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Original Research Paper

Composting of Sewage Sludge and Municipal Solid Waste

Farshad Golbabaei Kootenaei, Hasan Aminirad* and Maedeh Ramezani
Young Researchers and Elite Club, Islamic Azad University, Qaemshahr Branch, Iran
*Faculty of Civil Engineering, Babol Noshirvani University of Technology, Babol, Iran
Corresponding Author: Farshad Golbabaei Kootenaei

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ABSTRACT

Co-compost can be obtained by combination of sludge and municipal solid wastes which were used in the agricultural lands and solve municipal waste and wastewater treatment plant problems. The goal of the study was to investigate a methodology for settling optimum conditions such as aeration rate, temperature, moisture content, C/N ratio and size of particle in composting process. Two pilots were prepared and in every pilot different combination of municipal waste, sludge and wood pulp were used. Particle size of blend and aeration rate was the differences between two pilots. The results showed that the pH of compost pile was about 10 at the beginning of process and decreased to 7.25 gradually after 7 days. The proper size of particle was between 10-40 mm. The suitable C/N ratio was between 25 to 35 and it was about 33 in this experiment. Higher temperatures caused increasing microbial activity at the beginning of process. To homogenize the temperature, it is vital to make an agitation of the compost pile every 4-6 days. Increase in co-compost temperature happened when the moisture content was between 50 and 60%. Aeration with three times of required air has given the best result. Finally, we found that the moisture content has a greater effect on the microbial activity than the temperature. These results support the use of co-composting process with make-up particle size and moisture capabilities in preference to forced aeration enclosed reactors.

INTRODUCTION

More production and consequently more consumption is one of the specifications of novel world. Composting is a natural process by which microorganisms decompose organic matter into simpler nutrients. As the quickest way to produce high quality compost, aerobic composting is a widely accepted way of stabilizing organic wastes and converting them to a usable, and value added compost product. Modern wastewater treatment plants use a combination of biological, physical and chemical processes to treat wastewaters. A by-product of this treatment is biosolids, the dewatered sludge generated during primary, secondary or advanced treatment of municipal wastewater (Doubleta et al. 2010).

Sludge refining is more sensitive and taking cost than others sections in the wastewater treatment plants (Doubleta et al. 2010). For example, 30% of total expenditure for manufacturing of wastewater treatments plants is allocated to sludge stabilization unit (Eghball & Barbarick 2007, Asadi et al. 2012). Many researches have carried out work for selection of suitable pattern of sludge stabilization in some developing countries, and it should be considered by Iranian researchers too. Co-compost should be provided and used in the suitable and sanitary situation, because the municipal waste has incongruous component and all of its components do not have ability to decompose and generate compost. Also, if some of the components of the garbage would have been mixed in soil, the quality of soil would have been decreased and it was infected with pathogens. These pathogens could have been created several diseases in animal and human beings too. Also the sludge contains high content of heavy metals that could decrease the quality of sludge (Alten & Edrin 2005). One of the effective ways to neutralize unfavourable effects of wastes and sludge is conversion of these materials to compost and reusing them as organic fertilizer for agriculture (Kulikowska & Klimiuk 2010, Pandebesie & Rayuanti 2013). Raj & Antil (2012) carried out 150 days of research work on production of compost from farm waste with agro-industrial wastes. Their results suggest that neutral pH and a decrease in bacterial counts may be accepted as an indicator of compost maturity. Menaa et al. (2003) have done a research on bioremediation of sewage sludge by composting. In their work, a sewage sludge mixed with wood shaving as bulking agent has been composted. During the process, a decrease of organic matter fractions due to organic matter mineralization was observed. Fresh sewage sludge contained high number of pathogenic microorganisms but when this material was submitted to composting process, microorganisms decreased to suitable level (Menaa et al. 2003). Zorpasa et al. (2000) have done a research on composting municipal solid waste, primary stabilized sewage sludge and natural zeolite (clinoptilolite). The final results indicated that the composted material produced from clinoptilolite 20% and 80% sludge and MSW (60% and 40%, respectively) provided better soil conditioning compared to the compost produced from sludge. Also, the heavy metal concentration in the final products was in lower concentration than in the sewage sludge compost (Zorpasa et al. 2000).

Therefore, the goal of our research is to evaluate the relationships between temperature, moisture content and microbial activity during biosolids composting, and quantify the effect of temperature and moisture content on microbial activity of a specific blend used in composting. Quantifying these relationships will lead to a new insight toward better control of commercial biosolids composting. In many of the researches that were done before, one or two factors were observed during the experiments but in the present work, three factors i.e., pH, moisture and temperature were investigated during the composting.

The scientific contributions of this paper are: obtaining the optimum temperature for composting, obtaining the optimum moisture content for compost and determination of the best conditions for a compost maturing.

MATERIALS AND METHODS

In this research, the sludge, produced from Yasreb wastewater treatment plant in Qaemshahr, was used. Also the municipal solid waste (MSW) was obtained from Anjelsi landfill in Babol. The particle size of MSW was 0-40 mm. The experiments were done in two stages in the different seasons. In the winter season, first stage was done by using municipal waste particles less than 10 mm and initial moisture about 78% without agitation and also different aeration rates.

In this research, the vertical plexiglass reactor with 20cm in diameter and 100cm in length has been used. In order to aerate the reactor, a vacuum engine with maximum aeration power of 66 L/min was used and it was installed in bottom part of reactor. Likewise, for circulation of air through co-compost was used from wooden bulking agent of 5×5 cm in dimensions. To maintain and control temperature in compost process, body reactor was covered by glass wool.

Initial compost mixture was made from dehydrated sludge of wastewater treatment plant after secondary sedimentation, municipal solid waste and bulking agent. To attain optimum ratio, several samples were tested. The wood particles (5×5 in dimensions) were applied as bulking agent due to high moisture content and small dimensions of inlet materials (Doubleta et al. 2011).

After sampling, the samples were kept in cool conditions

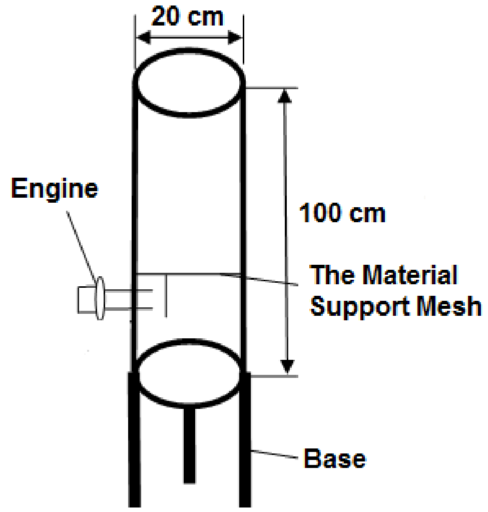

Fig. 1: Schematics of vertical pilot for co-composting.

until the experiment was performed. The experiments were done to measure some quality properties such as dry solids, organic materials, C/N ratio and pH. The percentage of total solids (TS) in sludge was evaluated between 1 and 2%. Before loading, the sludge should be concentrated and dehydrated to achieve 30% concentrated solids. In first stage, the sludge was placed in plastic container for several hours and then separated into two separable phases: water and dense solids phases, as the solids density in sludge reached to 2-3%. In next stage, these materials were scattered over a plastic on the ground under the sun until the materials were concentrated to 25-35%. To produce reliable compost at minimum time, the composting process has been monitored by sampling at suitable time to measure and adjust of index factors of process such as temperature, moisture content and pH.

Monitoring of process was accomplished via sampling and determination of content of index factors. Sampling was performed every 2 days manually. To determine the temperature and moisture content, the samples were provided from the middle and above of the pile. One sample was provided from this mixture to determine the pH.

Determination of organic matter and carbon: The mixture ratio should be chosen as it enables to modify characteristics of process such as stability, porosity, moisture content and C/N ratio. Therefore, the optimum C/N ratio to produce compost is 25:1 to 35:1 (Raja & Antil 2012, Srinivasan & Vijayalakshmi 2011).

In combustion method, 2 g of samples were weighed and dried in an air oven at 105°C for 24h (ASAE 2006). Then the dried sample was weighed to determine dry weight (A). The dried sample was burned in a furnace at 550°C.

After cooling in desiccator, it was weighed to measure the ash weight (B). The contents of organic matter and carbon were measured as follows (APHA 2005).

Organic Matter = [(A-B) × 100]/A ...(1)

Carbon = (Organic Matter)/1.8 ...(2)

Determination of nitrogen: The content of nitrogen was determined by Kjeldahl method using automatic Kjeldahl analyser (unit 2300). For determination of nitrogen content, 0.5 g samples were strewed into special experiment tube and then 10 mL of 0.1N H_2SO_4, a digestion pellet containing $CuSO_4$ or K_2SO_4 and some drops of octane normal as anti-scum were added. Digestion system has been turned on already and after placing the pipes inside the system, the temperature of furnace was raised up to 400°C till completion of digestion. After the digesting and cooling, some distilled water was added into each pipe and placed in titration section of automatic Kjeldahl analyser. The titration of samples was done for a few minutes and the total percentage of nitrogen was recorded on monitor (APHA 2005, Keshavarz et al. 2012).

Determination of moisture content, temperature and pH: After loading the compost pile to attain the optimum operation of process, the process was monitored by measuring of index factors such as pH, temperature and parentage of moisture content.

The moisture of sample removed from compost pile was measured using an oven drying method (Alten & Edrin 2005), in which 2 g of sample (A) was dried in a convection oven at 105°C for 24 hours and then dried sample was weighed (B). The moisture content of sample was measured by using the following formula (APHA 2005):

Moisture Content = [(A-B) × 100]/A ...(3)

For determination of pH, 10 g sample was weighed and strewed into an Erlenmeyer flask and then 100 mL of distilled water was added to it. The prepared sample was placed in auto-shaker for 30 min (APHA 2005). The pH of the sample was measured by using pH meter.

Measurement of temperature is one of the most obvious characteristics of progress of fermentation process. Three thermocouple sensors were used at the bottom, middle and the top surface of the compost pile to measure the bulk temperature. The values reported were the average of the material temperatures measured during the process in the three layers. Changes in the material temperature during drying were recorded using a data logger.

RESULTS AND DISCUSSION

Effect of the factors such as temperature, pH and moisture content in co-compost process was investigated in two stages.

First experiment: The C/N ratio in MSW and sludge was equal to 40:1 and 9:1, respectively. In this experiment, the combination of MSW to sludge was 3 to 1, and the C/N ratio was 33:1. The changes of index factors such as pH, temperature, moisture content and aeration quantity during the experiment are shown in Figs. 2, 3 and 4.

The variation in the pH over the co-composting time is illustrated in Fig. 2. The pH of compost pile was 9.63 in beginning of process and then decreased to 7.15 gradually.

In many studies, temperature has been shown to be a critical determinant of composting efficiency (Karak et al. 2013, Chai et al. 2013, Huang et al. 2004, Cronje et al. 2003). The variation of temperature for keeping time is represented in Fig. 3. It shows that by decrease in pH, the microbial activity was started simultaneously. We found that pH was apparently important factor impacting microbial activity in composting mixes due to increase in temperature.

Because of cold weather (8°C) increase in temperature was started from 6th day and reached to 50°C after 25 days. Many researchers reported that the temperature range for optimal composting is between 52°C and 60°C (Guerra-Rodríguez et al. 2001, Oudart et al. 2012). After this stage, the temperature is declined even though the aeration was stopped. In most cases, higher temperature induced an earlier initiation of increased microbial activity.

Lack of increase in compost temperature represents that the sludge does not have perfect stability in compost pile. This lack is correlated with covering of reactor and cold environment. Also the amount of materials and size of reactor have been affected the raising of temperature. Larger amount of materials and size of reactor produces high temperature.

Moisture content of the composting blend is an important environmental variable as it provides a medium for the transport of dissolved nutrients required for the physiological activities of microorganisms (Evans & Furlong 2012, Raj & Antil 2012).

The Fig. 4 shows the variation of moisture. It was indicated that the moisture has been decreased from the beginning (78%) till the end of process (48%). Due to production of emulsion, the reduction of moisture content was slightly higher during the first week and then the speed of moisture content reduction was decreased (Gigliotti et al. 2012).

Very low moisture content values would cause early dehydration during composting, which will arrest the biological process. On the other hand, high moisture may produce anaerobic conditions from water logging, which will pre-

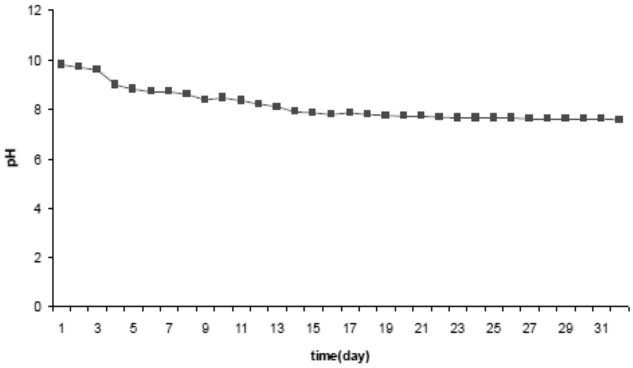

Fig. 2: Changing of pH values over time at first stage.

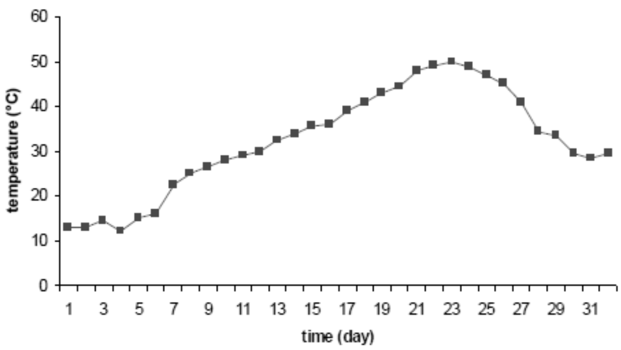

Fig. 3: Changing of temperature over time at first stage.

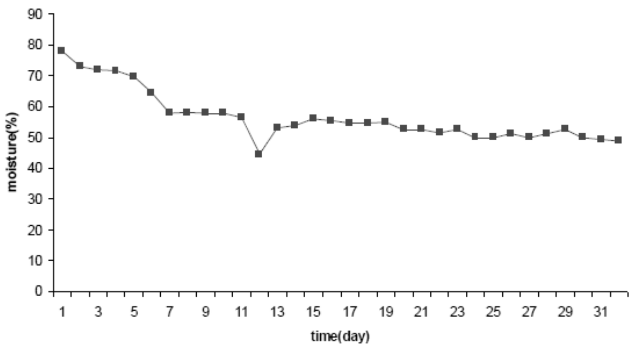

Fig. 4: Changing of moisture over time at first stage.

vent and halt the ongoing composting activities (Tang et al. 2003). The result shows that increase in compost temperature was occurred when the moisture content was between 50% and 60%. The results confirmed the obtained data by some earlier investigators (Tang et al. 2003, Kayikcioglu 2013, Liang et al. 2003) that 50% to 60% moisture content is suitable for effective composting.

Second experiment: Some parameters were changed to increase the fermentation efficiency in the second experiment such as the size of waste particles to simplify aeration, nonaeration in initial days and then increasing aeration rate.

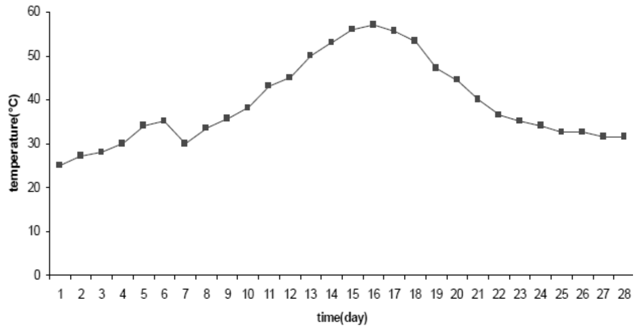

Fig. 5: Changing of temperature over time at second stage.

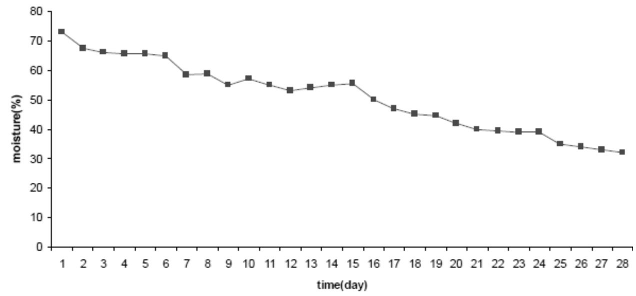

Fig. 6: Changing of moisture over time at second stage.

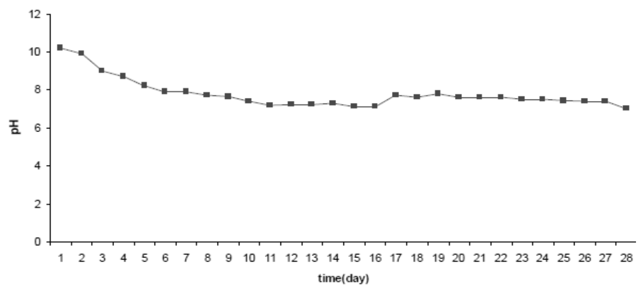

Fig. 7: Changing of pH values over time at second stage.

As shown in Fig. 5, increase in temperature rate was desirable. The compost temperature was decreased about 5°C after 7 days due to start of aeration. It is interesting to say that the compost temperature was kept at 55°C for 4 days.

As exhibited in Fig. 6, the amount of moisture has been declined (less than %33) by increasing aeration rate and it has also been shown to reduce the keeping time for 4 days. Decomposition of organic matter into simpler nutrients is natural process of microorganisms. Pathogens in compost have been related to all kinds of the microorganisms. Most of these pathogenic organisms prefer the temperature under

42°C. Some researchers suggested that upper temperature might be more suitable for composting (Kayikcioglu 2013, Liang et al. 2003).

In composting process, several items are effective on vital system of organisms such as temperature, emission of ammonia and duration of process (Ogunwande et al. 2008). Among of these parameters, high temperature in short time or low temperature in long time is much more important to destroy pathogens in the compost pile (Ahn et al. 2007, Tchobanoglous et al. 2009). Therefore, it could be concluded that the most of pathogenic factors present in compost pile would be destroyed due to suitable temperature due to which the final product will be devoid of any pathogen (Ahn et al. 2007).

Fig. 7 shows the pH of co-compost during the second experiment. It is clear that pH has a significant impact on composting performance (Yousefi et al. 2013). The pH of compost pile was about 10 in beginning of the process and decreased to 7.25 gradually after 7 days, and it was fixed during the experiment.

Measurement of the remaining organic matters: Stabilization in environment sanitation sciences is always synonymous with the oxidation of organic wastes and converting them into a usable, nonhazardous and value added materials. One of the measurement methods of stabilization degree is based on measuring of remaining organic materials during the process (Huang et al. 2004). Reduction of organic matters is depending on combination of materials and operation in composting process.

The organic matters can be stabilized in mature compost by measuring. Also by measuring the remaining organic matters in compost from a collection (batch), the degree of their stabilization can be compared together rapidly. The organic matters were 30% in the first stage whereas they decreased to 25.4% in the second stage. It is therefore concluded that the second stage compost is more matured (Gabhanea et al. 2012).

CONCLUSION

The goal of the study was to develop a methodology for determining optimum conditions such as temperature, moisture content and C/N ratio in composting process. The following results can be concluded. To increase the contact surface for attack of microorganisms, the particle size must be small. The materials smaller than 10 mm resulted in clod pile, which creates an impervious surface for passing the air for reducing moisture. Therefore, the microorganisms could not feed from nutrients in MSW. Therefore, the proper size of particles is between 10-40 mm.

The nitrogen is the main necessary nutrient for microorganisms. The suitable C/N ratio was about 25-35. By consideration of moisture importance for microorganisms, the suitable moisture content was 50-60% for effective composting. The aeration can decline the compost moisture. Aeration with three times of required air has given the best result. To homogenize and balancing the temperature, it is necessary to make an agitating of the compost pile every 4-6 days.

The results showed that the pH of compost pile was about 10 at the beginning of the process and decreased to 7.25 gradually after 7 days. The proper size of particle was 10-40 mm. The suitable C/N ratio was 25 to 35 and it was about 33 in this experiment. Higher temperature caused increasing microbial activity at the beginning of the process. Increasing in co-compost temperature was happened when the moisture content was between 50 to 60%.

Finally, there is closed relationship between moisture content and temperature but the moisture content has a greater influence on the microbial activity of biosolids blends than does the temperature. These results support the use of co-composting process with make-up particle size and moisture capabilities in preference to forced aerated enclosed reactors. Further work is required to validate these results in full-scale operations and different combinations.

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