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Determination of the Efficiency of Treated Sludge as a Fertilizer

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ABSTRACT

There is the inevitable increase in domestic and industrial waste with the increase in world population. The end products from the waste treatment plants are mounting and we are now faced with the inevitable end of one day being surrounded by our waste. Therefore it is crucial for us to find possible applications or uses for this waste. A social perception study was conducted by our research team to obtain acceptable uses of sewage sludge and treated waste water. In this research the possible application of sewage sludge as fertilizer for non –food crop such as the grass in the golf course was studied. The results show that using sewage sludge as fertilizer in golf courses may be an amenable application; as test conducted on soil post sludge application showed no significant threat in the increase of heavy metals and pathogens in soil.

Key words: biosafety, sewage sludge, fertilizer, non-food crop.

INTRODUCTION

The ever increasing human populations worldwide will increase the amount of domestic and biological wastes produced by humans. This is evident from the statistics provided by Jabatan Perangkaan Malaysia (2010) which stated the total human populations in Malaysiaof28.25 million people in the year of 2010 is an increase of 1.25 % in total population from figures obtained in year 2009. Indah Water Konsortium produces 4.2 million m^3 of treated sludge annually through the sewage treatment process in Malaysia. The human population is expected to increase continuously in the future and this will increase the amount of treated sludge produced by Indah Water Konsortium.

Domestic wastewater treatment produces mainly two end products, which are sewage effluent and biosolids. Sewage effluent is clear water that contains low concentrations of plant nutrients and some traces of organic matter. The solid portion remaining after sewage treatment is known as biosolids or sewage sludge. Fresh sewage sludge consists of 30 to 50 g solids kg^{-1} and may contain 200 g solids kg^{-1} or more if the materials are dried. According to previous reports, treated sludge contains essential plant nutrients, heavy metals and pathogen (Sigua 2004). Phosphorus is essential for plant biological production. The limited amounts of phosphorus-rich minerals which are often tapped in the making of commercial fertilizers have highlighted the importance of recycling nutrients in the soil using organic wastes rich in phosphorus, nitrogen, potassium, sulphur and other micronutrients (Bengtsson and Tillman 2004).

Countries such as the United States of America, Canada, Western Europe and Sweden have been practising the fertilisation of land using processed sewage sludge which is low in pathogens, endotoxins and industrial and household chemicals (Lewis *et al*. 2002). Treated sludge is also used as a soil conditioner to improve the soil structure and nutrient levels and in land reclamation. The agricultural usage of treated sludge has benefited the farmers mainly because they often receive the treated sludge at no cost thus reducing their need for mineral fertilizers. Hence, treated sludge is economically attractive for farmers especially those small holders whose profit margins are small (Bengtsson and Tillman 2004).

Previous research on the benefits of using treated sludge in agriculture has shown that treated sludge application improves the physical, chemical and biological properties of soil (Aggelides and Londra 2000). Treated sludge is also rich in nutrients which increase plant biomass and yield (Reed *et al*. 1991). The tomato yield was increased significantly from the fertilization of tomato plants with treated sludge and no significant difference was observed from the usage of other organic fertilizer treatments (Pedreno *et al*. 1996). Delgado *et al.* 2002 has proven the potential of treated sludge as a fertilizer which increases the maize yield significantly and higher than mineral fertilization while the observed increase in soil heavy metal concentrations did not exceed the Spanish and European legal limits.

In Malaysia, treated sludge is currently being disposed of in landfills although previous research has shown that treated sludge is rich in plant nutrients such as nitrogen, phosphorous and potassium, and organic matter which can encourage healthy plant development and growth (Frost and Ketchum 2000). However the landfills which are currently being used to accommodate treated sludge are overloaded and the number of new lands available as landfills is limited in the country. Improper ways of disposing treated sludge can pose threats to the environment and living organisms as well where the emissions released by the wastes will pollute the source of drinking water, for example the lakes, rivers and streams and the unbearable odour released will affect the lives of residents living nearby. The reuse of treated sludge as a fertilizer will benefit both the farmers and Indah Water Konsortium. This is because the farmers can utilise the treated sludge which is beneficial to plants at a lower cost compared to the commercial fertilizers while Indah Water Konsortium can invest the profits obtained to further improve their sewage treatment technology to preserve the environment.

The most significant restraint to land application of treated sludge despite its benefits is the feared contamination of soil with heavy metals. The trace metal contaminants in treated sludge are either non-essential in plant metabolism such as Cd, Cr, Hg, Ni, Pb or essential in only trace quantities such as Cu, Fe and Zn. The study of heavy metals contamination resulting from the usage of treated sludge as a fertilizer is very important because the transfer of heavy metals from treated sludge to soil and subsequently to plants can pose health risks by entering the food chains and environment (Jamali *et al.* 2007). Treated sludge may also contain bacteria, virus, fungi and parasites which can be reduced through sludge treatment. However the complete elimination of the pathogens requires a more advanced sewage treatment process (Bengtsson and Tillman 2004). Among the processes being carried out in sewage treatment plants to reduce the pathogens are the removal of bacteria by inactivation, grazing by ciliated protozoa and adsorption to sludge solids and/or encapsulation within sludge flocks followed by sedimentation (Bitton 1994). Some sewage treatment plants have reported the presence of faecal coliforms (FC), enterococci (ENT) and spores of sulphite-reducing bacteria (SRB) in treated sludge (Hill and Sobsey 1998; Vilanova *et al*. 2004).

A recent research was carried out by the National University of Malaysia (UKM) to study the social perceptions on the reuse of treated sludge and treated effluents produced by Indah Water Konsortium. The results obtained indicated that the majority of respondents, 81.5 % agreed to the usage of treated sludge as a fertilizer for non-food crops in gardening and landscaping. However the lack of awareness among the public regarding the modern technology of sewage treatments employed by Indah Water Konsortium today has resulted in psychological stigmas such as bad odour and pathogenic contamination and religious stigma that deems any contact with effluents is impure (Yang Farina *et al.* 2008). Currently, there has not been a research which studies the potential of treated sludge as a fertilizer based on all the important aspects which may negate the benefits of treated sludge which include the effects on physicochemical properties of the soil, heavy metal concentrations and pathogenic contamination of the soil.

Therefore, the main objective of this study was to determine the potential of treated sludge as a fertilizer which can increase the plant yield significantly compared to the chemical fertilizer in a month. Furthermore, the effects of using treated sludge as a fertilizer on the soil physicochemical properties, heavy metal concentrations and pathogenic content in the soil were also studied.

MATERIALS AND METHODS

This study was carried out in the greenhouse at the National University of Malaysia in Bangi, Malaysia. The dried treated sludge was sampled at the Indah Water Sewage Treatment Plant in Bunus, Setapak using a shovel and highly durable polypropylene bags. The treated sludge was measured into small bags containing appropriate amounts of treated sludge using a weighing scale at the laboratory. Philippine grass in the form of turf grass was obtained at a nursery in Klang, Selangor as the test plant because Philippine grass is often grownin landscaping of the golf courses, recreational areas and private gardens of mansions. Besides that, Philippine grass is also praised for its beautiful, soft and slender leaf blades which imply an aesthetic value to the landscape. N: P: K = 15:15:15 chemical fertilizer was selected and the soil was obtained at a nursery in Kajang. The initial soil samples and treated sludge were obtained for the analysis of total nitrogen, pH and pathogenic contents.

At the greenhouse, five plots of soil were prepared using plastic trays measuring 38.5 cm x 28 cm x 11 cm (Length x Width x Height). Different sludge concentrations were prepared and mixed with soil to achieve the final weight of soil at 800 g. The sludge concentrations used were 13 % (100 g of treated sludge), 38 % (300 g of treated sludge), 44 % (350 g of treated sludge), 50 % (400 g of treated sludge) and ST5 which contained 44 % of treated sludge and two applications of chemical fertilizers in the form of a teaspoon every two weeks during the study. The ST5 plot was used to study whether treated sludge can be used to supplement the usage of chemical fertilizers and to compare both treatments in terms of their abilities to increase the plant yield.Philippine grass was measured in equal dimensions using a measuring tape and grown in the plots for a month. All plants received equal amounts of sunlight and temperature at the greenhouse. The plants were watered every morning to maintain the moisture levels in the soil and weeding was performed frequently to ensure the optimal growth of Philippine grass in each plot.

Sampling of soil was performed every two weeks for each plot to be analysed for the physicochemical properties (pH and total nitrogen), heavy metal concentrations (Zn, Cd, Cu, Ni and Pb) and the pathogenic contents. The soil was sampled from each plot using a sterile shovel, placed in a plastic bag and stored at 4 ^{o}C until analysis. After a month, the grass was harvested from all plots and the roots were rinsed with tap water to remove the soil and small stones. At the laboratory, the grass was placed on labelled aluminium foil trays and dried at 70 ^{o}C for 72 hours in the oven (Jamali *et al.* 2007). The dry weight of the grass was recorded as the grass yield in grams for different treatments.

Physicochemical analysis of the soil

A 1:2.5 soil-water suspension containing 8.0 g of soil in 20 mL of deionised water was prepared and left standing overnight for pH measurement (Jamali *et al.* 2007). This is to enable the soil to sediment and the pH of the supernatant was measured the next day using a Delta 320 pH meter (Mettler Toledo, USA). For the analysis of total nitrogen, 5 g of soil was mixed with 25 mL of deionised water (5x dilution) and filtered using a Whatman 542 filter paper. The samples were stored at 4^{o}C until analysis. Dilutions of the soil samples were performed because the soil contained high nitrogen concentrations and the method used could only detect the nitrogen concentrations in the range of 0.01-0.50 mg/L. At the Water Analysis and Research Centre (ALIR), nitrogen concentration in the soil was analysed a HACH DR/2400 Direct reading Spectrophotometer (HACH, USA) and ammonia salicylate method (HACH 1989).

Heavy metal concentrations analysis

The extractable fractions of heavy metals in the soil which was available for plant uptake was studied using the extraction procedure with EDTA solution. EDTA 0.05 M solution was prepared by dissolving 18.61 g of di-sodium dihydrogen ethylene tetraacetate salt dehydrate in 1000 mL of sterile, deionised water and the pH of the solution was adjusted to pH 7.0 by adding NH_4OH solution. This was because EDTA salt would only dissolve at a basic pH. A 250 mL polypropylene bottle containing 0.5 g of soil was mixed with 50 mL of EDTA 0.05 M and shaken on a Belly Dancer for an hour. The extract was immediately transferred into a 50 mL centrifuge tube and centrifuged at 5000 rpm for 30 minutes at 25°C using a Mikro 22R Hettich-Zentrifugen (Jamali *et al*. 2007). The supernatant was filtered, acidified with 2N nitric acid and stored in polypropylene tube at 4°C until analysis. Standard solutions of Zn, Cd, Cu, Ni and Pb metals were prepared in 0.1 ppm, 0.5 ppm, 1.0 ppm, 3.0 ppm and 5.0 ppm (APHA 2005). The soil was analysed for heavy metals, Zn, Cd, Cu, Ni and Pb concentrations using flame atomic absorption spectrometer (FASS) (Jamali *et al*. 2007).

Pathogenic content analysis

The contents of faecal coliforms (FC) and enterococci (ENT) in the soil samples were studied in the amended soil with treated sludge. Serial dilutions of soil were performed at 10^{-5}, 10^{-6} and 10^{-7} dilutions using sterile distilled water. 100 µl of the diluted sample was spread evenly on the eosin methylene blue agar (EMB) (Difco, USA) and the agar was incubated at 35°C for 24 hours. The procedure was performed for all three dilutions separately. The agar was observed for metallic green colonies that were characteristic of *Escherichia coli* after 24 hours. Enterococci was analysed by membrane filtration method on 0.45 *µ*m nitrocellulose membranes. Serial dilutions of soil were performed at 10^{-2}, 10^{-3} and 10^{-4} dilutions. The filtrated membranes were incubated on m-Enterococcus agar (MEA) at 37°C for 48 hours. Enumeration of pink or red colonies on the agar was performed after 48 hours (Vilanova and Blanche, 2005).

RESULTS AND DISCUSSION

In this study, the potential of treated sludge as a fertilizer has been determined by studying the effects of treated sludge on the grass yield compared to the usage of chemical fertilizer after a month, the physicochemical properties of the soil such as pH and nitrogen concentration, heavy metal concentrations and the pathogenic content in the soil.

Grass yield

After a month, the grass was harvested from all the plots, dried at 70°C for 72 hours and weighed to obtain the dry matter yield. The yield obtained were compared between the five different treatments in the amended soil, which were 13 %, 38 %, 44 %, 50 % sludge concentrations and ST5 (containing 44 % sludge concentration and two applications of chemical fertilizer). Comparisons were done between the different treatments in order to determine which sludge concentration could produce the highest grass yield compared to the chemical fertilizer.

Table 1: The Grass Yield Measured for Different Treatments After a Month

Sludge concentrations	Grass yield (g ± ó)
13 %	232.06 ± 11.41
38 %	188.21 ± 3.76
44 %	154.37 ± 5.26
50 %	124.96 ± 6.67
ST5	124.87 ± 0.64

All values were presented as mean ± standard deviations for two replications.

The results obtained showed that the highest yield was given by 13 % sludge concentration as 232.06 ± 11.41 g while the lowest yield was given by ST5 plot as 124.87 ± 0.64 g. The yield decreased with increasing sludge concentrations in the amended soil (Table 1). Statistical analysis of the data obtained was performed using Minitab software to conduct ANOVA (Analysis of Variance) and Tukey's Multiple Comparisons Tests analysis at 0.05 significant values. The yield obtained for different treatments differed significantly from each other ($p < 0.05$). Tukey's analysis showed that the 13 % sludge concentration has significantly increased the yield compared to all the other treatments. Besides that, the yield obtained for 44 % sludge concentration did not differ significantly from that of ST5.

The grass yield obtained by different treatments was correlated with the nitrogen and heavy metal concentrations in the soil. At higher sludge concentrations,the increase in nitrogen concentration exceeded the nitrogen requirements of the plant and the heavy metals also increased to a toxic level that impaired the plant growth. The soil amended with 13 % sludge concentration contained the optimal level of nitrogen and low heavy metal concentrations which promote the healthy growth and development of plants, thus providing the highest yield compared to other treatments. Smith (1996) discovered that the usage of biosolid increased the plant production and improved forage quality only when the biosolidapplication rates did not increase the nitrogen concentration exceeding the requirements of the treated plants and soil heavy metal concentrations were not toxic.Excessive nitrogen concentration in the soil will decreased the Nitrogen Use Efficiency, NUE of the plants and reduced the plant's yield. According to Binder *et al.* (2002), the NUE of nitrogen in the biosolids and chemical fertilizer by plants decreased with increasing nitrogen concentrations in corn production.Mamo *et al.* (1999) has also shown that the effects of increasing treated sludge and N fertilizer rates on the NUE were not significant.

The usage of 50 % sludge concentration and chemical fertilizer in ST5 produced yield which was not significantly different compared to that of 50 % sludge concentration alone based on Tukey's test. This has proven that treated sludge can be used to replace the usage of chemical fertilizer since treated sludge worked excellently as a potential fertilizer that has increased the yield without the supplementation of chemical fertilizer compared to the ST5 plot. This was supported by Albadejo *et al.* (1994); Spinosa and Vesilind (2001) which mentioned that treated sludge contains beneficial plant nutrients and organic matter and therefore can be used to supplement or replace chemical fertilizers to increase crop production. The nitrogen concentration in the ST5 plot was the highest at 137.5 mg/L due to theapplication of both treated sludge and chemical fertilizer, had reduced the NUE of the plant and grass yield compared to all the other treatments. Cogger *et al.* (2001) reported that the fertilizer value of sludge was comparable to that of chemical fertilizers because the grain and silage yield of corn obtained for both treatments was not significantly different.

Physicochemical properties of the soil

The soil pH was measured before and after being treated with treated sludge because the soil pH could affect the population of pathogens in the soil, heavy metal concentration, nutrient content and the suitable type of plants. During the four weeks of the study, there was no significant difference ($p > 0.05$) between the pH and the different treatments based on ANOVA. The soil pH remained acidic (pH < 7.0) after the treatments (Table 3). Soil pH was an important factor in this study because pH could influence metals adsorption, retention and movement (Mahdavi and Jafari 2010). At a low pH (pH < 7.0), the mobility and leaching of toxic heavy metals increase and their availability decrease as the pH approaches neutral or increases above pH 7.0 (Jamali *et al.* 2007). The content of pathogenic microorganisms

Table 2: The Physicochemical Properties of Soil and Treated Sludge Samples at ahe Initial of the Study

Samples	pH	Ammonical nitrogen,mg/L
Soil	6.70	110.0
Treated sludge	7.78	750.0

Table 3: Soil pH for Different Treatments During Four Weeks of Study

Sludge concentrations/ pH	Week 2	Week 4
13 %	6.17	5.90
38 %	6.01	5.93
44 %	6.13	6.12
50 %	6.24	6.25
ST5	5.91	5.89

Table 4: Soil Ammonical Nitrogen Concentration for Different Treatments

Sludge concentrations	Ammonical nitrogen, mg/L
13 %	85.0
38 %	67.5
44 %	120.0
50 %	100.0
ST5	137.5

in the soil also increases at a low pH and therefore it was further suggested to increase the soil pH to above pH 7.0, preferably at pH 12.0 in order to decrease the pathogens in the soil (EPA 2007).

The nitrogen concentration in the soil was analysed using a HACH DR/2400 spectrophotometer at a wavelength of 655 nm before and after treatments with treated sludge. Nitrogen is among the most essential nutrients for plants and it usually increases plant growth and crop yield (Akdeniz *et al*. 2006). Nitrogen functions as a constituent of protein, nucleic acids, chlorophyll and growth hormones in plants (Ahmadil *et al*. 2010). Treated sludge was rich in nitrogen, containing 750.0 mg/L of nitrogen (Table 2) and thus highlighting its potential as an attractive fertilizer.

Overall, nitrogen concentration in the soil has increased with the application of increasing concentrations of treated sludge (Table 4). However, the lowest nitrogen concentration observed in 13 % sludge concentration that was 85.0 mg/L produced the highest yield at 232.06 ± 11.41 g compared to the ST5 plot which contained the highest nitrogen concentration at 137.5 mg/L and produced the lowest yield at 124.87 ± 0.64 g.The NUE decreased with increasing nitrogen concentration and as a result, the higher nitrogen concentration in the soil became excessive to the requirements of plant and reduced the crop yield (Binder *et al*. 2002). The nitrogen concentration in the soil was studied after being treated to determine the optimum nitrogen concentration which could significantly increase the yield, because excessive nitrogen could leach out of the soil in the form of nitrate and degrades the environment. The results have shown that 13 % sludge concentration contained the optimum nitrogen concentration to increase the crop yield.

Heavy metal concentrations

In this study, the plant-available heavy metal concentrations of Zn, Cu, Cd, Ni and Pb were analysed using the extraction method with EDTA 0.05 M at pH 7.0 by Flame Atomic Absorption Spectroscopy (FAAS). It was important to study the effects of treated sludge application on the soil heavy metal concentrationbecause there is a wide public health concern over the elevation of heavy metal concentration in the soil which could be absorbed by plants, pollute the groundwater and surface water reservoirs and lead to food chain contamination (Selivanovskaya and Latypova 2003). The usage of EDTA 0.05 M at pH 7.0 to extract the plant-available heavy metals was approved by a group of European researchers and coordinated by the Measurements and Testing Program of the Commission of the European Communtiy (Jamali *et al.* 2007). EDTA was a very good indicator of heavy metals pollution and plant-available metals in soil (Cajuste and Laird 2000).

The application of treated sludge has significantly increased the concentration of Zn, Cu and Cd in the soil ($p < 0.05$) based on ANOVA. However, the heavy metal concentrations did not exceed the limits in Part 503: Standards for the use or disposal of sewage sludge (EPA 2007). Furthermore, the metals in treated sludge were generally organically bound and less available for plant uptake compared to the more mobile metal salt impurities in commercial fertilizers (Frost and Ketchum 2000). On the other hand, the increase in

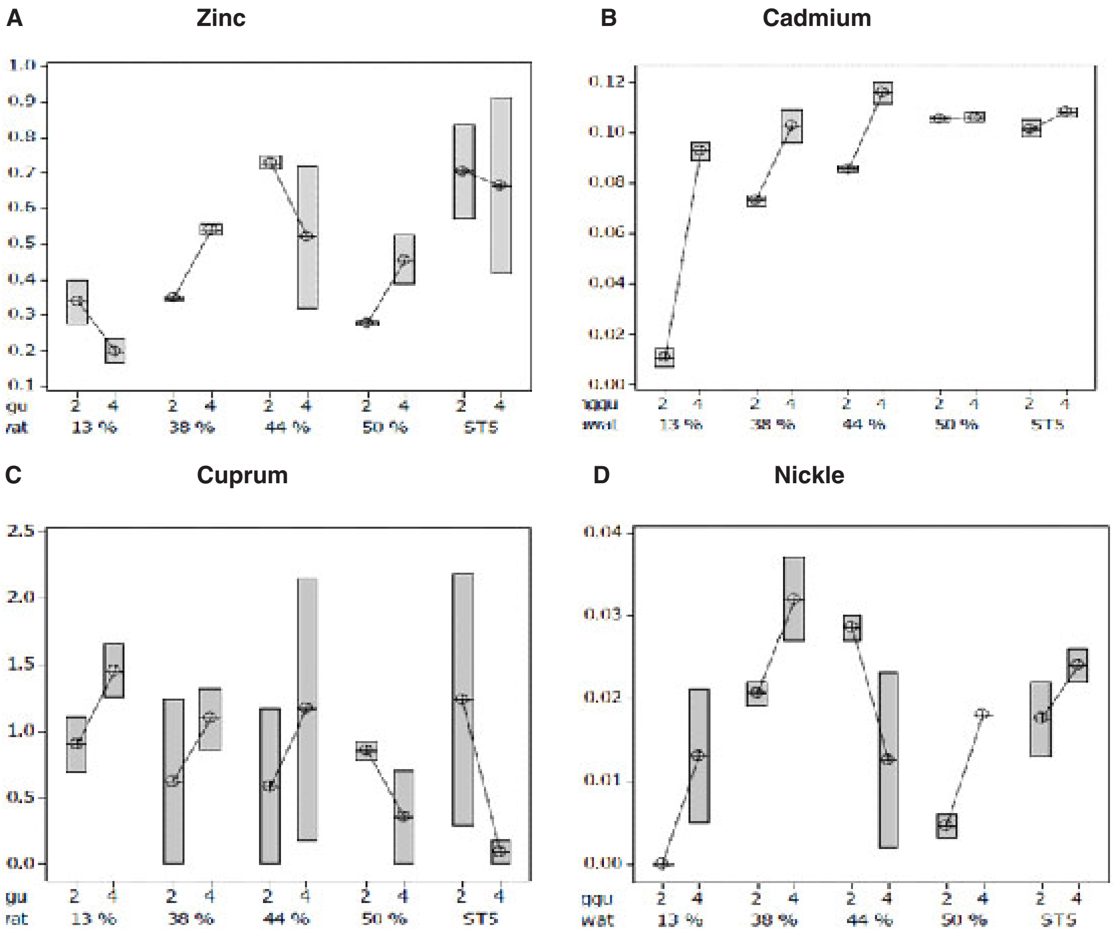

Fig.1: Boxplot of Heavy Metal Content in Soil Post Sewage Sludge Application.
The Y-axis is the concentration detected in mg/mL and the X axis has the weeks (2 and 4) post treatment where measurements were made and the concentration of sewage sludge used in the experimentation.

Ni concentration was not significant ($p > 0.05$). Pb was not detected in the soil before and after treatment with treated sludge during the study due to the low concentration in the soil (Fig 1).

Pathogenic content of the soil

The soil samples were analysed for the content of pathogens in the soil which were associated with faeces, faecal coliforms (FC) and enterococci (ENT) before and after treatments with treated sludge. This study was important to determine whether the usage of treated sludge as a fertilizer could increase or introduce pathogens to the soilwhich could harm the health and living quality of humans and animals by polluting the water reservoirs such as lakes and rivers. FC was not detected in the soil samples for all treatments during the study. *Escherichia coli*is commonly used as an indicator of water contamination with faeces and can cause severe diarrhoea in children and adults.

ENT lives in the intestines of humans and animals and can also live freely in the soil, plants or milk products. ENT is the main nosocomial pathogen in humans (Devriese *et al.* 1991). ENT is also an indicator of faecal contamination in water resources because ENT is present in large amounts in faeces and can persevere in the environment for a long period (Manero and Blanch 1999). The application of treated sludge has significantly increased the ENT content in the soil ($p < 0.05$)

based on ANOVA. The total ENT colonies was the highest in the soil amended with 50 % sludge concentration which was 1200 colonies/mL compared to all the other treatments. Tukey's test further implied that the application of 50 % sludge concentration significantly increased the ENT colonies in the soil. Nonetheless, the total enterococci colonies have decreased to zero colonies/mL in the fourth week of study in 13 %, 38%, 44 % and ST5 plot due to the antagonistic relationships between the rhizospheric bacteria in the soil. Even the test plot for 50% sewage sludge showed significant decrease (63%) in the ENT colony counts over the period of four weeks. The treatment of soil with 13 % sludge concentration did not significantly increase nor introduce any ENT colonies throughout the study and no ENT colonies were detected in the treated soil.This has shown that the 13 % sludge concentration was safe to be applied as a fertilizer compared to all the other treatments.

CONCLUSION

In this study, the efficiency of treated sludge as fertilizer has been determined with relations to the increase in yield of Philippine grass and by studying the physicochemical soil properties such as pH and nitrogen concentration, heavy metal concentration and the content of pathogens in the soil. The results obtained have shown that the 13 % sludge concentration can be proposed as an efficient fertilizer because it has significantly increased the yield, contained the optimum nitrogen concentration and did not increase nor introduce enterococci to the soil. Heavy metal concentration of Zn, Cd and Cu were significantly increased in the soil following treatment with treated sludge, however the concentration did not exceed the guidelines drawn by the Environmental Protection Agency. Based on this study, the usage of treated sludge as a plant fertilizer can be recommended because it is safe enough to be used based on the biological and physicochemical aspects tested in this research. In addition it has been proven to increase the plant yield comparatively to that of a chemical fertilizer.

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REFERENCES

1. Akdeniz, H., Yilmaz, I., Bozkurt, M.A. & Keskin, B. The effects of sewage sludge and nitrogen applications on grain sorghum grown (*Sorghum vulgare* L.) in Turkey. *Polish Journal of Environmental Studies,* **15(1):** 19-26 (2005).
2. APHA, AWWA, WEF. *Standard Methods for the Examination of Water and Wastewater*. New York: American Public Health Association (2005).
3. Bengtsson, M. & Tillman, A.M. Actors and interpretations in an environmental controversy: the Swedish debate on sewage sludge use in agriculture. *Resources, Conservation and Recycling,* **42:** 65-82 (2004).
4. Binder, D.L., Dobbermann, A., Sander, D.H. & Cassnman, K.G. Biosolid as nitrogen source for irrigated maize and rainfed sorghum. *Soil Science Society of America Journal,* **66:** 531 (2002).
5. Bitton, G. Activated sludge process. Dlm. Wiley-Liss (pnyt.). *Wastewater Microbiology*, hlm. 147-166. New York (1994).
6. Cajuste, L.J. & Laird, R.J. The relationship between phytoavailability and the extractability of heavy metals in contaminated soils. Dlm. Iskandar, I.K. (pnyt.). *Environmental Restoration of metals-contaminated soils*, hlm. 189-198. Boca Raton: Lewis Publishers

(2000).

7. Cogger, C.G., Bary, A.I., Fransen, S.C. & Sullivan, D.M. Seven years of biosolids versus inorganic nitrogen applications to tall fescue. *Journal of Environmental Quality,* **30:** 2188-2194 (2001).
8. Delgado, M., Porcel, M., Miralles de Imperial, R., Beltran, E., Beringola, L. & Martin, J. Sewage sludge compost fertilizer effect on maize yield and soil heavy metal concentration. *Reviews of International Contamination and Ambient,* **18(3):** 147-150 (2002).
9. EPA. Part 503: *Standards for the Use or Disposal of Sewage,* Sludge. USA: Environmental Protection Agency (2007).
10. Frost, L.H. & Ketchum, L.H. Trace metal concentration in durum wheat from application of sewage sludge and commercial fertilizer. *Advances in Environmental Research,* **4:** 347-355(2000).
11. Hill, V.R. & Sobsey, M.D. Microbial indications in alternative treatment systems for swine wastewater. *Water Science and Technology,* **38:** 119-122(1998) .
12. Indah Water Konsortium. *Sewage treatment plant*. Putrajaya: Indah Water Konsortium (2010).
13. Jamali, M.K., Kazi, T.G., Arain, M.B., Afridi, H.I., Jalbani, N., Memon, A.R. & Shah, A. Heavy metals from soil and domestic sewage sludge and their transefer to Sorghum plants. *Environmental Chemistry Letters,* **5:** 209-218 (2007) .
14. Lewis, D.L., Gattie, D.K., Novak, M.E., Sanchez, S. & Pumphrey, C. Interactions of pathogens and irritant chemicals in land-applied sewage sludges (biosolids). *BMC Public Health,* **2:** 11 (2002).
15. Mamo, M., Rosen, C.J. & Halbach, T.R. Nitrogen Availability and Leaching from Soil Amended with Municipal Solid Waste Compost. *Journal of Environmental Quality,* **28:** 1074 (1999).
16. Mohammad Mahdavi & Jahangir Jafari. Environmental risks due to application of sewage sludge in farmlands. *Ozean Journal of Applied Sciences,* **3(2):** 303-313 (2010).
17. Reed, B.E., Carriere, P.E. & Matsumoto, M.R. Applying sludge on agricultural land. *Biocycle,* **37:** 58-60 (1991).
18. Sigua, G.C. Current and future outlook of dredged and sewage sludge materials in agriculture and environment. *Journal of Soils and Sediments,* **5(1):** 50-52 (2004).
19. Vilanova, X. & Blanch, A.R. Distribution and persistence of fecal bacterial populations in liquid and dewatered sludge from a biological treatment plant. *Journal of General and Applied Microbiology,* **51:** 361-368 (2005).
20. Vilanova, X., Manero, A., Cerda-Cuellar, M. & Blanch, A.R. The composition and persistence of faecal coliforms and enterococcal populations in sewage treatment plants. *Journal of Applied Microbiology,* **96:** 279-288 (2004).
21. Walters, G.L. (pnyt.). *Water Analysis Handbook*. Colorado: HACH Company (1989).
22. Yang Farina, Junaenah Sulehan, Abd. Hadi Harman Shah, Kalaivani Nadarajah, Md Pauzi Abdullah, Jumat Saliman, Azmi Aziz, Zuriati Zakaria, Lee Lin Jian, Sasidharan Velayutham, Lim Pek Boon & Rosmini Hashim. Social perception on the reuse of treated effluent from sewage treatment plants from the Klang valley for commercial and domestic applications. Bangi: Universiti Kebangsaan Malaysia (2008).