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Research Paper

Evaluation of Water Hyacinth Compost Stability Using Respirometric Techniques

Das Ayan , Kalamdhad Ajay S.*
Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati, INDIA

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Abstract - *Composting is one of the alternative methods to convert water hyacinth into useful product. Because of its decomposed structure it easily transforms into stable compost. Stability is an important compost quality characteristic, but also one that is difficult to measure. Simple respirometric techniques i.e. CO_2 evolution and oxygen uptake rate (OUR) for the assessment of compost stability were performed for six waste combinations (trial 1, 2, 3, 4, 5 and 6) of water hyacinth, cattle manure, rice straw and sawdust in the agitated piles. Trial 3 achieved higher temperature (59.4°C) and entered into thermophilic phase after 1 day. Consequently, trial 3 and 4 showed higher loss of organic matter and lower final OUR and CO_2 evolution, considered as very mature compost.*

Keywords: Water hyacinth, Stability, CO_2 evolution, Oxygen uptake rate etc.

Introduction

The water hyacinth (Eichhornia crassipes) is the most important noxious fresh-water plants. Its rate of proliferation under optimum conditions is extremely rapid and it can spread to cause infestations over large areas of water causing a variety of problems. Its excessive growth affects the utilization of water resources by: (1) fouling drinking water with its exudates or decomposition products; (2) obstructing navigation (3) interfering with the production of rice and other agricultural crops; (4) killing fish by depletion of oxygen in the water (5) habitat of variety of harmful animals. Water hyacinth also has advantages in many ways. It functions as a food source for aquatic bio-phages, water currents controls, purifies turbid water through sedimentation and sorption, and reduces pollutants through absorption of minerals [1]. Composting as an alternative treatment has the advantage of producing a product that is easy to work into the soil compared with dried water hyacinths, because of the decomposed structure. Composting is a biooxidative process in which the microorganisms transform the more easily biodegradable organic matter into carbon dioxide (CO_2), water vapors (H_2O), and other minerals (mineralization process) or, with time, into more stable organic matter (humification process) called humic substances which are structurally very similar to those present in soils. The composting process should be followed by a maturation process in order to obtain a product with stable organic matter whose incorporation into soil will increase its "humus" content and avoid the risks derived from the use of raw composts on agricultural land. Therefore, it is essential to check the compost stability before its use as it is important for product brewer quality assessment, and to avoid its adverse effects on the plants and soil media.

Compost stability can be defined as the extent to which readily biodegradable material has decomposed [2]. Compost is considered unstable if it contains a high proportion of biodegradable matter that may sustain high microbial activity. If the material contains mainly recalcitrant or humus-like matter, it is not able to sustain microbial activity and therefore, it is considered stable. Compost stability is an important aspect of compost quality in terms of compost nuisance potential, nitrogen immobilization leaching and phytotoxicity. If insufficiently stabilized compost is applied to land, it can create anaerobic conditions in the rhyzosphere or induce phytotoxicity, mainly caused by organic acids present during the early stages of composting process [3, 4].

Different methods for evaluating the stability of compost are based on physical (pile temperature, aeration demand, odor and color, optical density of water extracts), chemical (volatile solids, C/N ratio, COD, polysaccharides, humic substances, etc.) and biological (respiration measured either as O_2 consumption, CO_2 production or heat generation, enzyme activities, ATP content, seed germination and plant growth, etc.). Characteristics of composts have been proposed, but none has found universal acceptance [5]. Current thought is that respirometric techniques are well suited for compost stability measurement. Simple respirometric techniques for the assessment of compost stability are CO_2 evolution rate by trapping CO_2 in the known weight of oven dried (105°C) soda lime and oxygen uptake rate (OUR) that utilizes a dissolved oxygen probe to measure changes in the oxygen concentration in an aqueous compost extract, under conditions ensuring optimum microbial activity and maximum reaction rates. Numerous studies have been carried out on stability of compost using either physico-chemical and/or biological methods [5, 6, 7, 8, 9]. But the above mentioned studies generally dealt with the different technologies of composting (windrows, static piles and rotary drum) of various types of municipal solid wastes. However, information on stability of compost in a windrow or agitated pile for water hyacinth mixed with cattle manure and rice straw/saw dust is rather limited.

Therefore, in order to understand the compost stability of high rate agitated pile composting, long term studies are required under different waste combinations. The aim of this study is to investigate the evaluation of stability parameters i.e. oxygen uptake rate (OUR) and CO_2 evolution during high rate pile composting of water hyacinth in various combinations with cattle manure, saw dust and rice-straw.

Material and Methods

Feedstock materials

Water hyacinth, cattle (cow) manure, saw dust and rice straw/husk were used for preparation of different waste mixtures. Water hyacinth was collected from the lakes situated in the Indian Institute of Technology Guwahati campus. Cattle manure was obtained from dairy farm near the campus. Rice straw and saw dust were purchased from farmers of nearby village and from nearby saw mill, respectively. Prior to composting, the maximum particle size in the mixed waste was restricted to 1 cm in order to provide better aeration and moisture control. The compost was prepared with six different proportioning of water hyacinth, cattle manure, saw dust and rice straw and initial characterizations are detailed in Table 1.

Agitated pile composting

Six different waste combinations were formed into trapezoidal piles (length 2100 mm, base width 350 mm, top width 100 mm and height 250 mm, having length to base width (L/W) ratio of 6. Agitated piles contained approximately 100 kg of different waste combinations and were manually turned on 3, 6, 9, 12, 15, 18, 21, 24, 27 and 30 days. Composting period of total 30 days was decided for agitated pile composting. The samples from the piles were collected after mixing the whole pile thoroughly by hand; when the piles was made (0 day); piles were turned. Homogenized sample was collected from five different locations within the piles.

Experimental analysis

Temperature was monitored using a digital thermometer throughout the composting period. About 100 g of each grab samples were collected from five different points, mostly at the mid span and ends of the pile by compost sampler without disturbing the adjacent materials. Finally all the grab samples were mixed thoroughly to make a homogenized sample. Triplicate samples were collected and stored at 4^{o}C for subsequent analysis. Each sample was analyzed for the following parameters: moisture content (105^{o}C for 24 h), volatile solids (VS; 550^{o}C for 2 h, previously oven-dried at 105^{o}C), CO_2 evolution rate and oxygen uptake rate (OUR).

The oxygen uptake rate (OUR) was performed according to the method described by Lasaridi and Stentiford [5]. The OUR was measured on a liquid suspension of compost (8 g of compost in 500 mL of distilled water added with 5 mL each of the $CaCl_2$, $MgSO_4$ and $FeCl_3$ nutrient solutions and 15 mL of phosphate buffer at pH 7.2, made up according to the standard methods BOD test procedures incubated at room temperature (24±2^{o}C). The DO probe was placed in the sample bottle, its sensor being at a depth of 5-7 cm below the water surface [10]. The suspension was continuously stirred by means of a magnetic stirrer. The O_2 concentration was measured continuously and this value quoted as the OUR in mg/g volatile solids (VS)/day.

Microbial respiration of compost samples based on CO_2 evolution was measured using static measurement method [9]. Approximately, 10 g of sample was sealed in a 0.5 L vessel along with a beaker containing a known weight of oven dried (105^{o}C) soda lime (1.5-2.0 mesh). The samples were incubated at room temperature (24±2^{o}C). Soda lime trap were removed after 24 h, oven dried and reweighed to determine CO_2 absorbed.

All the results reported are the means of three replicates. Repeated measures treated with analysis of variance (ANOVA) were made using Statistica software. The objective of the statistical analysis was to determine any significant differences among the parameters analyzed for different trials.

Results and Discussion

Initial characterization indicated higher moisture content in water hyacinth and cattle manure compared to saw dust and rice straw (Table 1). However, composting process required 40-70% of initial moisture content for proper microbial growth for degradation [11]. Due to higher moisture content in water hyacinth and cattle manure, some amount of saw dust or rice straw is required to maintain the optimize moisture content. The non-volatile inorganic matter of a compound remains same after subjecting it to a high decomposition temperature (550^{o}C). The experiment shows that water hyacinth has less volatile matter content as compared to others (Table 1).

Temperature

During composting the temperature determines the rate at which many of the biological processes take place and plays a selective role on evolution and succession on the microbial communities [12]. The variation in temperature of composting materials with time is illustrated in Fig. 1. Trial 3 and 5 achieved higher temperature (59.4 and 57.3^{o}C, respectively and entered into thermophilic phase after 1 day indicating quick establishment of microbial activities in the pile. Rapid rises in temperature at the beginning of composting was attributed to higher content of easily biodegradable carbon. Afterwards cooling period was observed until the end of the composting process. The combination of water hyacinth, cattle manure and rice straw/saw dust in trial 3 and 5 provided favorable conditions for microbial growth, resulting higher rise in temperature. Trial 2, 4 and 6 reached up to 51.7, 56.1 and 50.8^oC respectively, due to high amount of water hyacinth as compared to cattle manure, which did not provide favorable conditions for growth and biological activity of microorganisms. There was no increase in temperature during trial 1 due to non-availability of carbonaceous materials and easily biodegradable carbon i.e. cattle manure and rice straw/saw dust. On analysing the results by ANOVA, the temperature varied significantly among all six waste mixtures ($P < 0.0001$).Figure 1

Volatile solids (Organic matter)

During the composting process, carbon dioxide is emitted from the composting mass as one of the metabolic end product. Thus, the total carbon content of the composting mass decreases as composting proceeds [13]. After maturation, it could be possible that most of the organic matter is in the form of stable humic substances. Fig. 2 shows the trend of organic matter degradation during six different combinations of water hyacinth, cattle manure and rice straw/saw dust. The content of organic matter decreased as the decomposition progressed. The organic matter decreased significantly between the six waste mixtures ($P < 0.0001$). Trial 3 showed higher loss of organic matter (37.2%) as a result of higher temperature evaluation compared to trial 2 (16.5%), trial 4 (28.4%), trial 5 (26.6%) and trial 6 (12.7%). Poor decomposition was observed during trial 1 (3.8%). Figure 2.

CO_2 evolution rate

Respirometric techniques are widely used as stability indicators and seem well suited for this purpose. Insufficiently stable compost has a strong demand for O_2 and a high CO_2 production rate as a consequence of the abundance of the easily biodegradable compounds in the raw material, resulting in high rates of microbial activity. For this reason, O_2 consumption or CO_2 production are indicators of compost stability [14].

CO_2 evolution is the most direct technique of compost stability because it measures carbon derived directly from the compost. Thus, CO_2 evolution directly correlates to aerobic respiration, the truest measure of respiration and hence aerobic biological activity [9]. In general, the CO_2 evolution rate has been used as an index representing microbial activity, because CO_2 is a by-product of organic compound. The rate of CO_2 evolution during maturation decreased. Early in the initial phases of maturation, all of the piles showed a high respiration rate due to the intensed mineralization of organic matter. The CO_2 evolution rates of trial 1, 2, 3, 4, 5 and 6 decreased from initial values of 15.18, 19.04, 18.36, 16.04, 21.5 and 21.51 mg/g VS/day to 4.9, 2.39, 0.39, 0.37, 1.22 and 1.38 mg/g VS/day respectively (Fig. 3). Decrease of CO_2 contents was observed to be significant ($P < 0.0001$) in all trials which were most probably due to the thermal inhibition of microbial activities and the readily soluble nutrients [15]. Results indicated rapid decrease of CO_2 values in trial 3 and 4 as compared to other trials; therefore, trial 3 and 4 became more stable. Figure 3

Oxygen uptake rate (OUR)

Oxygen uptake rate is the most accepted method for the determination of biological activity of a material. The OUR test measures compost stability by evaluating the amount of readily degradable organic matter still present in the sample, through its carbonaceous oxygen demand [5]. Higher respiration rates were observed in the beginning of the composting in all trials especially in trial 5 and 6. Similarly, Iannotti et al. [6] found OUR to be high in raw material, as microbes grow rapidly. As composting begins, large organic molecules are broken down to smaller, soluble ones and temporarily more substrate may become available. In all trials, decrease was observed after 30 day of composting periods. The OUR of trial 1, 2, 3, 4, 5 and 6 decreased from initial values of 17.74, 24.61, 20.96, 18.22, 26.01 and 25.61 mg/g VS/day to 6.65, 3.79, 0.54, 0.58, 1.82 and 1.84 mg/g VS/day respectively (Fig. 4). Decreases of OUR values were 62.5, 84.6, 97.4, 96.8, 92.9 and 92.8% for trial 1, 2, 3, 4, 5 and 6 respectively. Results indicated more decrease of OUR values in trial 3 and 4 than trial 1, 2 and 5 and 6. Therefore, trial 3 and 4 become more stable than other trials. The OUR dropped steadily after the initial sharp decrease in all trials, while after 1 week of composting the drop is moderate indicating that the compost is approaching the maturation period. The decrease in OUR between the six trials varied significantly ($P < 0.0001$).

Linear regression models were generated for the correlation between O_2 consumption rate and CO_2 evolution. In this regards R^2 values obtained for trial 1, 2, 3, 4, 5 and 6 are 0.99, 0.98, 0.99, 0.95, 0.99 and 0.98, respectively. However, the results obtained for all trials revealed better degree of oxidation of organic carbon. Figure 4

Conclusion

Compost stability studies carried out in pile compost for different composition with water hyacinth. Trial 3 showed higher loss of organic matter as a result of higher temperature evaluation compared to other trials. The variation in OUR and CO_2 concentration during the active phase follows a similar trend to that of the temperature measurements, with maximum OUR and CO_2 concentrations being recorded during the first 5 days and a steady decrease thereafter in all six trials. Lower percentage reduction in OUR and CO_2 evolution rate was observed during trial 1 and 2 which indicated the significance of cattle manure mixed with water hyacinth. Surprisingly, there was no increase in temperature during trial 1 which may be due to non-availability of carbonaceous materials and easily biodegradable carbon i.e. cattle manure and rice straw/saw dust. This study revealed that trial 3 and 4 having lower final OUR and CO_2 evolution, could be considered as the much matured compost. The study also observed that rice straw and cattle manure is good bulking agent for composting of water hyacinth.

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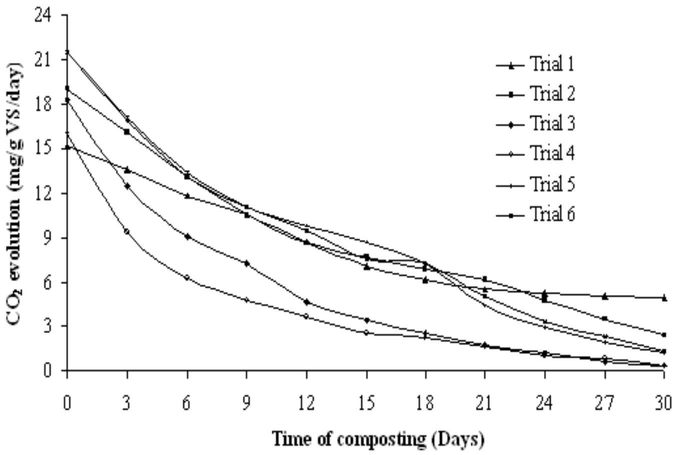

Fig. 1: Temperature evolution during pile composting

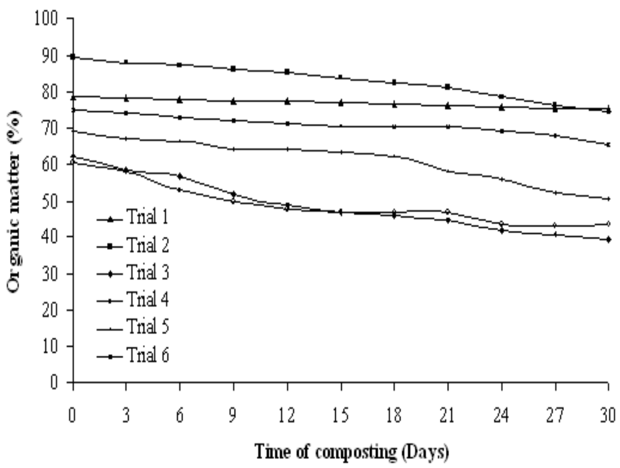

Fig. 2: Changes in organic matter/volatile solids during pile composting

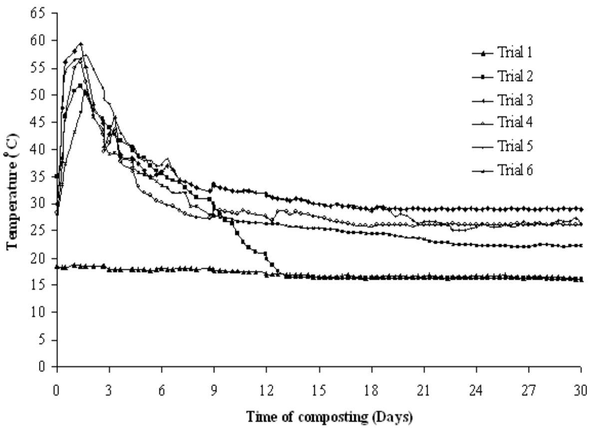

Fig. 3: CO_2 evolution rate during pile composting

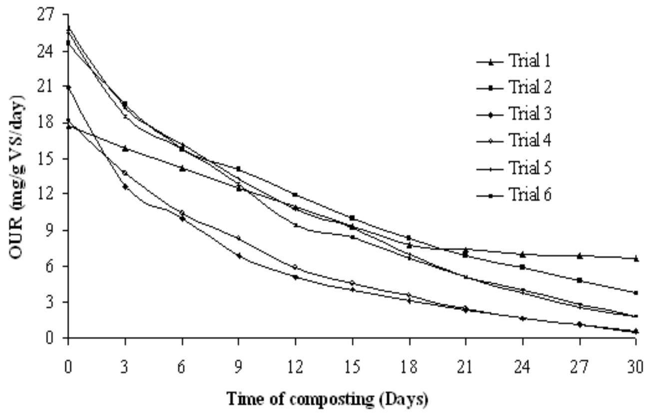

Fig. 4: OUR during pile composing

Table 1: Waste composition and characteristics of waste materials

Trials/parameter	Waste materials (kg)			
	Water hyacinth	Cattle manure	Rice straw	Saw dust
Trial 1	100	--	--	--
Trial 2	70	--	30	--
Trial 3	60	30	10	--
Trial 4	80	10	10	--
Trial 5	60	30	--	10
Trial 6	80	10	--	10
Moisture content (%)	90.2±1.7	85.3±1.9	38.1±2.1	13.2±1.1
Organic matter/Volatile solids (%)	76.8±1.1	87.8±1.4	94.9±1.2	86.6±1.3
CO_2 evolution (mg/g VS/day)	25.3±0.8	41.8±0.6	10.4±0.5	14.5±0.5
Oxygen uptake rate (mg/g VS/day)	22.4±0.7	39.4±0.9	8.4±0.4	12.4±0.3