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DESIGN AND CONSTRUCTION OF A PILOT SCALE AERATED STATIC PILE COMPOSTING SYSTEMS

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Abstract

The amount of agricultural and industrial wastes is increasing due to increase in industrial and agricultural activities in the world. Therefore, sustainable management of wastes, which is a major challenge being faced by both agricultural and industrial sectors in the world, is required. Composting, which is one of the valorization methods used to accelerate decomposition and stabilization of organic wastes, is well known and getting widespread. This study covers design and instrumentation of a pilot scale aerated static pile composting systems based on engineering principles. With this system, basic scientific data (decomposition rates of composting materials, optimum temperature and moisture values) which are required for construction of large-scale composting facilities and operation of composting process will be obtained. The system consists of (1) aeration system, (2) control, data acquisition and recording unit, and (3) measurement system (temperature, instant CO_2/O_2 concentrations, airflow, and energy consumption by aeration). In this study, each components of this system will be introduced. This study has been conducted under the program of 1007 of the scientific and technological research council of Turkey.

Key words: *aerated static pile composting, composting, instrumentation.*

INTRODUCTION

Sustainable management of wastes is a major challenge for the environment. Composting is one of the most important valorization methods for agricultural waste materials. Several studies have demonstrated that composting could be a suitable low-cost strategy for the recycling of wastes (Keener et al., 2014). Composting is a decomposition of organic materials and a process of which physical, chemical, and biological factors interact simultaneously. At the end of composting process, the new and economic products (humus like materials) are produced (Keener et al., 2000). Compost is used in open fields, orchards, vineyards, urban landscapes, and nursery to improve soil fertility, to increase water holding capacity of soils, and to prepare potting mixes. Composting technology step forward in Turkey among the waste utilization and disposal methods (incineration, land filling etc.,) due to low organic matter content in agricultural soil, erosion control, the need for land rehabilitation in agricultural areas, and wide lands to be forested. Aerated static pile composting method is widespread in the world. Aerated static pile composting is performed with air blower. The process can be controlled directly using blowers and larger piles can be created. The bulk material is not returned or not mixed form. In general terms, the composting process with aerated static pile method is faster and results in higher quality composts (Stentiford, 1996). Keener et al. (1993) noted "optimization of a design, whether based on cost of construction and operation, energy use (conservation of resources) or pollution levels (odors, dust, etc.) can be done through field experimentation. Field experimentation implies collection of basic information for real working systems (pilot or full scale) and evaluation of the results. Evaluation of how system design and management affects time to reach compost stability is critical to optimizing the process. Therefore, this study focused on design and construction of a pilot scale aerated static pile composting systems for field experimentation of composting process.

MATERIALS, METHODS, RESULTS AND DISCUSSIONS

Pilot scale aerated static pile composting system

The pilot scale aerated static pile composting systems with the annual processing capacity of

10 tons of compost was designed and constructed. The system was designed for various agricultural and industrial wastes. Aeration and automation systems allow the management of composting process for both unified and individual piles (triangular, trapezoidal etc.). Figure 1 is the picture of the pilot scale aerated static pile composting systems. Figure 2 shows the layout for four individual triangular composting piles. Composting pad housed in closed structure has a total area of 108 m^2 (9 m x12 m) concrete floor with effective area of 48 m^2. Closed structure protects compost pile in the active phase from the sun and rainfall.

The pilot scale aerated static pile composting system has three main parts: (1) Aeration system, (2) Control, data acquisition and recording unit, and (3) Measurement system.

Figure 1. The pilot scale aerated static pile composting systems

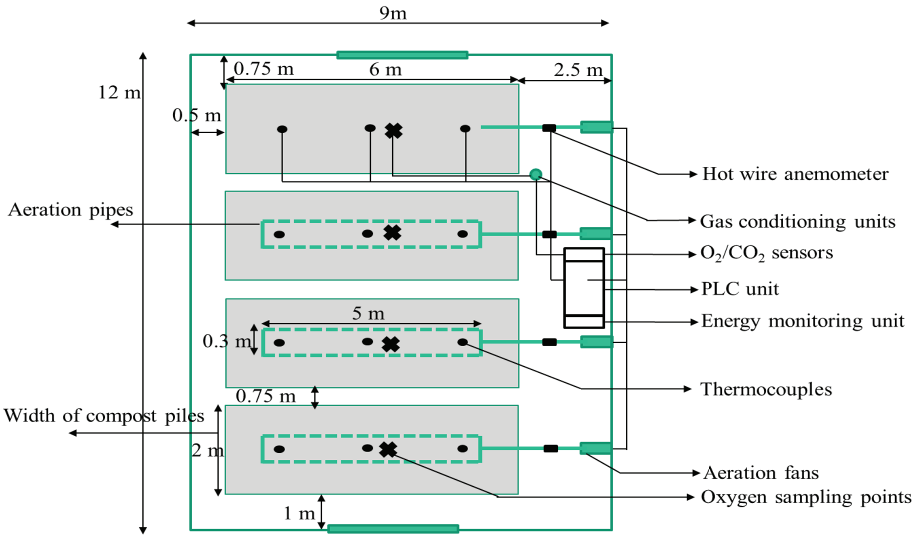

Figure 2. Layout for four individual triangular aerated static pile composting piles

Aeration system

The system was designed to apply for the two different aerated static pile methods. Firstly, four independent compost piles with 6m of length, 2 m of width and 1.5 m height can be formed. In the combined aerated static pile method, the piles form a single volume. In this system, 10 m long, 6 m wide and 1.50 m high trapezoidal pile can be formed. Combined aerated static pile composting method can contain 2.5 times more material than other system. Free air space (FAS) and the bulk density of raw materials are determining factor for selection of methods. The aeration fan and the air distribution units to be used in both methods is the same. Aeration fans, each with a 0.5 horsepower electric motor and an air capacity of 1000 m^3/h supply air to the compost piles. 50 mm PVC pipes for distributing air were installed under the piles. The schematic layout and appearance of the ventilating pipes are provided in Figure 3. PVC pipes for delivery of air into the piles effectively are configured to form a closed circuit. Each of the holes opened on the pipe has a diameter of 8 mm at 20 cm intervals. Ventilation pipes laid on the bale of straw are coated by greenhouse covering material with 50% openings.

The composting process control is performed through Rutgers aeration strategy based on temperature feedback control of the aeration fan. Aeration system consists of aeration fans, fan speed drives, programmable logic controller (PLC), and sensors (thermocouple and hot wire anemometers). Temperature is the controlled system variable and air flow is the manipulated variable. If the compost temperature is lower or equal to the temperature set point (T_{sp}), aeration fans supply minimum aeration rate (Q_{min}) to meet the oxygen needs with the predetermined on-off mode.

Figure 3. Aeration system

If the compost temperature is higher than T_{sp}, aeration fans maintain higher airflow rate (Q_{max}) for evaporative cooling of compost bed to lower compost temperature to T_{sp} or lower point. Compost temperature control at a certain temperature tolerance is executed (Figure 4). Additionally, airflow control is performed during composting process when the temperature is below or equal to Tsp. Fans of airflow control is executed through air velocity (hotwire anemometer) feedback (Figure 5). Speed drives are connected to the aeration fan. Checking the set airflow, frequency of electric motor of fans is reduced or increased through speed drives.

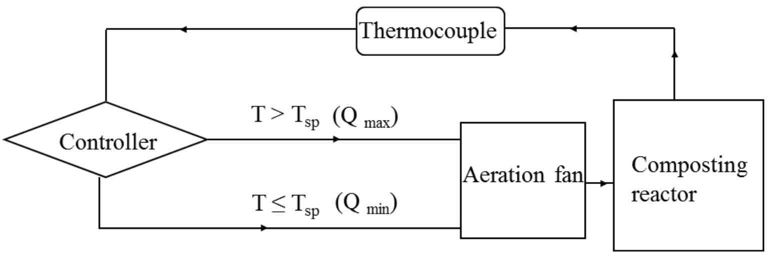

Figure 4. Rutgers aeration strategy based on temperature feedback control of the aeration fan

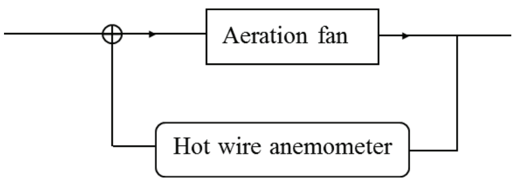

Figure 5. Airflow control

Control, data acquisition and recording unit
Monitoring and control of composting process are performed by PC and PLC-based process control device (Figure 6). In this system, Visual Basic^{TM} program was written for temperature feedback control of aeration fans. ADC and TC modules of PLC were used. Signals received from the sensors are preceded by PLC and connection between PLC and PC software is executed by RS 482. The encoded data from the PLC transmitted to PC thereby utilizing measurement and control purposes. Data evaluated by PC software is sent back to the PLC for controlling of the aeration (Figure 6a). Software interface includes temperatures, O_2/CO_2 concentrations, airflow, electric motor frequency, and velocity (Figure 6b). Proportional-Derivative control is applied when compost temperature is above T_{sp}.

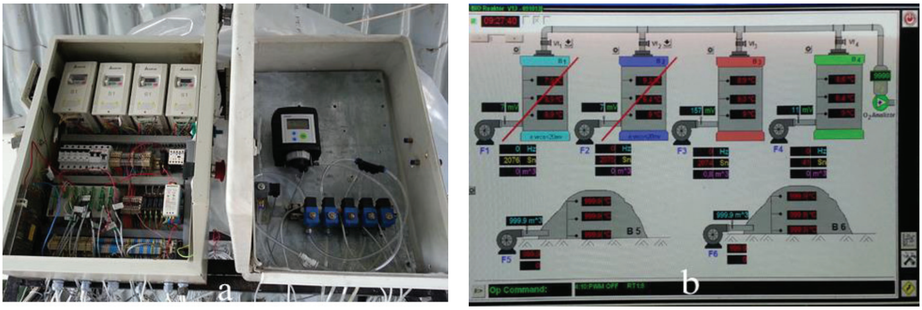

Figure 6. Control, data acquisition and recording unit

Measurement system
Measurement system consists of (1) temperature, (2) instant O_2/CO_2 concentrations, (3) air flow measurement, and (4) energy consumption by aeration.
Temperature: K-type thermocouple is used to determine compost temperature (Figure 7). The signal produced by the thermocouples is detected by TC module in PLC. TC module brings low output to the range of 0-10 volts. There is a linear correlation between temperature and analog output. Measured temperature value can be recorded and used in temperature feedback control of aeration fans.
Thermocouples are inserted into front, central and end of each at the height of middle point of piles. The temperature feedback control of aeration fans can be conducted individual or the average of two or three thermocouples.

Figure 7. Measurement system

Instant O_2/CO_2 concentrations: It is necessary to provide the required oxygen concentration to piles for aerobic decomposition. Monitoring the concentration of CO_2 provides information on the activities of microorganisms. Gas sampling unit allows the monitoring O_2/CO_2 concentrations independently (Figure 7 and Figure 8). This unit consists of dehumidifying containers, O_2/CO_2 sensors, four normally closed solenoid valves, one normally open solenoid valve, transparent pipes with the diameter of 5 mm, five relays, and PLC digital output module for control of relays.

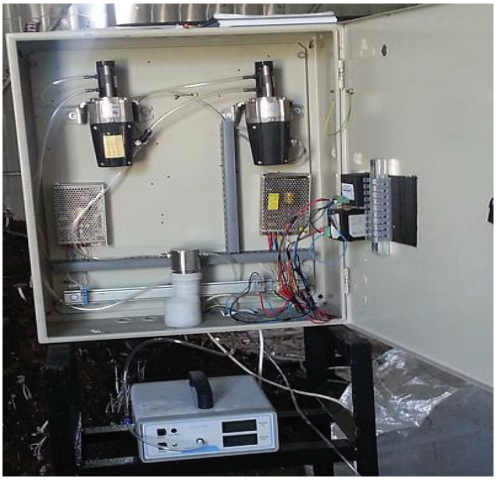

Figure 8. Gas measuring unit

Air flow measurement: Airflow is supplied by fans (m^3/h) adjusting the frequency of electric motors through chopper speed drives. The air entering the piles to be at the desired level must be measured. Hot wire anemometers have been used for this purpose. In this system, airflow rate is obtained by multiplying the measured flow velocity (m/s) of the anemometer by the pipe cross sectional area (m^2). Hot wire anemometers have working ranges of 0-5, 0-10 and 0-15 m/s depending of composting operations. PC software runs the aeration fans at predefined set point. If the temperature is above the T_{sp}, airflow rate is increased gradually (0.1 Hz).

Energy consumption by aeration: Energy consumption (kWh) by aeration fans is measured by electric meter counter (Figure 10) connected to PLC. Data obtained from energy consumption aeration fans is expected be used in economic analysis of composting operations.

Figure 9. Airflow measurement unit

Figure 10. Electric meter counter to determine energy consumption by aeration fans

CONCLUSIONS

The design and construction of a pilot scale aerated static pile composting systems built in Suleyman Demirel University, Faculty of Agriculture, Agricultural Machinery and Technologies Engineering Department under the program of 1007 - Public Institutions Research Funding Program (KAMAG) of the Scientific and Technological Research Council of Turkey (TÜBİTAK) was presented. Exploration of factors affecting the composting process or experiencing the problems during the composting process in field experiment-tation and transferring this knowledge to industry will be performed in the future.

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REFERENCES

Keener, H.M., Dick, W.A., Hoitink, H.A.J., 2000. Composting and beneficial utilization of composted by-product materials. In: Power, J.F., Dick, W.A., Kashmanian, R.M., Sims, J.T., Wright, R. J., Dawson, M. D., Bezdicek, D. (eds.), Beneficial Uses of Agricultural, Industrial and Municipal By-products. Soil Science Society of America. Madison, Wisconsin, 315-341.

Keener, H.M., M., Wicks, F.C. Michel, and Ekinci, K, 2014. Composting broiler litter. World's Poultry Science Journal, 70, 709-719.

Keener, H.M., Marugg, C., Hansen, R.C., Hoitink, H.A.J., 1993. Optimizing the efficiency of the composting process. In: Hoitink, H.A.J., Keener, H.M. (eds.), Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects. Renaissance Publications, Ohio, 59-94.

Stentiford, E.I., 1996. Composting control: principles and practice. In: De Bertoldi, M., Sequi, P., Lemmes, B., Papi, T. (Eds), The Science of Composting. Blackie Academic & Professional, London, pp. 49-59.