, 20%, 30% dan 50% telah digunakan. Pertumbuhan jagung dari aspek ketinggian, bilangan daun, dan berat kering jagung direkodkan selama empat minggu.Rawatan dengan 50% dan 30% kompos 'biosludge' menunjukkan pertumbuhan terbaik manakala tiada signifikasi antara setiap rawatan dalam pertambahan daun. Rawatan 50% kompos 'biosludge' turut menunjukkan berat kering yang terbanyak. Elemen makronutrien (N, P, K, Ca dan Mg) dan logam berat (Zn, Cu dan Pb) telah dianalisa. Rawatan 50% kompos "biosludge" menunjukkan pengambilan kadar nutrien N, P, K, Ca, Mg, dan Zn yang paling tinggi. Kawalan dan rawatan 10% kompos "biosludge" menunjukkan pengambilan Pb paling tinggi. Semua rawatan menunjukkan pengambilan Cu yang paling tinggi kecuali rawatan dengan 20% kompos "biosludge". Kajian tentang penggunaan SMDS kompos "biosludge" haruslah diperluas memandangkan ia amat berpotensi sebagai baja perapi tanah.

Kata kunci: *Kompos 'biosludge'; makronutrien; logam berat; pengambilan nutrien; Zea mays L.*

CHAPTER ONE: INTRODUCTION

1.1 Background

Agriculture is one of the major land uses in Malaysia. Commercialization of the main crops planted is expanding and goes also the usage of chemical fertilizer. The survey been made by Statistic Department of Agriculture in Malaysia shown that the importations of manufacture chemical fertilizers has cost about RM 1.32 billion of annual purchase for 14.5 million tons (Ahmad, 2001).

Recently, the awareness on health and environmental issues has rings a bell in people head about the hazard cause by an extensive use of chemical fertilizers in agriculture sector. The application of inorganic matter can build up toxic in the soils, thus creating to imbalances of nutrients needed for growth and development of plant. Meanwhile, human activities are destroying the soils even more. Mismanagement of land and dumping wastes and toxic helps to degrade the quality of the soil. Sustainability of food production on a long-term basis cannot be achieved where soil degradation on peaks. That is why an effort must be made to improve the overall fertility of the soil and at the same time maximize uses of the resources.

Hence of this crisis, composting has been proposed to improve the soil fertility. The composting process is essentially the bioconversion of biodegradable materials into carbon dioxide (CO_2) and water (H_2O) (Stoffella and Kahn, 2001). Thus, many current studies carried out to expand the variety of compost from raw materials of plant till biosludge from wastewater treatment plant. This leads to recycle of organic waste for productive use and at the meanwhile ensuring utilization of natural resources in the optimum ways. Therefore, further studies about the biosludge compost has to develop even more as an alternatives of the over dependence on chemical fertilizer.

For an overview, this study is conducted to expand the use of biosludge compost as a soil amendment. Other compost such as sewage sludge may contain highly concentration of heavy metals and these minerals can accumulate in the soil and causing contaminants. Also, the usage of chemical fertilizer in crop can build up a toxic concentration in the soil, thus creating chemical imbalances. On the other hand, the chemical fertilizer can easily washed away from the root system level through leaching.

Furthermore, the demands for healthy and fast growing crop are increases as the population increase. In addition, the supply of food is in large quantities and these bring to more efficient and good management of natural resources. The problem comes when the main sources for food are susceptible with toxicity. Nowadays, the soil for agriculture has lost its purity because of the toxic and chemical things that come from development and industrialization. Thus, further studies should be carried out towards maximizing the use of resources and at the same time preserving the environment. That is why, the biosludge compost from the Shell's MDS has been introduced recently and further studies should be carried out to utilize SMDS biosludge compost in the optimum way.

1.2 Objectives

The objectives of this study was to make an evaluation the uptake and concentration of essential nutrients and heavy metals by *Zea mays* L. from soil that been treated with the SMDS biosludge compost. The concentration and uptake of essential nutrient such as N, P, K, Ca, and Mg by the sample (*Zea mays* L.) were compared in each of the treatment (biosludge compost that been mixed to the soil). Evaluation of heavy metals such as Pb, Cu, and Zn also carried out.

CHAPTER TWO: LITERATURE REVIEW

2.1 Background

Soil management problems including soil pH decrease, replant disorders and the rapid development of various nutrient imbalances, have been attributed to poor nutrient and water-holding capacities of the soils (Neilsen *et al.*, 2003). To enhance the soil properties and productivity, composting has been introduced. For example, in Southern Ontario, composts are often applied and incorporated in soils in the fall after harvest to improve soil physical quality (Yang *et al.*, 2003).

2.1.1 Compost

Theoretically, compost is an outstanding source of organic matter that can be dug into the soil to improve structure, aeration, water retention, drainage, nutrient quality, and other soil properties (Ball & Kourik, 1992). A University of California researcher suggests that compost may provide a slow-release substrate that sustains microbial activity over longer periods than would have been possible with cover crops alone (Humpert, 2000). Recently, China has made more extensive use of compost than any other country. The compost was made from crop residues, animal manures, and human wastes are mixed with soil and sludge to make compost (Brady, 1990). However, some of the organic waste are extremely toxic and, when applied to the soil along with the organic amendments, adversely affect plant development and even enter the food chain (Moreno *et al.*, 1997).

Moreover, increasing costs and environmental concerns associated with landfilling or incineration of municipal, agricultural and industrial wastes have generated substantial interest in converting some of them to soil conditioner suitable for application to agricultural land. Examples of such converted materials include composts derived from urban yard wastes or livestock manures, rockwool waste from the commercial greenhouse industry, and various waste sands from the mining and casting industries (Reynolds *et al.*, 2003).

However, Genevini et al. (1997), in fact, reported that the degradation of cellulose and lignin from the wastes such as municipal and rural wastes was a limiting factor for quick composting. On the other hand, the concentration of livestock in large animal farms adopting industrial technologies replaces very frequently a former cyclical movement of nutrients by a linear one, resulting in the loss of the nutrients through deterioration, and even pollution to the environment.

Interest has recently developed in accumulation of heavy metals such as copper and zinc in soils fertilized with animal waste (Pederson *et al.*, 2002). To make things worse, excessive manuring with animal wastes may lead pollution of ground water by nitrate and a decrease in the quality of feed to achieve self-sufficiency (Harada *et al.*, 2002).

Sludge from a wastewater treatment plant can contain proteins, carbohydrates, fats and oils, and some metals, which diffuse into sludge from industrial processes, households, ground surface activities, corrosion, and erosion of pipes (Chiang *et al.*, 2003), and this leads to environmental concern. The studies indicated that long-term use of sewage sludge increased the soil levels of Zn, Cu, Ni, Cr, Pb, Cd, and Hg (Kabata-Pendias & Pendias, 1984).

Biofiltration in making compost holds great promise to preserve nature. Biofiltration is a control technology for processes that emit large off gas volumes with relatively low concentration of contaminants. It is known that specially prepared biomass support media, such as wood mulch, improve performance and have a lower pressure drop than just soil or compost in biofiltration applications. The large size wood chip residues left after compost screen processing have several characteristics that could make them ideal for use as support and biofiltration media (Jones & Banuelos, 2000). In addition, co-compost produced from lime-stabilized, anaerobically digested biosolids and wood chips may have been a better source of plant-available Phosphorus than uncomposted, aerobically digested biosolids (Stoffella & Kahn, 2001).

2.1.2 SMDS Biosludge Compost – A profile

Shell Middle Distillate Synthesis Sdn Bhd (SMDS) has taken the approach to turn the biosludge they produce into a safe compound with biofiltration media. Shell's MDS plant in Bintulu, Malaysia is the world's first commercial-scale low temperature Fischer-Tropsch GTL (gas to liquids) plant. The plant itself estimated that about 1500 to 2000 cubicmetres/day (m^3/d) of wastewater was produced each day (Agency, 2003).

Generally, the Shell Middle Distillate Synthesis (SMDS) is the series of partnership projects between Shell companies and the people of Malaysia, which now operate at Bintulu, Sarawak. SMDS new plant uses advanced technology to convert natural gas, abundantly available from the Central Luconia field offshore Sarawak, into liquid fuels of high purity, which also release few emission and the large quantities of water that it produces are, after biotreatment, sufficiently pure to be pumped directly into the sea; indeed, if irrigation were needed in Malaysia. The water produced could be applied directly to growing crops (Anon, 2002).

In an earlier small-scale studied cited by Petrus (2003), the SMDS biosludge was mixed with wood shaving and composted using the forced aeration with temperature feedback method. The resulting compost showed good promise as a soil conditioner. The successful treatment and recycling of these waste products, which are otherwise hazardous to the environment, if disposed of indiscriminately is an encouraging and positive step towards maximizing the use of resources and preserving the environment.

2.2 Nutrient uptake by plant

Practically, organic amendments such as biosludge compost are commonly applied to agricultural soils to provide plant nutrients, to improve soil quality and in some cases to divert these materials from landfills (Yang *et al.*, 2003). It is universally accepted that all plants require a minimum of sixteen chemical elements (C, H, O, N, S, P, K, Ca, Mg, Fe, B, Mn, Cu, Zn, Mo, and Cl) for their normal growth and development (Baliger & Duncan, 1990).

Furthermore, plants absorb essential nutrients and water directly from the soil solution. The level of essential nutrients in the soil solution at any one time is far less than is needed to produce a crop. Hence, the soil solution nutrient levels must be constantly replenished from the inorganic or organic parts of the soil or from fertilizers or manures (Brady, 1990). Hence, a fertile soil that possesses the inherent capacity to supply beneficial nutrients in adequate proportions is essential to achieve high yield. Consequently, the higher the yield, the greater the nutrient uptake and nutrient removal (Jaafar *et al.*, 2002).

Preliminary studies by DOA (Department of Agriculture) have shown that with proper use of compost, the fertilizer requirement for vegetable crops can be reduced to 1/5 of the total nutrient requirement applied in the form of chemical fertilizers (Ahmad, 2001). On the other hand, excessive fertilizer use is not only wasteful of the nutrients applied but can adversely affect the quality of the environment. According to Brady (1990), undesired levels of phosphates and nitrates in drainage water from heavily fertilized areas can be harmful to humans and wildlife. Also, nitrogen oxides resulting from denitrification can have adverse effects on global climate as they move into the upper atmosphere. For this reason, nutrient recycling is extensively important for sustainable agriculture. This involves the return of essential elements that the plants have taken up and then find their way into conserving it.

2.2.1 Nitrogen

Nitrogen is one of the various essential elements that probably has been very well studied and still receives much attention. According to Harborne (1984), only 2% of the dry weight of plant consists of the element nitrogen, compared to 40% for carbon and to be likely, still having a very large number of different nitrogen-containing organic substances.

The amount of this element in available forms in the soil is small, while the quantity withdrawn annually by crops is comparatively large. Nitrogen is essential for carbohydrate use within plants and stimulates root growth and development as well as the uptake of other nutrients. Deficiency of it is evident when the older leaves of plants turn yellow or yellowish green and tend to drop off. Unlike nitrogen, phosphorus is not supplied through biochemical fixation but must come from other sources such as commercial fertilizer, animal manures, and plant residues to meet plant requirements (Brady, 1990). Nitrogen concentration for was highly correlated with phosphorus, copper, and zinc concentrations in aboveground plant parts, suggesting that improvements in nitrogen fertility would improve phosphorus, copper, and zinc concentration in plants (Pederson et al., 2002). Also, nitrate uptake enhances the uptake of K^+ as a counterion (Okamoto & Okada, 2004).

Nitrogen content however, increased with the composting process, due to organic matter degradation and to very low ammonia (NH_3) losses (Genivini, 1997). As plant analysis undergone, determination of nitrogen content in plant can be done with several methods. The Kjeldahl method is one of most popular method used to determine the nitrogen content in samples of vegetable and animal origin (Bilbao *et al.*, 1999). According to Bilbao *et al.* (1999), then, described an alternative technique, which uses the colorimetric determination of ammonia (NH_3) in digested samples of animal origin and many food products.

2.2.2 Phosphorus

Phosphorus is one of the three major nutrients in plants because it is required for the construction of important chemical components such as nucleic acids, phospholipids, and sugar phosphates, and for energy metabolism. However, since the phosphorus concentration in the soil solution is low compared to that of nutrients such as nitrogen, potassium, calcium, and magnesium (Kai *et al.*, 1997), phosphate absorption mechanisms by plant roots have been investigated extensively (Kai *et al.*, 1997). As cited by Stoffela and Kahn (2001), tabled that the concentration of P in composts generally ranges from <0.4 to <23 g. kg^{-1} depending on the sources.

Although total phosphate is quite abundant in many soils, it is largely unavailable for root uptake. It was recorded that crop yield 40% of the world's arable land is limited by phosphorus availability (Liu *et al.*, 2004). However, plant available P is usually <1% of the total soil P, whereas as much as 20 to 40% of the P in compost can be available to plants. Therefore, application of composts can increase plant available P in the soil (Stoffella & Kahn, 2001). The deficiency of phosphorus can be detected by the stunted growth of the plant, delayed ripening and purplish colour, particularly at the leaf tips (Purseglove, 1972). For determination of phosphorus, the sulfuric-perchloric acid digestion, modified for the malachite green method, gave the best recovery and reproducibility. IHP (Inositol hexaphosphate dipotassium salt) was successfully determined concentrations as low as 6.45 X 10^{-7} M of phosphorus (Martin *et al.*, 1999).

2.2.3 Potassium

Potassium in other part act as activator to dozens of enzymes responsible for such plant processes as energy metabolism, starch synthesis, nitrate reduction, and sugar degradation (Brady, 1990). It is highly mobile in plants at all levels within individual cells and within tissues. Most agricultural soils contain total K concentrations between 4 – 25 g. kg^{-1}. Composts can be an alternative source of K for crops, since plant availability of K in composts can be more than 85% of the total K content (Stoffella & Kahn, 2001).

Potassium was normally taken up in the largest amount. Over the range of K and Ca concentrations that occur in soil solutions, K uptake appears to compete with Ca uptake, and K also competes with Mg and with Na (Whitehead, 2000). The deficiency of potassium can be detected on the plant by the small whitish yellow spots on the leaves, followed by scorching or browning of the leaf edges (Purseglove, 1972).

2.2.4 Calcium

Much of the plant Ca is bound to the galacturonic acid component of pectin, and the resulting calcium pectate is an important constituent of the middle lamella of cell walls. Since Ca is divalent, it is able to link adjacent polymer molecules that contain acidic groups, and this role probably explains why Ca is important in the growths of meristems, and particularly in the growth and functioning of root tips. Calcium is also involved in maintaining the integrity and selectivity of membranes, and is required by a number of enzymes, including amylase and some nucleases (Whitehead, 2000).

The deficiency of calcium can be detected on the plant by the brownish colour at the growing tips of roots and leaves. The edges of the leaves will look ragged, as the margins of emerging leaves tend to stick together. If the deficiency is severe, leaves may never fully emerge; and for corn, emerging leaves will stick together, giving a ladder-like appearance to the plant. Lack of adequate Ca may result in the decay of the lower stem conductive tissue, with plants easily wilting when a high evaporative demand exists (Kalra, 1998).

2.2.5 Magnesium

Magnesium is required for many cellular functions including production of chlorophyll, protein synthesis, regulation of cellular pH and cation-anion balance. However, high levels of potassium usually due to high fertilizer applications also may reduce magnesium uptake (Sparks *et al.*, 1996).

Ortas *et al.* (1999), cited that potassium and magnesium uptake by plants depend on the change of ionic equilibrium in soils. When concentration of potassium in soil solution increases, uptake of magnesium by plant considerably decreases. Although the concentration of magnesium in soil solution was higher than that of potassium, plant uptake of magnesium was lower than potassium uptake per unit of dry matter and root length. The deficiency of magnesium can be detected on the plant by the whitish or yellowish striping between the leaf veins (Purseglove, 1972).

2.2.6 Heavy metals

Generally, plants take up Zn mainly as the Zn^{2+} ion. It activates a large number of enzymes, often by linking the enzyme to the corresponding substrate or by modifying the conformation of the enzyme or its substrate. Zinc is thought to play a key role in stabilizing the structures of RNA and DNA and in regulating the enzymes that control their synthesis and degradation. It appears to be necessary for the production of the auxin, indole-3-acetic acid (IAA) (Whitehead, 2000).

The deficiency of zinc can be detected on the plant by the chlorotic fading of the leaves with broad whitish areas, especially towards the centre and leaf base (Purseglove, 1972).

Copper is absorbed as the Cu^{2+} ion, and there is competition in uptake between Cu and Zn. It is an essential component of several enzymes that catalyse oxidations involving molecular oxygen. These enzymes include cytochrome oxidase, phenol oxidase, laccase and amine oxidase, and their catalytic activity is thought to depend on the reversibility of oxidation between Cu^{2+} and Cu^{+}. Copper also plays a role in photosynthesis, as a constituent of the Cu-protein, plastocyanin, which is involved in the transfer of electrons (Whitehead, 2000).

2.2.7 *Zea mays* L. – A profile

Maize has used as plant indicator for this study. The name maize is derived from an Arawak-Carib word, 'mahiz'. It is also known as 'Indian corn', and in America simply as 'corn'. Maize was selected upon this study because it is a fast growing crop, moderate temperatures and a plentiful supply of water and nutrients (Purseglove, 1972).

Sweet corn that been used in this study was one of the cultivars of *Zea mays* L. Botanically, sweet corn was known as *Z. mays* L. var. *saccharata* Sturt. or synonym as *Z. mays* L. var. *rugosa* Bonof (Martin *et al.*, 1976). The grains contain a glossy sweetish endosperm, which is translucent when immature, and dry to give a wrinkled appearance (Purseglove, 1972). Taxonomically, *Z. mays* are classified in the family of Poaceae. Hence, the germination of the corn seed is similar to that of many grasses (Fageria *et al.*, 1997).