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Agitated Pile Composting of Water Hyacinth

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***Abstract*—The water hyacinth (*Eichhornia crassipes*) is a free floating aquatic weed originated in the 23.15% wetland area of north east region of India. Due to its fast growth and the robustness of its seeds, the water hyacinth has since then caused major problems in the whole area. However, the composting 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. Therefore, the aim of this study was to investigate the evolution of some physico-chemical parameters during agitated pile composting of water hyacinth in combination with cattle manure and saw dust as a bulking agent (Trial 1, 2 and 3). Results suggested that the optimal degradation of water hyacinth can be possible in the presence of large amount of cattle manure; and rice straw could be a better option as a bulking agent in comparison with saw dust.**

Keywords-water hyacinth; composting; cattle manure; saw dust

I. Introduction

North East India is well acknowledged for its distinctive socio-cultural set up with diverse Ethnic groups and designated as one of the "Biodiversity Hotspots" on the globe with rich biological diversity and numerous endemic and endangered species. Agriculture is the mainstay of the region and people mainly depend on agriculture for their sustenance and livelihoods. The region does not enjoy technological advancement in terms of agriculture and road connectivity etc. as compared to mainland India. However, the indigenous people of this region are hard working and have been managing their agricultural activities especially in the upland with their traditional know-how's since ages. Agricultural system is mostly organic in the region. Farmers, especially the marginal ones, often do not get access to chemical fertilizers and pesticides. This may well be one of the reasons why chemical fertilizers and pesticides have not been able to make a strong hold in the upland agricultural system of the region. Quality organic compost is the basic requirement of the motivation of effective and beneficial agricultural system of the region.

The water hyacinth (*Eichhornia crassipes*) is a free floating aquatic weed originated in the 23.15% wetland area of north east region of India, where it was kept under control by natural predators [1, 2]. Due to its fast growth and the robustness of its seeds, the water hyacinth has since then caused major problems in the whole area, e.g., a reduction of fish. Other effects of the fast growth are physical interference with fishing, obstruction of shipping routes and losses of water in irrigation systems due to higher evaporation and interference with hydroelectric schemes and increased sedimentation by trapping silt particles. It also restricts the possibilities of fishing from the shore with baskets or lines and can cause hygienic problems [3]. At an average annual productivity of 50 dry (ash-free) tones per hectare per year, water hyacinth is one of the most productive plants in the world [4, 5] attributing the weed to cover water surfaces faster than most other plants.

Much work has been carried out in different parts of the world to develop environmentally sound and appropriate methods for the management and control of this weed. It recapitulated that the only means of utilization of water hyacinth which has proved economically viable across the world [6]. In this background authors studied the utilization of water hyacinth as substituting bean straw with water hyacinth as animal feed [7], feed for solid-phase fermentation [8], raw material for making pulp, paper and paper board [9] and the vermicomposting of water hyacinth [6, 10]. However, a novel technology with ecological sound and economically viable is urgently required to solve the problem of aquatic weed disposal and management.

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. But the structure of the compost will also make it more difficult to transport, and will because of the relatively high nitrogen losses, require more transport work compared to dried water hyacinths [11]. The windrow or pile composting method the most popular example of a nonreactor, agitated solids bed system. Mixed feedstocks are placed in rows and turned periodically, usually by mechanical equipment. Several successful studies were conducted on pile composting of cattle manure, swine manure, municipal bio-solids, animal mortalities and food residuals [12, 13, 14]. However, limited investigations have been made on high rate windrow/agitated pile composting of water hyacinth in combination with cattle manure, saw dust

Therefore, in order to understand the compost dynamics of high rate agitated pile composting, long term studies are required under different waste combinations. The aim of this study is to investigate the evolution of some physico-chemical parameters during high rate pile composting of water hyacinth in various combinations with cattle manure and saw dust.

II. Materials and Methods

A. The compost materials

Water hyacinth, cattle (Cow) manure and saw dust was used for preparation of different waste mixtures. Water hyacinth was collected from the lakes situated near the Indian Institute of Technology Guwahati campus. Cattle manure was obtained from nearby Amingaon village. Saw dust was purchased from nearby saw mill. The compost was prepared with different proportioning of waste composition as described in Table I.

TABLE I. WASTE COMPOSITION OF THREE MIXTURES

Feedstock material	Trial 1	Trial 2	Trial 3
Water hyacinth (kg)	60	70	80
Cattle manure (kg)	30	20	10
Saw dust (kg)	10	10	10
Proportion	6:3:1	7:2:1	8:1:1

B. Agitated pile composting

Three trials (Trial 1, 2 and 3) have performed on pile composting of water hyacinth in combination with cattle manure and saw dust as a bulking agent. All waste combinations was 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.

C. Measuring techniques

Temperature was monitored using a digital thermometer throughout the composting period. Four grab samples from the piles were collected after mixing the whole pile thoroughly by hand; when the piles were made (0 day) and the piles were turned. All the grab samples were mixed together and considered to be a homogenized sample. Triplicate homogenized samples were collected and air dried immediately, ground to pass through a 0.2 mm sieve and stored for further analysis.

Each air dried and grounded sample was analyzed for the following parameters: pH and electrical conductivity (EC) (1:10 w/v waste:water extract), ash (550°C for 2 h) (loss on ignition), NH4-N and NO3-N using KCl extraction [15], total organic carbon (TOC) determined by Shimadzu (TOC-VCSN) Solid Sample Module (SSM-5000A), potassium and sodium and calcium (acid digest) using flame photometry, trace elements including Cr, Mn, Fe, Cd, Pb, Zn, As and Cu (acid digest) were analyzed using atomic absorption spectroscopy [16].

III. Results and Discussion

A. Temperature evaluation

The variation in temperature of composting material with time is illustrated in Fig. 1. Trial 1 reached 57.3^{o}C (maximum in all 3 trials) and enters into thermophilic phase after 1 days indicating establishment of microbial activities. Higher rise 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. In trial 2, the initial temperature was 28.8^{o}C which further increased up to 54.4^{o}C. However, trial 3 observed a maximum temperature of only 50.8^{o}C. This was 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.

B. Moisture content

Higher initial moisture content of 90.5% was observed in trial 1 due to large proportion of cattle manure and water hyacinth which further dropped to 70.5% at the end of 30 days of pile composting (Fig. 1). Moisture content dropped up to 70.5 and 75.2% respectively in trial 2 and 3. Percentage decrease in moisture content was 22, 18 and 13% during trial 1, 2 and 3 respectively justified the higher temperature evaluation in trial 1 and lower in trial 3. The moisture content of the final compost was found to be on the higher range and not within an acceptable range of 50% to 60% which may be attributed to high initial moisture in composting material i.e., water hyacinth and cattle manure. Therefore, compost should be dried in natural environment before application in the agriculture field.

C. pH

Fig. 1 displays the results of the monitored pH of the composting mixtures. During the nitrification process, the nitrifying bacteria lowered the pH of the medium due to the liberation of hydrogen ions however, once nitrification had begun after the thermophilic stage, pH decreased and pH values of the compost were directly related to nitrification [17]. As composting proceeds, the organic acids become neutralized and mature compost tends toward a neutral pH. Similar observations were found in all trials as pH reduced during initial 6 days, further increased up to 8. Lower initial pH was observed in all the three trials especially in trial 3, which may be due to higher amount of water hyacinth and saw dust which show acidic pH.

D. Electrical conductivity (EC)

Fig. 1 shows the reduction of EC during all three trials. The volatilization of ammonia and the precipitation of mineral salts could be the possible reasons for the decrease in EC at the later phase of composting. The EC value reflected the degree of salinity in the compost, indicating its possible phytotoxic/phyto-inhibitory effects on the growth of plant if applied to soil [12]. For the improvement of agricultural soils, the acceptable level of EC required in compost is > 4 dS/m [18]. Results indicated the required EC values in compost of trial 1 and 2 compared to trial 3.

E. Ash content

As shown in Fig. 2 ash contents increased with composting time by about 59, 56 and 37% for trial 1, 2 and 3, respectively, owing to the loss of organic matter through microbial degradation [19]. The decrease in organic matter synchronized with an increase in the mass ash of trials.

F. Total organic carbon (TOC)

Change in TOC during the composting period is detailed in Fig. 2. The content of organic carbon decreased as the decomposition progressed. Initially, the amounts of TOC were 41.3, 41.9 and 44.8% which then reduced to 30.3, 31.8 and 39.1%, respectively in trial 1, 2 and 3. Results indicated higher carbon degradation during trial 1 (27%) due to higher amount of cattle manure as a result of higher temperature evaluation compared to trial 2 (24%) and trial 3 (13%). Similarly, decomposition was about 63% during trial 1 as compare to 61 and 49% during trial 2 and 3, respectively.

G. Ammonical nitrogen (NH_4-N) and Nitrate (NO_3-N)

Fig. 2 shows the time course of inorganic forms of nitrogen (ammonium (NH_4-N), nitrate (NO_3-N)). The changes in concentration of NH_4-N and NO_3-N in all trials followed the general trend during composting. During the first 3 days of composting, NH_4-N concentration decreased from 3.08 to 2.58%, 3.8 to 3.2% and 4.18 to 3.53% respectively in trial 1, 2 and 3. An increase was observed for around 6 days, afterwards sudden drop was noticed in all the trials and then stabilized at around 0.79, 0.71 and 0.9% in trial 1, 2 and 3, respectively by the end of the pile composting. The increase in NH_4-N concentration could be due to the conversion of organic nitrogen to NH_4-N through volatilization and immobilization by microorganisms [12]. It has been noted that the absence or decrease in NH_4-N is an indicator of both high-quality composting process [20]. Therefore, trial 1 and 2 showed better stabilization compared to trial 3, which contained considerable NH_4-N concentration.

The rapid decrease in NH_4-N concentration during composting did not coincide with similar increase in the NO_3-N concentration. Nitrate was almost absent in the cattle manure and straw dust but higher concentration was observed in water hyacinth, so in all the mixtures initial nitrate concentration was found. The high temperature and excessive amount of ammonia inhibited the activity and the growth of nitrifying bacteria in the thermophilic phase. This seem to suggest that organic nitrogen mineralization is the limiting step in nitrification since such mineralization was extremely low during the last phase of composting, when the supply of ammonium available to the nitrifying bacteria would have been reduced [17]. Therefore, NO_3-N was increased after 18^{th} day composting although no significant difference in NO_3-N content between all trials.

H. Trace elements

Aquatic plants are known to accumulate metals from their environment and affect metal fluxes through those ecosystems. Water hyacinth has exceptionally high affinity and accumulation capacity for several metals. It has proved by initial characterization of water hyacinth which indicated higher concentration of Pb, Zn and Mn. Many of these elements are actually needed by plants for normal growth, though in limited quantities. Certain trace elements are not biodegradable and become toxic at some concentration, therefore, measuring the concentration of these elements can provide fertilizer requirements of plants. Results showed a steady increase in all metal contents especially in trial 3 due to higher content of water hyacinth (Table II). The increase of metal level is due to weight loss in the course of composting followed by organic matter decomposition, release of CO_2 and water, and mineralization processes [21]. The total metal content of final compost in all the three trials was lower and can be considered as soil fertilizer with good quality according to the standards to ensure safe application of compost laid down in Municipal Waste Management & Handling Rules notified by the Ministry of Environment and Forest, Government of India [22] and Canadian Council of Ministers of the Environment [23].

IV. CONCLUSIONS

Trial 1 observed higher temperature compared to other trials due to high amount of water hyacinth, which did not provide favorable conditions for growth and biological activity of microorganisms. Percentage decrease in moisture content during trial 1 justified the higher temperature evaluation. Lower initial pH was observed in all the trials especially in trial 3 due to higher amount of water hyacinth and saw dust. Lower final EC, NH_4-N and TOC in trial 1 concluded the optimal waste combination of water hyacinth, cattle manure with straw dust. Higher final concentration of nutrients and limited metal content ensured the quality of compost prepared from water hyacinth in combination with cattle manure and saw dust. It suggested that the optimal degradation of water hyacinth can be possible in the presence of carbonaceous material i.e., cattle manure and saw dust.

TABLE II. TRACE ELEMENTS IN THE FINAL COMPOST (30 D) OF TRIAL 3, AND LIMIT VALUES FOR CLASS A OF COMPOSTS ''WHICH HAVE NO RESTRICTIONS IN USE'' AND CLASS B OF COMPOST ''WHICH CAN BE USED ON FOREST LANDS AND ROAD SIDES AND FOR OTHER LANDSCAPING PURPOSES ACCORDING TO CANADIAN NORMALIZATION CCME (1995) AND INDIAN NORMALIZATION (CPHEEO, 2000)

Trace	CCME guidelines	CPHEEO	Final

elements	Class A	Class B	guidelines	compost content in Trial 3
	mg/kg of dry matter			
As	75	15	20	17
Cr	210	--	300	67
Cu	400	--	500	78
Zn	1850	370	2500	795
Cd	20	4	20	14
Mn	--	--	--	1250
Pb	500	100	500	150

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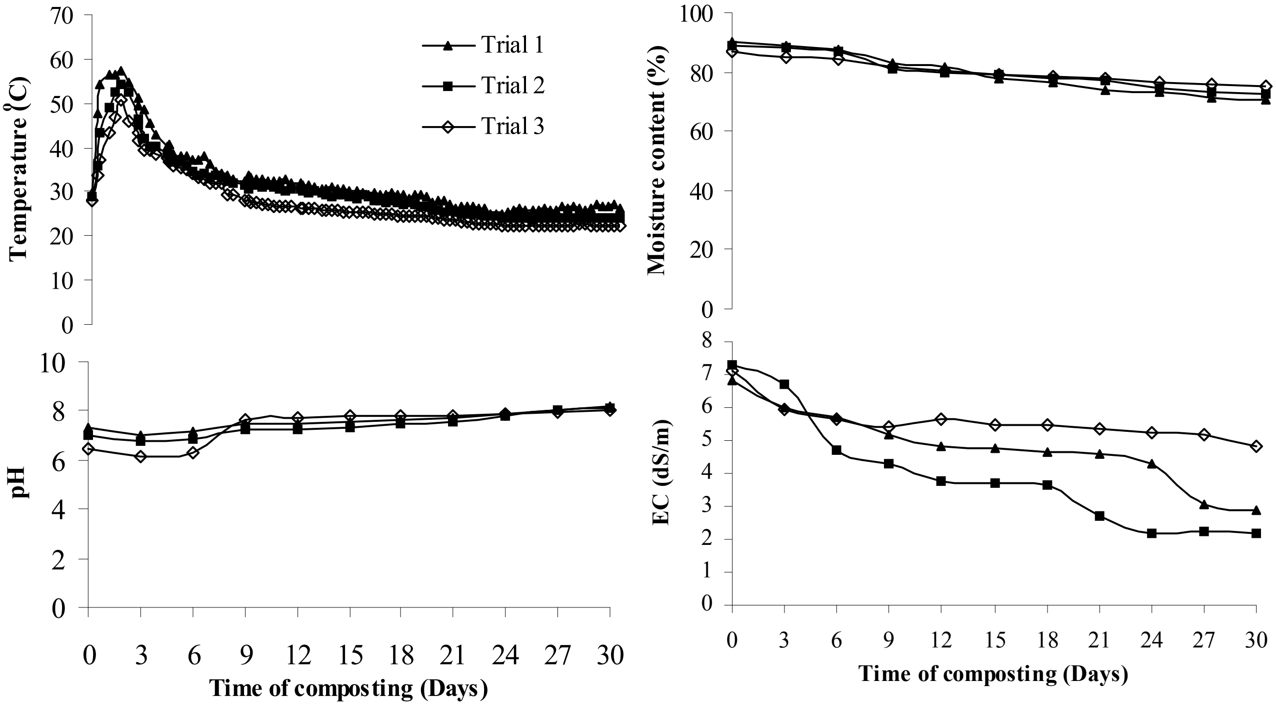

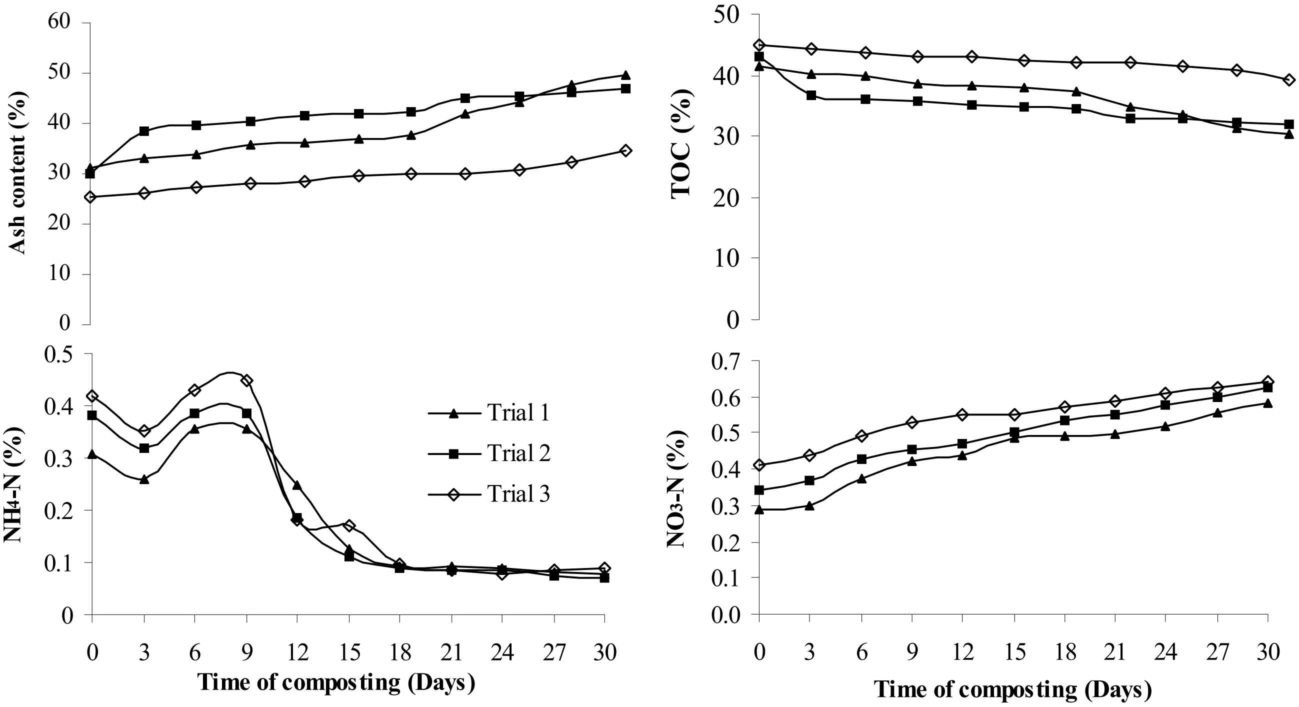

Figure 2. Ash content, TOC, NH4-N and NO3-N during pile composting