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Study on the Characteristics and Utilization of Sewage Sludge at Indah Water Konsortium (IWK) Sungai Udang, Melaka

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Abstract**—**The volume of biosolids produced in Malaysia nowadays had increased proportionally to its population size. The end products from the waste treatments were mounting, thus inevitable that in the end the environment will be surrounded by the waste. This study was conducted to investigate the suitability of biosolids to be reused as fertilizer for non-food crop. By varying the concentration of biosolids applied onto the soil, growth of five ornamental plant samples were tested for eight consecutive weeks. The results show that the pH of the soil after the addition of biosolids ranges from 6.45 to 6.56 which is suitable for the plant growth. The soil samples that contains biosolid also show higher amount of macronutrients (N, P, K) and the heavy metals content are significantly increased in the plant however it does not exceed the guidelines drawn by the Environmental Protection Agency. It is also proven that there was only small significant different in the performance of plant growth between biosolids and commercial fertilizer. It can be seen that biosolids was able to perform just as well as commercial fertilizer.

Keywords**—**Biosolids, fertilizer, *R. chinensis*, waste sludge.

I. Introduction

SEWAGE sludge or biosolids is a by-product of municipal wastewater treatment. In Malaysia, the sewage sludge produced is mainly from domestic and light industrial area. About 3 million metric tons of sewage sludge is produced annually and it has been estimated to rise to 7 million metric tons in the year of 2020 [1]. Rapid urbanization, a consequence of economic development and increased population has led to production of huge quantities of sewage sludge in Malaysia and has posed serious environmental problems for their disposal. The total cost of managing sewage sludge is estimated at US$ 0.33 billion per year [2]. However, the treated-sewage sludge is commonly being disposed either at landfills or being burned in incinerators [3].

Sewage sludge is a good source of micro/macronutrients for plants besides its richness in organic matter. It is also beneficial to the soil, crop and livestock productivity. Furthermore, it is stated that the application of treated-sewage sludge can improve soil structure and organic matter content and provides nutrients [4]. Usually, the sewage sludge is applied at the rate which is designed to supply crops with adequate nitrogen. Naturally, sewage sludge has lower nutrient content as compared to the commercial fertilizers where, it contains 3.2% nitrogen, 2.3% phosphorus and 0.3% potassium. Meanwhile, a commercial fertilizer might contain 5 to 10% nitrogen, 10% phosphorus and 5 to 10% potassium [5]. Other than macronutrients and micronutrients, sewage sludge also contains biocatalysts such as amino acids, vitamins, enzymes, and growth regulators [6]. Despite that, the use of sewage sludge helps to condition the soil and reduces or eliminates the need for commercial fertilizer, thereby reducing the impacts of high levels of excess nutrients entering the environment. With full utilization of nutrient content in treated sewage sludge, it would prove significant cost reduction in fertilizer acquisition while minimizing overall disposal of solid wastes to landfills or incinerators [7]. Therefore, the studies on the sewage sludge are important due to the economic and environmental implications of application of these materials to soils and plants. This study aim to identify the nutrient content in sewage sludge and the feasibility of sludge to be used as fertilizer through the comparison of nutrient content between the sewage sludge and commercial fertilizer sold in public market. The potential of the utilization of sludge also will assess through the observation and analysis on the growth of *R. chinensis* (ornamental plant).

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II. Material and Method

A. Site Description

The experimental study was carried out at the Environmental Science Laboratory, University Kuala Lumpur Malaysian Institute of Chemical and Bioengineering Technology (UniKL MICET), Melaka. The study period was within two months, from September to October. This research actually is the collaboration between UniKL MICET and Indah Water Konsortium (IWK) waste water treatment plant located in Sungai Udang, Melaka.

B. Growth Media

The media used for planting were aggregates, sand and red soil with ratio of 1:6:3. The aggregates, sand and red soil were filled into 5 plastic pots. During the setup, a portion of aggregates was layered at the bottom followed by 6 portions of sand and 3 portions of red soil on the top layer. The growth media was prepared using soil with different levels of biosolids fertilizer; R1 (100% control soil + no addition of biosolids), R2 (soil + 30% biosolids (0.3g)), R3 (soil + 50% biosolids (0.5g)), R4 (soil + 100% biosolids (1g)) R5 (soil + commercial organic fertilizer (1g)).

C. Test Plant and Planting

*R. Chinensis*was used as the test plant. After filling the plastic pots with appropriate soil, sewage sludge and commercial fertilizer mixture, plants were transplanted into the pots and grown for 2 months under experimental condition.

D.Intercultural Operation and Growth Variable Measurement

Intercultural operation (watering) was done when necessary to ensure normal growth of the plants. The morphological studies were plant height (cm), days to flower emergence (days) and the number of flowers.

E. Sampling and Chemical Analysis

Plant sample were collected every week from each pot. For analysis of heavy metals, 1.0g of dried plant sample and 20ml aqua regia solution (mixture of concentrated HNO_3 and HCI in a ratio of 3:1) was placed into a beaker for digestion. The process was completed at 80^0C for 2 hours. The digest was filled into 50ml beaker and the solution was analyzed for micronutrient (Nickel, Lead and Copper) using AAS (Atomic Absorption Spectrophotometer). The macronutrient of the plant was analyzed by using DR2800. The pH of the soils was determined by pH meter (Mettler Toledo, USA) [8].

III. Results and Discussion

A. Physicochemical Properties of the Soil

Maintaining the proper pH level in the soil was important to the overall health of the plants. The pH of soil is important because it could affect the population of pathogens in the soil, the heavy metal concentration, the nutrient content and the suitable type of plants [9]. During 8 weeks of study, there was significant different of pH before and after the plant was being applied with the biosolids and commercial fertilizer (Fig. 1).

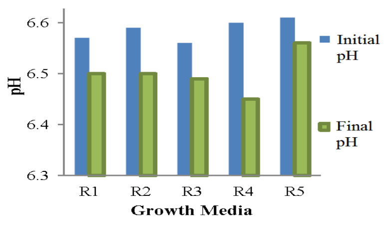


Fig. 1 Influence of different nutrient application on the pH of the growth media

Based on Fig. 1 above, the pH of the soil was decreasing at the end of this study. At the beginning of the study, the pH values varied from 6.56 to 6.61 having the highest pH values of 6.61 in R5 and the lowest pH value of 6.56 was in R3. All the growth media showed low pH values, which means the medium was acidic. After the growth medium of R2, R3, R4, and R5 were applied with biosolids and fertilizer, the pH value increased, ranging from 6.45 to 6.56. The maximum pH value (6.56) was shown in R5 and the minimum was shown in R3. The pH of the soil is an important factor in this study because it influences metal absorption, retention and movement [10].

Regarding the decreasing value of pH after increasing the amount of application of biosolids, it is due to the treatment of wastewater in IWK that used alum in their treatment. Very low and very high pH values cause direct damage to plant roots [8]. However, a slightly low or high pH can also decrease the plant growth. In this study, the values of pH in every growth medium are suitable for the plants to grow. Reported in [4] by the expert of ornamental plant, the optimum pH for most ornamental plant ranges between 6.0 and 6.5, which is a slightly acidic condition. The result showed that the pH of the soil for all growth medium were still in the range of the optimum pH. Therefore, there were no effects on the plant growth despite the decreasing of pH value in the soil.

B. Growth Development of R. chinensis

For appropriate growth, a root medium must fulfil four functions: continuous supply of water, provide nutrients, allow the exchange of gases to and from the roots, and offer support for the plants [11]. The quality production of ornamental plant can be attained by the use of appropriate potting media, which have a prominent effect on the growth [12].

Comparisons were made between the different types of growth media in order to determine which biosolids concentration could produce the highest *R. chinensis* growth as compared to the commercial fertilizer. The growth of *R. chinensis* was being monitored by measuring its stem height. By observing the graph presented in Figs. 2 and 3, it is noted that the increasing value of sludge application on the plant had affected the growth of development of the plants. The result obtained showed that the highest plant growth was from R4 followed by R5, R3 and R2 (39.6, 37.5, 31.7, 30cm). Meanwhile, the lowest growth of Rose was from the growth media, R1 (26.63cm). It was noted that the soil itself contained some of the existing nutrients that is enough to promote growth despite a slow growth rate. For the time being, the growth media R5, which was fed with commercial fertilizer, had shown such a rapid growth of Rose in the initial week. However, it started to die in the week 7 due to the excess supply of nutrients.

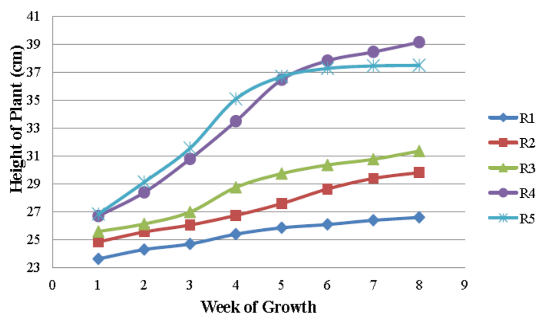


Fig. 2 The effect of different growth media on *R. chinensis'* height

It can be said that the rapid growth of Rose plant depends on the amount of biosolids concentration in the soil. Generally, it has been shown that the addition of biosolids to soil had increase the plant growth rate. Reference [13] reported that the increase of plant growth due to biosolids application often exceed that of well-managed fertilized controls. Unfortunately, the growth media of R5 died because of the uncontrolled of fertilizer nutrient inside plant.

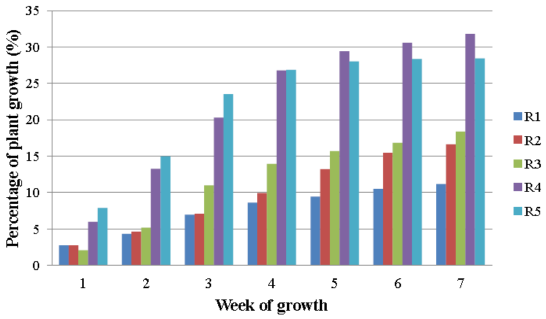
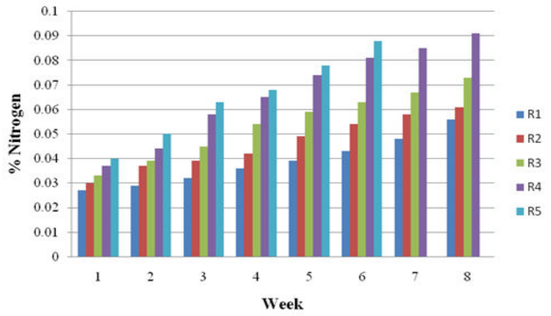


Fig. 3 The effect of different growth media on *R. Chinensis'* growth percentage

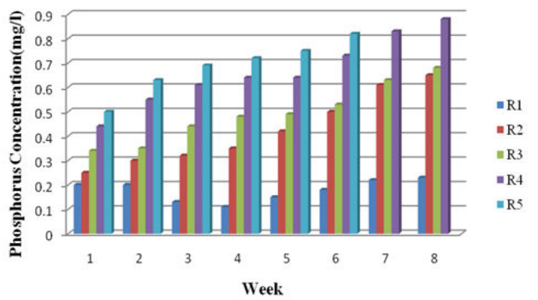
C. Macronutrients Content in Plant

Nitrogen is one of the important elements required for the plant growth and reproduction. It ranks after carbon, hydrogen, and oxygen in total quantity needed and it is the mineral element most demanded by plants. Sewage sludge contained a maximum amount of nitrogen that can contribute to the plant growth. It can be proven from Figs. 3 and 4 (a), where the highest applications of biosolids in growth media, which was R4, gives the rapid growth as compared to the other media growth that contained less amount of biosolids. These results are supported by [14]-[16], who showed that plants growth and N uptake increased with the biosolids application as compared to plants that did not received sludge. Day by day the growth of plant in all growth media was increasing greatly, except for the R1, which the growth rate was slow. The less nitrogen in the soil was the reason of slowed growth.

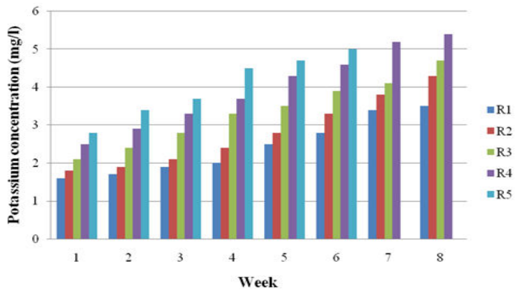
Normal plant growth cannot be achieved without phosphorus. It activates coenzymes for amino acid production used in protein synthesis and it decomposes carbohydrates produced in photosynthesis. It enhances seed germination and early growth, stimulates blooming, enhances bud set, aids in seed formation and hastens maturity [17]. Flowers are the vital elements in ornamental and flowering plants and they look terrific in the landscape where we live. Balanced potting soil plays an important role in the production of flowers. A high number of flowers will indicate suitable conditions for growing plants. Based on the result from Fig. 4 (b) and Table I, the number of flowers has a positive correlation with the soil phosphorus content because the adequate supply of phosphorus in R4 and R5 produced more flowers per plant. In the first week of experiment, R4 and R5 started to produce buds and within two to three days after that the flowers started to bloom.



(a)



(b)



(c)

Fig. 4 The occurrence percentage of macronutrients, (a) nitrogen, (b) phosphorous and (c) potassium in *R. chinensis's* leaves and stem

These results were in line with [18], who noted a greater number of flowers in organic residues with a high phosphorus concentration. Besides that, these results were also supported by a study performed by [19] in which they observed that *Dahlia coccinea* (ornamental plant) produced more flowers when grown in media featuring maximum phosphorus levels.

Potassium (K) on the other hand is an essential nutrient for plant growth. Large amounts were absorbed from the root zone in the production of most agronomic crops [20]. Whenever the plants were deficient of K supplied, the growth of plants was stunted and yields were reduced [21]. Potassium had the ability to stimulate early growth, increases the protein production, improves the efficiency of the water used, and improves resistance to diseases and insects [21]. This statement can be proven by comparing the concentration of potassium (Fig. 4 (c)) and the growth of *R. chinensis* (Figs. 2 and 3). Based on the result, whenever the concentration of potassium in the plants was increased the growth rate of plants also increased.

TABLE I
THE NUMBER OF FLOWERS BLOOMING

Plant Sample	Weeks of Flowers Blooming	Number of Flowers
R1	4	3
R2	3	4
R3	3	4
R4	2	5
R5	2	5

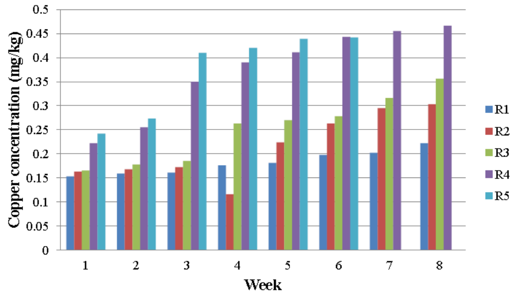
D. Micronutrients Content in Plant

The trace elements (also referred to as pollutants) in biosolids which are the greatest concern in this study were Copper (Cu), Nickel (Ni) and Lead (Pb). These elements were essential nutrients for plant growth except for lead (Pb), which is less concerned because of its insolubility and lower bioavailability. The specific amount of trace elements taken up by a plant species is directly proportional to the amount of sludge metals added and the growth stage of the plants [22].

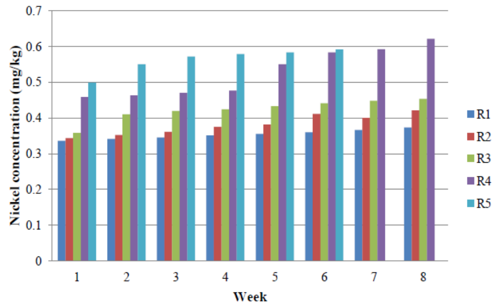
Based on the result from Fig. 5 (a), the highest concentration of copper was found in the leaves and stem of R4 growth media (0.466mg/kg) followed by R3 (0.356mg/kg) and R2 (0.303mg/kg). The lowest copper concentration was in the growth media R1 (0.222mg/kg). Although Copper is potentially toxic, it is an essential metal for normal plant growth and development. Thus, plants require Cu as an essential micronutrient for normal growth and development; when this ion is not available, the plants will develop specific deficiency symptoms, most of which affect young leaves and reproductive organs. The leaves twisted or malformed and showed chlorosis or even necrosis [23].

Nickel (Ni) has just recently won the status as an essential trace element for plants. According to [24], the seeds required nickel in order to germinate and plants without additional Ni will gradually reach deficient level whenever the time they mature and begin reproductive growth. If Ni is deficient, the plants may fail to produce viable seeds. The Ni concentration in plant leaves ranges from 0.05 to 5mg/kg [25]. Based on the result obtained from Fig. 5 (b), the maximum concentration of Ni was in the medium growth R4 (0.621mg/kg), followed by R3, R2, R1 (0.453, 0.421, 0.373mg/kg). The increasing of Nickel concentration in the *R. chinensis* leaves and stem was proportional to the *R. chinensis* growth rate. It indicates that the plants had received enough nutrients of Ni for the development and growth of the plant.

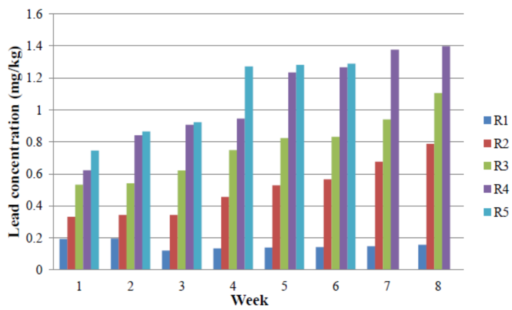
Lead (Pb) concentration in the plant leaves were influenced by the different concentration of additional nutrients. The leaves and stem of *R. chinensis* showed highest concentration of Pb in the growth media R4 (1.397mg/kg), followed by R3 and R2 (1.104 and 0.787mg/kg) (Fig. 5 (c)). The lowest concentration of Pb was from the growth media R1 (0.157 mg/kg). It was observed that, Pb absorption of plants increased proportional to the amount of biosolids in the growth media. Accumulation of Pb was in order of stems>roots>leaves [26]. A high level of Pb can cause inhibition of growth, interference with the cell division and water absorption and balance and the reduction of photosynthesis. However, according to [27], the ornamental plants can be grown safely in lead-contaminated soil.



(a)



(b)



(c)

Fig. 5 The concentrations of (a) copper, (b) nickel and (d) lead in *R. chinensis'* leaves and stem

All the essential elements in this study posed relatively little hazard to the growth of the plants because all of them have low solubility in soil and it present in the biosolids in such small quantities. Thus, it only provides the essential nutrient to plants and soil without contaminating them.

IV. CONCLUSION

The efficiency of the sewage sludge as a fertilizer has been determined by its proportional contribution to the growth development of *R. chinensis* and by studying the physicochemical of plants and soil such as pH, macro and micronutrients content. The results obtained had shown that 1gram of sludge can be proposed as an efficient fertilizer for ornamental plant. Heavy metal concentration of Cu, Pb and Ni were significantly increased in the plant, however it does not exceed the guidelines drawn by the Environmental Protection Agency. Based on this study, the utilization of sewage sludge as ornamental plant fertilizer can be recommended as it is safe enough to be used on the physicochemical aspects tested in this research. Additionally, it has been proven to increase the plant growth comparatively to a commercial fertilizer.

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