

STUDY ON SLUDGE TREATMENT BY THE AEROBIC STABILIZATION PROCESS COMBINED WITH BULKING AGENT AND HEATED AIR SUPPLY

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Abstract. This paper presents the results of evaluation of sludge stabilization ability from a municipal wastewater treatment plant by the organic wastes treatment device of Mikuniya Corporation, Japan with a capacity of 50 kg/day. An average sludge amount of 30 kg/day was added into the reactor, with the moisture of 80.2 - 83.6 %, the C/N ratio of around 22 - 35. After 30, 60, and 90 days of fermentation with bulking agent combined with heated air supply at 50 °C, the results from experiments showed that the sludge volume decreased within a range of 83 - 85 %, the stabilization efficiency by dry weight of sludge reached at 32 - 39 %, corresponding to the average decomposition rate of 12 [g/(kg.day)], the evaporation efficiency was more than 95 %. Sludge after stabilization had the colour of brown-grey, pH of about 6.5 - 7.2, the humus particles with the size of less than 1 mm accounted for over 60 %. Evaluation of TOC and T-N met the standard of Organic-Biofertilizer from household waste-Technical parameters and testing methods (10TCN 526:2002/BNN&PTNT). The stabilized sludge using for growth tomato plant test showed time for fruits was 2 months, leaves were large and dark green. The stems were harder and higher of 20 cm compared to the plant fertilized by a market organic fertilizer under the same conditions of cultivation and monitoring. The initial results of this study were a basis for sludge treatment technology approaches towards waste recycling orientation in urban areas in Viet Nam.

Keywords: WWTP sludge, aerobic process, bulking agent, stabilization ability, organic fertilizer.

Classification numbers: 3.3, 3.3.2.

1. INTRODUCTION

Currently in Viet Nam, the resources recovery from sludge does not concern for the drainage and wastewater treatment projects [1]. In big cities, a small number of wastewater

treatment plants (WWTPs) produce compost from sludge after stabilization process of WWTP Binh Hung, Ho Chi Minh city, or by drying yards in Da Lat, Lam Dong province. However, the compost amount does not meet the local market demands due to the small sludge input quantity. Lack of land area to expand the capacity and odour generation from sludge stabilization are the limitation problems of these technologies. Whereas WWTP Yen So in Hanoi city, had been designed with a capacity of 200,000 m³/day, applied an anaerobic decomposition technology to stabilize sludge. However, the plant is still not operating at full capacity, this results in the amount of generated sludge is low. On the other hand, because the influent is from the combined drainage system with low concentrations of organic constituents, biogas cannot be formatted from this plant at present [2]. In the case of Danang city, WWTPs are generating a significant amount of sludge which are being disposed at Khanh Son Landfill [3], this results in increasing the volume of treated wastes and leachate as well as contributing to greenhouse gases emissions from burial sites [4, 5].

The energy recovery from sludge of WWTPs is not suitable for current municipal wastewater characteristics of Viet Nam, and the process of sludge stabilization technology to compost is still quite simple. Sludge after drying process have to add nutrients and leave for stabilizing several times if the effective microorganisms are not added in the treatment process, the decomposition duration will be prolonged and lead to environmental problems. These lead to additional cost of sludge stabilization process and increases the compost prize. On the other hand, the researches and applications currently are focusing mostly on sludge from drainage systems [6, 7, 8] and also from sanitary facilities [9, 10, 11] or organic sludge mixed with biodegradable wastes to produce compost [12, 13, 14], while there are a few studies focusing on sludge from WWTPs in Viet Nam. Therefore, in the context of current wastewater management in Viet Nam, it is necessary to study and apply a new technology for sludge treatment in WWTPs. This paper presents the initial research results of the sludge stabilization process by the organic wastes treatment device which was developed by Mikuniya Corporation, Japan (The Mishimax device). The detail information of Mishimax has been registered in UNIDO's environmental technology database in 2018 [15]. The Mishimax device have been operated successfully at WWTPs in some prefectures in Japan and supplied treated sludge as an organic fertilizer for agriculture activities. Recently, it has been used for sludge waste treatment studies at pilot scale in Can Tho city and Dong Nai province, Viet Nam. This study aimed to evaluate the feasible technology and materials in applying Mishimax technology for treating sludge from Hoa Xuan WWTP in the condition of Da Nang and Vietnamese cities.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. The Mishimax device

The Mishimax device of Mikuniya Corporation, Japan (MK-50) for organic wastes treatment with a capacity of 50 kg/day was used in this study. The principle of the sludge stabilization process was based on the microorganisms activated by the bulking agent as a bio-carrier to decompose organics composition and increase the evaporation process by heating. According to the information of the manufacturer (MC), the Mishimax can reduce the volume of wastewater sludge, food waste, and other forms of organic waste by more than 90 % in 24 hours [15]. Figure 1 shows the overall drawing (Fig.1a) and the inside structure of MK-50 device (Fig.1b). The main reactor of MK-50 had been designed as a cylindrical round with the useful

volume was approximately 1.8 m^3 . For the instruction operation, MK-50 could be operated on manual or automatic mode. In this study, the device was set up on the automatic mode. After starting the device by the control panel, the intake fan combined with a flange heater supplied fresh heating air at the bottom of the reactor which was set up by the temperature controller (not allowed over $70 \text{ }^\circ\text{C}$). When the device was stability, depended on the study aim, an amount of bulking agent (wood chips) and organic wastes were calculated and put in the Mishimax fermentation tank. During the experiment, the mixer mixed all materials in 4 minutes of rotation (including forward and reversal rotation time) and 120 minutes of idle. At the same time, the exhaust fan was operated with the scrubber to absorb exhaust gas and reduce odors. Every day, the device is stopped for showering the scrubber on manual operation before a new sludge input step. The fan stopped within 5 minutes after pressed the manual button, prickled for 2 minutes through the water supply pipe, then stopped for 10 minutes for drainage. When the shower step finished, the device was restarted on automatic mode for next operation process. Organic waste can be added to the Mishimax every day, but the bulking agent are replaced only biannually. After three months, biodegraded organic waste becomes available as an organic fertilizer [15].

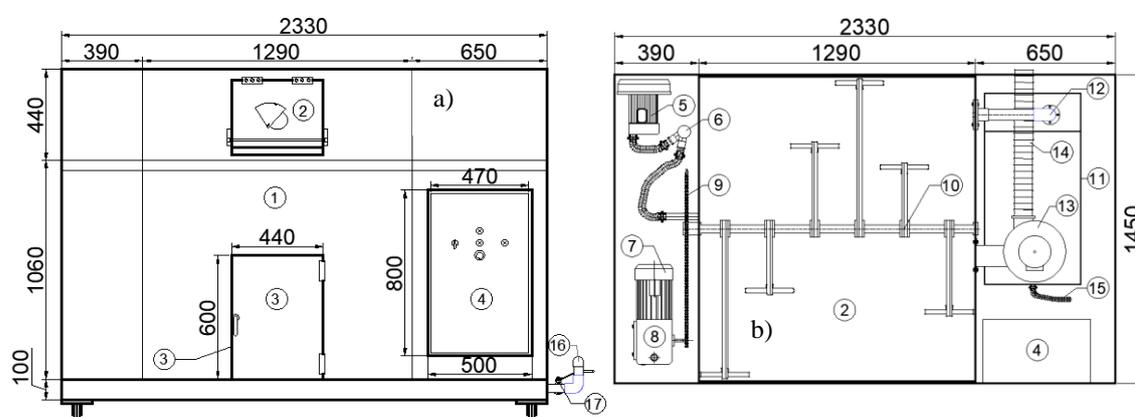


Figure 1. The overall drawing of MK-50 (a) and the inside structure of the device (b).

Where: 1-Reactor; 2-Materials input; 3-Materials output; 4- The control panel (Power manager); 5-Air supply fan; 6-Flange heater; Agitator motor; 8-Speed reducer; 9-Transmission sprockets; 10-Mixer (Forward and Reversal rotation); 11-Scrubber; 12-Exhaust pipe; 13-Exhaust fan; 14-Treated air pipe; 15-Water supply pipe; 16-Water drainage pipe; 17- Blowdown valve

2.1.2. Sludge from Hoa Xuan WWTP

Sludge samples were taken from Hoa Xuan WWTP treating wastewater from the combined drainage system in the southern basin of Cam Le district, Danang city. The plant is operating with a capacity of $20,000 \text{ m}^3/\text{day}$ using C-Tech technology, which is a variant of Sequencing Batch Reactor - a continuous batch reaction process. The amount of sludge generated from the system after pressing by the conveyor belt process was about 4 - 5 tons/day. The spec floc C-1492 LMW flocculant cation polymer with the main ingredient of Polyacrylamide - PAC ($\text{CONH}_2[\text{CH}_2\text{-CH-}]_n$) was used for dewatering the sludge. The origin of polymer product was from Kemira Brand (England), it was widely used in the sludge concentration process with a ratio of 4 kg PAC/3.5 tones pressed sludge [16]. The sludge sample was stored to the laboratory

for analyzing. Sampling frequency was two times/week. The process of sludge analysis was conducted using Vietnamese standard methods and shown in Table 1.

Table 1. Vietnamese standard methods for sludge analysis’.

No.	Parameters	Method	No.	Parameters	Method
1	Moisture	TCVN 9297:2012	4	T-C	TCVN 6642:2000
2	Ash	TCVN 9297:2012	5	T-N	TCVN 8557:2010
3	pH	TCVN 5979:2007	6	P ₂ O ₅	TCVN 5815:2001

2.1.3. Baking agent (Cedar chips)

The baking agent of cedar chips (named *Cryptomeria Japonica*), imported from Japan was used in this study as a kind of bio-carrier (Fig. 2a). The size of material was quite 10 mm (Fig. 2b). The surface structure of the chips was determined by Scanning Electron Microscope (SEM), JSM-6010PLUS/V (Fig. 2c), at 500-time magnification. SEM image (Fig. 2d) showed the surface of the chips shaped like a hive, uniform in hole size (20 μm). It was a favorable environment for activating of microorganisms and supplying of carbon to balance the C/N ratio in sludge for the aerobic decomposition process.

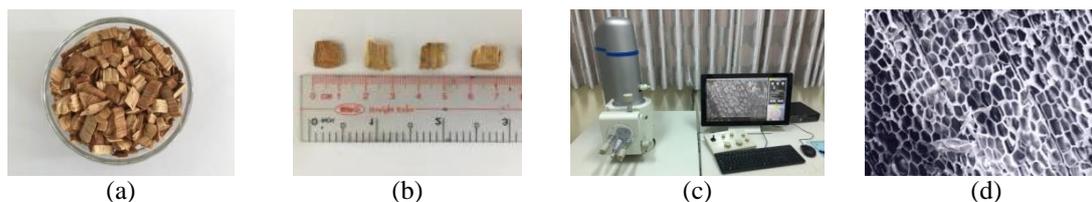


Figure 2. Characteristic of Cedar chips.

2.2. Methods

The experiment was conducted as follows: Start the MK-50 and put 400 litres (equal to 72 kg of weight) of cedar chips into the reactor of the device, and everyday added 30 kg/day of sludge into the reactor. Heating air at the temperature of 50 °C was supplied to the reactor while the device was operating. Every day, a sample was taken for monitoring of some basic parameters such as temperature, moisture, and pH. After the intervals of 30 days, 60 days, 90 days of adding sludge, remove all materials in the reactor, then determined the amount of the stabilized sludge by weighing method. The mixture after weighing was returned to the reactor for the next test. From October to December 2019, the experiment has been conducted three times with each time for 30 days to determine the sludge reduction rate. The ability of decomposition was determined by the reduction rate of material weight in the reactor, using the following formula:

$$H = \frac{M(1) - M(4)}{M1} \times 100 (\%) = \frac{M(1) - [M(2) - M(3)]}{M1} \times 100, (\%) \quad (1)$$

where: H-Sludge reduction rate (wet weight, %); M(1)-The total amount of waste loaded by wet weight (kg/30 days); M(2)-Total weight after decomposition (kg/30 days); M(3)-The amount of wood chips (kg/period); M(4)-The total amount of residual waste (kg/30 days).

Based on the result of the sludge reduction rate, the stabilization efficiency by dry weight of sludge, the evaporation performance and the average decomposition rate were also determined according to below formulas:

$$D = \frac{\text{Amount of dry sludge (input-output),kg}}{\text{Amount of dry sludge input,kg}} \times 100, (\%) \quad (2)$$

$$E = \frac{\text{Amount of water in sludge (input - output),kg}}{\text{Amount of water in sludge input,kg}} \times 100, (\%) \quad (3)$$

$$\beta = \frac{\text{Amount of dry sludge (input-output),g}}{[\text{Amount of dry sludge input,kg}] \times [\text{Experimental time,day}]}, \text{ g/(kg.day)} \quad (4)$$

where: D - The stabilization efficiency of sludge (dry weight, %); E - The evaporation performance (%); β - The average decomposition rate of sludge [dry weight, g/(kg.day)].

The stabilized sludge after 90 days decomposed by the MK-50 device was analyzed for quality testing according to the standard of 10TCN 526:2020/BTN&PTNT. Some parameters such as carbon, nitrogen and phosphate of this stabilized sludge were compared with three kinds of organic fertilizers in Da Nang (Thien Phu brand), Viet Nam (Song Gianh brand) and Japan (Yamanouchi fertilizer produced from WWTP sludge in Yamuchi Prefecture). At the same time, stabilized sludge was used as a fertilizer for tomato growth to evaluate the potential of reuse as an organic fertilizer. Three models with the different weight ratios of soil and stabilized sludge - CC1 (5:1), Thien Phu organic fertilizer - CC2 (5:1) and without fertilizer - CC0 (5:0) were used for tomato growth. The tomato plant was grown with a density of 4 seedlings/model. All three models were monitored on the tomato growth and characteristics of stems, leaves and fruiting ability for a period of 03 months with the same conditions of cultivation.

3. RESULTS AND DISCUSSION

3.1. Characteristic of the Hoa Xuan WTPP sludge

The properties and composition of pressed sludge are presented in Table 2.

Table 2. The pressed sludge characteristics (Total samples: n = 6)

Samp.	Moisture (%)	Ash (%)	pH	C (%)	N (%)	C/N	P ₂ O ₅ (%)
Value	80.2 - 83.6	31.7 - 36.2	6.9 - 7.4	28.6 - 35.3	1.02 - 1.52	22 - 35	0.83 - 0.96
Average	81.4	33.8	7.2	31.2	1.26	24.7	0.91

The moisture of samples was approximately 82 %, the ash was relatively high (over 33 %), and the C/N ratio was about 25. It was suitable for stabilization in an aerobic condition [17]. In the year of 2017, when the WWTP operated stably, the sludge was analyzed to check the hazardous compositions. The analyzed results of Danang Technology and Environment Center belongs to Institute of Environmental Technology, Vietnam Academy of Science and Technology showed that heavy metals and toxic substances of Hoa Xuan WTPP sludge after pressing by the

conveyor belt process were not detected or the concentration were lower than the absolute content limitation (H^{lc}), which calculated according to the QCVN 50:2013/BTNMT National Technical Regulation on Hazardous Thresholds for Sludge from Water Treatment Process) [18]. This was an important point for hazardous wastes generation management from Hoa Xuan WTTs and proved that the pressed sludge was a safe material for experiments in this study.

3.2. Parameters of the sludge stabilization process

The parameters of the process observed during the experiment are shown in Figures 3. The temperature of the mixture was monitored in the range of 26 - 43 °C, whereas was around 35 °C at the end of 30 days. The temperature in a few beginning days was low because of moisture of the input sludge, and the heated air supply was at 50 °C to balance the temperature of the material mixture. The moisture in the first seven days was rather low, less than 15 %, because the moisture of the mixture was mainly affected by cedar chips volume. When the amount of the input sludge added more, the moisture increased significantly and reached to 37 % in the next ten days, due to the hygroscopic absorption phenomenon of bio-carrier. At the end of the first cycle, the average moisture fluctuated in the range of 20 - 25 %. The temperature and moisture of the materials could be stabilized by adjusting the air supply temperature or heating the walls of bioreactor.

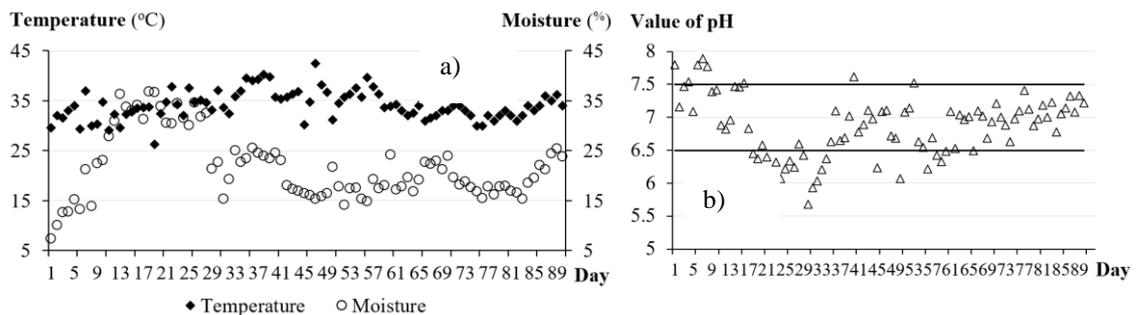


Figure 3. Variation of temperature and moisture value (a) and pH value (b) during the sludge stabilization process.

The pH value was rather high at the beginning due to the effect of pH value of cedar chip (pH of cedar chip was around 8). It was then reduced to a range of 5.5 - 6.5 at the end of the first monitoring cycle. In the subsequent periods, the pH tended to increase from 7 to 7.5, which was in the pH range for aerobic biochemical process. These results can be explained that at the first stage of the sludge stabilization process, the pH was acidic as a result of degradation of organic matter by the acid-forming bacteria, then it became alkaline due to ammonia formation, and finally it dropped back to near neutral as a result of humus formation with its pH-buffering capacity [17].

3.3. The sludge stabilization ability by MK-50

The results of evaluating technology efficiency through the reduction rate of sludge volume are shown in Figures 4 and 5. Figure 4 shows that, with the total amount of sludge added into the device in 30 days, 60 days and 90 days were 750 kg, 1,620 kg and 2,400 kg, the rate of volume reduction concerning to the evaluation times calculated at 84.6 %, 85.1 % and 83.5 %, respectively.

respectively. These values were higher than the values of 74.9 % for the sludge from WWTP and 83.3 % for food waste of a similar MK-50 experiment in Can Tho city in 2017 [19]. The degree of weight reduction depended on the ability of dewatering material before entering the device. The sludge moisture content of Hoa Xuan WWTP averaged at 81.4 %, was lower than that of the experiment in Can Tho, was at 88 %. Meanwhile, the sludge treatment efficiency of Mishimax technology for dewatering sludge at Syoubara city, Japan in 2016 was approximately 90 % [20].

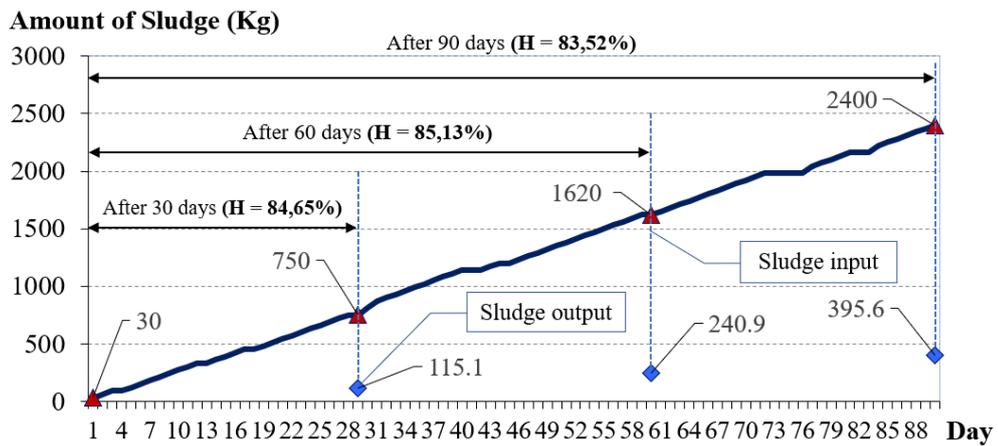


Figure 4. The reduction percentage of sludge weight.

Based on the operation data and the moisture value of the material at the end of our experiment (every one month) were 22,7%, 24,2% and 23,8%, the rate of sludge decomposition, calculated as dry matters, averaged at 12.1, 13.1 and 10.8 [g/(kg.day)], respectively. The average sludge stabilization efficiency was approximately 36 %. This value related to the high ash concentration of sludge (33.8 %) in the WWTP, therefore it is necessary to add more organic matters to the sludge for increasing the decomposition efficiency in the next experiments. With the average moisture of the input sludge was 81.4 %, the moisture of the output sludge was 23.8 %, and the evaporation efficiency reached above 95% because of blowing heated air at 50 °C during the experiment (Figure 5).

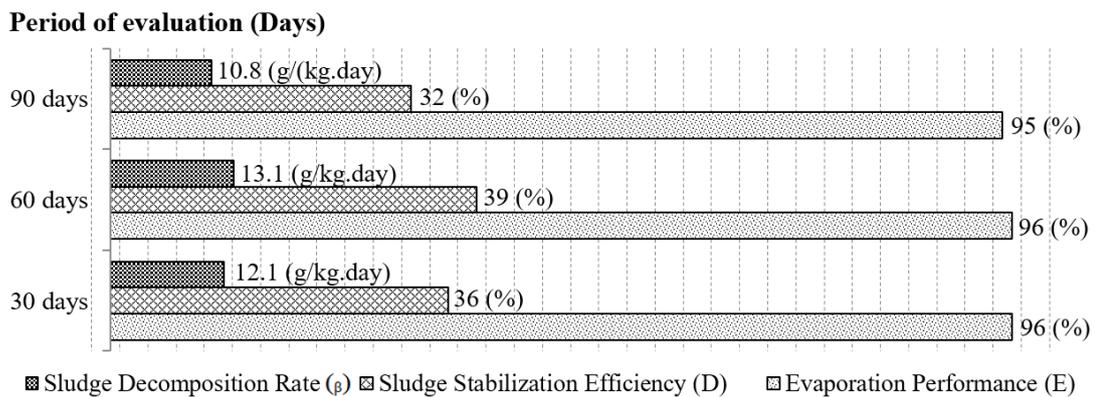


Figure 5. The stabilization rate of sludge.

3.4. The assessment of stabilized sludge quality

3.4.1. The parameters of stabilized sludge

According to the evaluation of senses, stabilized sludge had the brown-grey colour, the smell of pine wood. The percentage of humus particles after sifting 2 kg of products (Figure 6) to the size of 1 mm, 2.36 mm, 4.0 mm and 5.6 mm were 16.5 %, 14 %, 5.5 % and 2 %, respectively. The proportion of particles with a size of less than 1 mm reached 62 % and the fineness when crumpled by hand, met the standard of 10TCN 526:2020/BTN&PTNT. The cedar chips were screened and reused for the next experiment.



Figure 6. The process screening of sludge and cedar chips.

The results in Figure 7 show that the value of total organic carbon and total nitrogen of the stabilized sludge treated by MK-50 and some other kind of organic fertilizers met of the standard 526:2002/BNN&PTNT (22 % for TOC and 2.5 % for T-N), whereas the phosphate calculated as P₂O₅ of stabilized sludge was only 1.58 %, lower than the permitted value of 2.5 % of the standard when compared with the remaining fertilizers. The C/N ratios of all samples with the values of 8 - 10 were rather low.

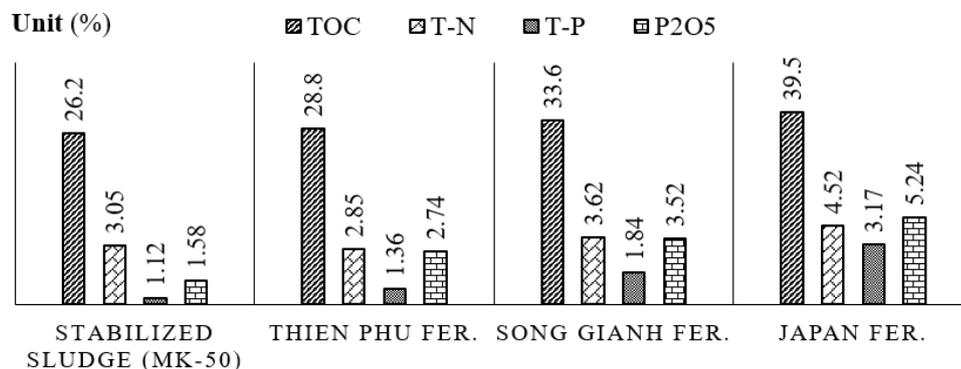


Figure 7. Result analysis of Nutrients.

For the hazardous compositions of the sludge from Hoa Xuan WWTP, the concentrations of heavy metals and other toxic substances met Vietnamese National Technical Regulation (QCVN 50:2013/BTNMT). It was an important condition for the input material of the experiments. For further in-depth research, the heavy metals and pathogen parameters need to be analyzed to assess the stabilized sludge for recycling as an organic fertilizer.

3.4.2. Experimental results on the tomato plant

After three months of cultivation, the growth of tomato plants was significant difference between the three models. Time for fruits of CC1, CC2 and CC0 was 2 months, 1.5 months, 2.5

months, respectively. In terms of colour, morphology of branches and leaves, the CC1 model showed hard stems, with the outstanding height of 130 cm, which was higher than the height of 20 cm of CC2 and 45 cm of CC0, leaves were larger and dark greener than the other two models. The tomato plants in CC1 model grown up and developed faster than two others, it meant that the stabilized sludge by MK-50 had a certain role during the growth cycle of tomato plant.

Based on the results of product quality assessment compared to the standard 10TCN 526:2002/BNN&PTNT and the test on the tomato growth showed that sludge after stabilization by MK-50 could provide some essential nutrients for the plant growth. However, if the product from sludge stabilization on MK-50 device is used as an organic fertilizer, it is necessary to add additional nutrients to balance the C/N ratio and some organic fertilizer components as well as to ensure that there are no heavy metals and pathogen according to the quality requirements of the Ministry of Agriculture and Rural Development regulations.

4. CONCLUSIONS

The deposited sludge at the landfill had been occupied a large land area, generated the leachate with high cost treatment and increased greenhouse gas emissions. The sludge treatment technologies in some WWTPs in Viet Nam to organic fertilizer were still limited in product quality and generated environmental problems.

The sludge decomposition approaches following Mishimax technology could reduce the volume of waste up to 90 %, without supplied effective microorganisms because of the cedar chips as a bio-carrier addition to decompose organics composition and increase the evaporation by heating. The total carbon and total nitrogen concentration of the product after stabilization by Mishimax model met 10TCN 526:2002/BNN&PTNT standard for organic fertilizer quality. Test on plant growth fertilized by the sludge stabilization products and compared to a market organic fertilizer under the same conditions of cultivation and monitoring showed that the stabilized sludge could supply nutrients for outstanding plant growth. This technological solution, although consuming more electricity power during the sludge stabilization process, it could reduce harmful bacteria due to high temperature of heated air supply. In addition, this technology (MK-50 model) could also control of odour generation during the sludge decomposition process. Some initial results for sludge treatment on stabilization efficiency and quality product using MK-50 model were significant. In the subsequent studies, the local bio-carriers such as wood chips of eucalyptus, acacia, nacre trees from tree pruning activities in urban areas will be tested to replace Japanese cedar chips. In addition, to prove the product after stabilization can be used as an organic fertilizer, the heavy metal and pathogen need to be tested carefully. Besides, the benefit-cost analysis needs also to be conducted to assess the suitability as well as the feasibility of applying Mishimax technology in practical conditions in Da Nang, Viet Nam.

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