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Investigation on Preparation, Characterization and Application of Effective Microorganisms (*EM*) Based Composts - An Ecofriendly Solution

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ABSTRACT

Nowadays, solid waste disposal is the most pressing problem facing mankind throughout the world. The solid waste management plays a significant role to create a sustainable environment. Composting is a controlled decomposition of an organic matter into nutrient rich humus, which is relatively a stable organic end product. The activated Effective Microorganisms (EM) are used to decompose the solid organic materials. EM considerably improves the decomposition of organic materials and quality of compost and reduces the volume of compost by 50% or less in the raw material. This paper deals with the comparison of four matured composts from different waste organic materials such as kitchen waste, leaf waste, paper waste and water hyacinth waste using Effective Microorganisms. The parameters like pH, temperature, moisture content and height of bed were monitored and maintained throughout the process. The end products of humus like compost were characterized and analysed for physico-chemical characteristics like pH, moisture content, organic carbon, nitrogen, phosphorus, potassium and C:N ratio. The results of all the matured composts showed better quality and as an effective adsorbent medium for the removal of crystal violet dye from aqueous solution.

INTRODUCTION

The rate of waste generation increases due to increase in population. The environmental impact of the waste is significant. Solid waste is solid or semi-solid, non-soluble material such as agricultural refuse, demolition waste, industrial waste, mining residues, municipal garbage and sewage sludge. In earlier days, the disposal of solid waste did not pose a significant problem since the population was small and the land availability was vast. Throwing the waste on the streets and roadways will cause unnecessary odour and breeding of flies, rodents, etc. Hence, the management of solid waste is needed to reduce the land pollution and to maintain the ecological balance.

Solid waste management is a systematic controlled generation, collection, storage, transport, source separation, processing, recovery and disposal of solid wastes. Onsite small scale composting of organic waste was encouraged as an effective solution to reduce the waste management problem globally (Nair & Okamitsu 2010). Composting is the biological degradation of organic matter under aerobic conditions to a relatively stable humus-like material called compost (Rynk et al. 1992). The microorganisms present in the organic materials are responsible for the decomposition. So, the decomposition by Effective Microorganisms (EM) is the safe and simple way of improving the composting system.

EM was developed by Teruo Higa (1970) at the Ryukyus University, Okinawa, Japan (Sangakkara 2002). Basically, this is a micro based solution for natural organic farming systems, however, its results and uses have also been expanded for solving some environmental issues. The various studies have suggested that EM may have a number of applications including agriculture, livestock, gardening and landscaping, composting, bioremediation, cleaning septic tanks, algal control and household uses (Higa & Chinen 1998).

EM is a mixture of group of organisms that has a reviving action on human being, animals and the natural environment and has also been described as a multi-culture of coexisting anaerobic and aerobic beneficial microorganisms (Higa 1995). EM can ensure high quality compost as the microbial inoculant increases the production of aerobic bacteria and increases the composting speed. The main species involved in EM include lactic acid bacteria, photosynthetic bacteria, yeasts, actinomycetes and fermenting fungi (Diver 2001). Ideal composting not only depends on EM, but also on other parameters such as moisture, type of bulking agents added and size, shape and surface of the organic waste material used. In this study the four kinds of organic waste materials such as kitchen waste, paper waste, neem leaf waste and water hyacinth waste were selected for the aerobic composting process with the application of EM.

Disposal of kitchen waste, which contains about 80% of moisture to the landfills, causes various problems like easy putrefaction, offensive odour and pollution of water sources by leachate (Rogoshewski et al. 1983, Wang et al. 2001). When the kitchen waste compost is used as a manure, it has been reported that the compost results into higher crop performance, better soil physical structure, better presence of plant growth hormones and higher levels of soil enzymes (Edwards 1995). Kitchen waste provided a better environment for the EM to grow and produced a higher quality of compost (Sekaran et al. 2005).

The amount of paper waste produced is enormous, so the environmental impact is also significant. It is worth pointing out that some materials cannot be recycled over and over again. At best, it can be recycled only four times before the fibres are too short to be used to make more paper. Paper products are generally considered safe for composting because they typically contain very low levels of chemical substances that could contaminate compost, according to the Environmental Protection Agency (1998).

Neem (*Azadirachta indica* A. Juss) is a large, evergreen, hardy tree, native to the Indian subcontinent (Usher 1984, Chari 1996). Leaves of neem have been explored as a substrate for generating vermicompost (Gajalakshmi & Abbasi 2004). The neem leaves are cost free and abundantly available material, hence they can be also used in compost. Decomposition of an organic material is achieved by billions of microscopic organisms naturally present in the leaf waste, including bacteria, actinomycetes, and fungi.

The water hyacinth (*Eichhornia crassipes*) is a free floating aquatic weed originated in the 23.15% wetland area of the north east region of India (Abbasi 1998, Husain 2003). The water hyacinth growth forms dense mats that averts river traffic, block irrigation canals, interfere with hydel power projects and destroy rice fields (Gupta et al. 2007). The quantities of water hyacinth used for other purposes like waste water treatment, poultry/veterinary feed, as a material for furniture, carry bags, source of medicinal plant, etc. were very low and thus the disposal problem of the huge waste biomass of water hyacinth is still remaining as a burning problem (Hemen Deka et al. 2013). However, a new technology is required to solve the problem of disposal and management of water hyacinth with ecological balance and economical viability. Hence, it was proposed to utilize the water hyacinth waste as a good source for composting.

This study was aimed to investigate the evaluation of some important physico-chemical characteristics of compost from four organic wastes namely, EM based kitchen waste compost (EM_{KC}), EM based paper waste compost (EM_{PC}), EM based leaf waste compost (EM_{LC}) and EM based water hyacinth waste compost (EM_{WHC}). The parameters like pH, moisture content, temperature and height of the compost beds were monitored throughout the composting process.

Normally, the matured compost is used as a manure or fertilizer. The compost also has a potential to remove the Crystal Violet (CV) dye from wastewater by the method of adsorption. Crystal violet dye, a member of the triphenylmethane group, is extensively used in veterinary medicine as a biological stain and in various commercial textile operations (Senthil Kumaar et al. 2006). For the environmental safety concern, it is essential to remove the crystal violet dye before the discharge of wastewater. In this concern, an attempt was made to evaluate the applicability of matured EM based composts as an adsorbent for the removal of CV from the aqueous solution. To best of our knowledge, the EM based compost has not yet been reported as an adsorbent for the removal of CV.

MATERIALS AND METHODS

Collection of organic materials: The kitchen waste materials used for compost preparation were collected from the hostel pantry and canteen. The discarded waste papers were collected from the college premises. The neem leaves of the plant pile up as waste during defoliation and they were collected from nearby town, and the water hyacinth from the ponds and channels of nearby area. In order to increase the composting speed and nutrient content, the bulking agents of cow dung from the local livestock farm and saw dust from nearby saw mill were added to the each of the materials during the process of composting. The dormant EM was supplied by Environ Biotech, Coimbatore, which was used as a decomposer for the compost.

Adsorbate and adsorbent: The adsorbate of crystal violet, a basic dye, with a wavelength of 586 nm, molecular formula $C_{25}H_{30}N_3Cl$, was purchased from Sigma Aldrich. The stock solution of 1000 mg/L was prepared and the working solutions were adjusted to the desired pH values by adding 0.1 M HCl and 0.1 M NaOH. The prepared EM based composts of EM_{KC}, EM_{PC}, EM_{LC} and EM_{WHC} were used as adsorbent for this evaluation. The prepared adsorbent was air dried for 24 hours and oven dried at a temperature of 70° C for 2 hours and sieved.

Activation of EM: EM was available in a dormant state and it required activation before application. This was done by adding 20 L of water and 2 kg of pure cane sugar to 1 L of dormant EM. The mixture was then transferred into a clean air tight container and kept away from direct exposure to sunlight at ambient temperature for 7 days. The gas was made to escape every day until fermentation was complete. During the period of activation, a white layer of actinomycetes formed on the top of the mixture accompanied by a sweet smell. For the activated EM, the pH is a determining factor and it should be below 4.0. This indicates the activation of Effective Microorganisms.

Preparation of compost: The degradable wastes were first screened and separated according to the particle size and then dried for a few hours. The composting process was initialized by preparation of the compost bin. The compost bin of plastic with suitable size was selected and the bottom was filled with crushed stones and sand which helps in leaching of excess water in the bed through the holes provided at the bottom. Above that, a layer of cow-dung, followed by the desired solid waste, and again followed by a coat of saw dust was spread one over another as number of layers. The activated EM was sprayed along with them for each layer. This layering process was repeated till the suitable height was reached. The entire unit was kept moist by spraying activated EM at regular intervals till the compost was obtained. During this composting process, the bed was maintained in the temperature range of 25 to 30°C. The organic waste was turned periodically (once every few days) for better aeration and to mix its contents. After about 30 to 45 days the volume of bed had dropped significantly and white mold appeared above the biomass in the bin. The end product was obtained in dark brown colour and humus like material. At this point, the prepared compost was collected and sieved. It was then analysed for pH, moisture content, electrical conductivity, organic carbon, nitrogen (N), phosphorus (P), potassium (K) and C : N ratio.

The composition of four EM based composts were characterized and analysed by the following methods: The pH of compost was measured by pH meter (Ecosan, EUTECH instruments), moisture content by oven dry method, electrical conductivity by conductivity meter, organic carbon by Walkely and Black titration method, nitrogen and phosphorus by UV-visible spectrophotometer (Merck, Spectroquant Phara 300) and potassium by a digital flame photometer.

Adsorption studies*:* The removal of crystal violet dye by EM based composts was done in the 100 mL of working solutions prepared with parameters of pH 7, initial CV concentration 30 mg/L, adsorbent particle size 1.18 mm and adsorbent dosage 6g/L in an orbital incubator shaker (Technico) for 6 hrs until equilibrium was reached. The samples were then centrifuged at 3500 rpm for 5 min and analysed by UV-visible spectrophotometer. The percentage of removal of CV onto the EM based composts was calculated by the following equation:

$$\% \text{ Removal} = [(C_i - C_o)/C_i] \times 100$$

where, C_i - Initial concentration of dye solution mg/L and C_0 - Final concentration of dye solution mg/L

RESULTS AND DISCUSSION

The past literatures revealed that, an increase in the composting rate and microbial activity intensification can be achieved by Effective Microorganisms which creates the suitable environmental conditions for decomposition of organic materials used. The microbial activity is influenced by the particle size of the feedstock material, pH, moisture content, temperature and height of compost bed. The particle sizes of less than 5 cm were used for this study. Other parameters were monitored during the composting period and presented in Figs. 1 to 4.

The Fig. 1 indicates that pH, in all types of wastes, decreased with the passage of time and found to be in the range of 7.6-6.28. The shift in pH during the process of composting could be due to the microbial decomposition. The production of CO_2 and organic acids by microbial decomposition during the process had resulted in the lowering of pH (Naresh & Surinder 2014). Reduction in pH towards neutrality should be important in retaining nitrogen and seems to promote the availability of nutrients to plants (Brady 1998). The pH reduction may be attributed to mineralization of nitrogen and

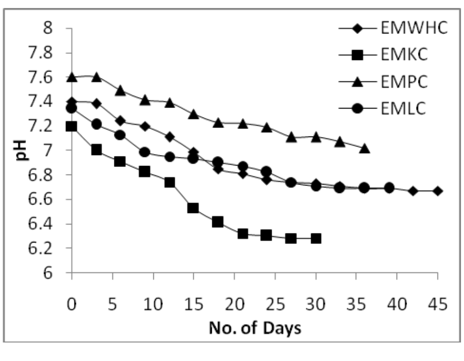

Fig. 1: Profile of pH.

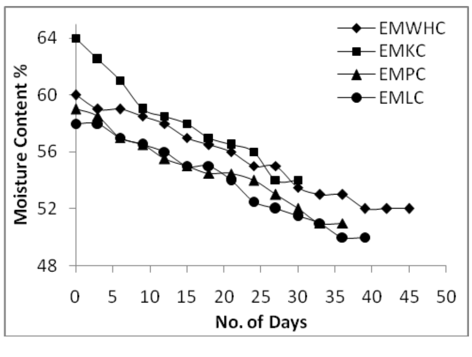

Fig. 2: Profile of moisture content.

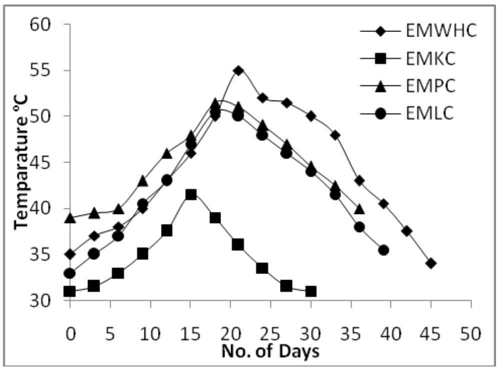

Fig. 3: Profile of temperature.

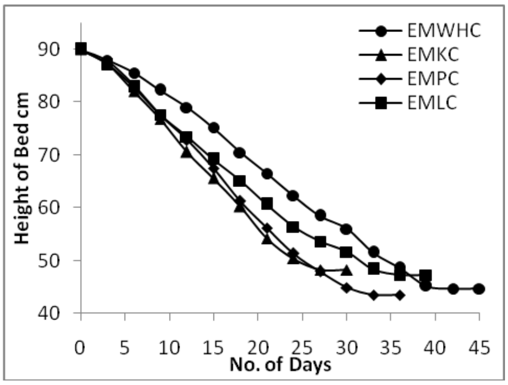

Fig. 4: Profile of bed height.

Table 1: Physical and chemical characteristics of fresh organic wastes.

S.N.	Parameters	Unit	KW	PW	LW	WHW
1.	pH	-	7.2	7.6	7.34	7.4
2.	Moisture content	%	64	59	58	60
3.	Electrical conductivity	dSm^{-1}	0.59	0.49	0.69	0.71
4.	Organic carbon (C)	%	18.3	36.8	14.3	32.16
5.	Nitrogen (N)	%	0.61	0.89	0.31	0.98
6.	Phosphorus (P)	%	0.25	1.24	0.69	1.02
7.	Potassium (K)	%	2.1	0.75	0.9	0.402
8.	C:N ratio	-	30.0	41.3	46.1	32.8

Table 2: Physical and chemical characteristics of matured composts.

S.N.	Parameters	Unit	EM_{KC}	EM_{PC}	EM_{LC}	EM_{WHC}
1.	pH	-	6.28	7.12	6.69	6.67
2.	Moisture content	%	54	51	50	52
3.	Electrical conductivity	dSm^{-1}	1.2	0.9	0.61	1.74
4.	Organic carbon (C)	%	7.2	13.7	6.9	13.5
5.	Nitrogen (N)	%	0.3	0.49	0.21	0.64
6.	Phosphorus (P)	%	0.7	0.22	0.59	0.21
7.	Potassium (K)	%	0.6	0.02	0.5	0.045
8.	C:N ratio	-	24.0	28.0	22.3	21.1

phosphorus into nitrites/nitrates, orthophosphates and bioconversion of the organic material into intermediate species of organic acids (Ndegwa et al. 2000). In the EM_{KC}, the pH value was low compared to the other composts because the kitchen waste material contains the acidic nature.

Effective Microorganisms require moisture to assimilate nutrients, metabolize new cells, and reproduce. They also produce water as part of the decomposition process. If water is accumulated faster than it is eliminated via either aeration or evaporation (driven by high temperatures), then oxygen flow is impeded and anaerobic conditions result (Gray et al. 1971). Water is the key ingredient that transports substances within the composting mass and makes the nutrients physically and chemically accessible to the microbes. If the moisture level is below, i.e. about 45 percent, the nutrients are no longer in an aqueous medium and not easily available to the microorganisms. Their microbial activity decreases and the composting process become slow. Below 20 percent moisture, very little microbial activity occurs (Haug 1980). So that, the moisture content for all four types of materials during the process was maintained at regular intervals between 45 to 65 % by spraying activated EM and plotted in Fig. 2.

Temperature is also a critical factor in determining the rate of decomposition that takes place in a compost pile. Compost temperatures largely depend on how the heat generated by the microorganisms is offset by the heat lost through controlled aeration, surface cooling and moisture losses. The most effective composting temperatures are between 45 and 59°C (113 and 138°F) (Richard 1992) and in this investigation all the composting temperatures were found to be within the range. The decomposition by Effective Microorganisms was confirmed by the increase in the compost bed temperature during the initiation process (Fig. 3). The peak temperatures were acquired from 15 to 21 days, which indicates the thermophilic phase. After that the temperatures were decreased to the ambient temperature in the mesophilic phase at 30 to 45 days according to the waste materials used.

The height of the compost bed substantially decreased with increase in decomposition rate. The initial height of compost bed was fixed at 90 cm. It was observed from Fig. 4, that all the four compost beds had reduced in height, which indicates the decomposition has taken place at constant rates. During the last 6 days of process, the bed height was no longer reduced due to the maturity of compost. The EM_{KC}, EM_{PC}, EM_{LC} and EM_{WHC} were matured at 30, 36, 39 and 45 days respectively. At these days, the temperatures for all the four compost were within ambient temperature and that also supports the previous statement.

Nutrient parameters: The analysis of nutrients present in the compost was necessary to evaluate the quality of compost. The physical and chemical characteristics were tested for fresh wastes of kitchen, paper, leaf and water hyacinth

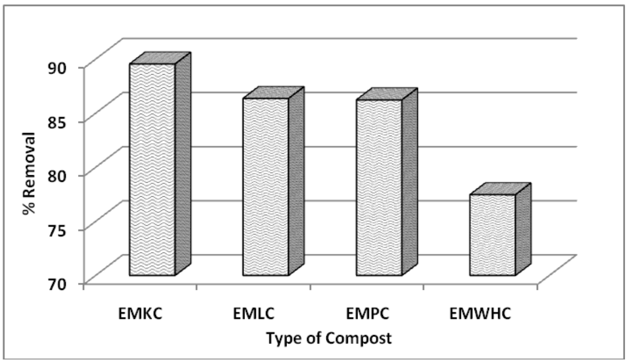

Fig. 5: Removal of Crystal Violet by EM_{KC}, EM_{PC}, EM_{LC} and EM_{WHC}

and their own matured composts are presented in Table 1 and Table 2 respectively.

The results exhibited that the pH values of all four composts were lower than those of their respective raw materials. The reduction in pH was due to the mineralization and decomposition of organic materials as discussed earlier. Acceptable pH for the microorganisms is generally in the range of 6.0-7.5 (Boulter-Bitzer et al. 2000). The pH value of all four matured composts EM_{KC}, EM_{PC}, EM_{LC} and EM_{WHC} was found in the optimum range of 6 to 9 (Rynk et al. 1992). Neutral and partial alkaline pH values are usually indicators of stable composts.

The moisture content values were decreased compared to the fresh wastes used. The decrease of moisture content was due to heat released by the microorganisms during decomposition. The electrical conductivity affects the quality of compost in a large way because it reflects their salinity and suitability for crop growth. The electrical conductivity increased for EM_{KC}, EM_{PC} and EM_{WHC} and decreased for EM_{LC} compared to the fresh wastes. The release of mineral salts such as ammonium and phosphate during decomposition and mineralization of organic substances increased the electrical conductivity during the composting process (Wong et al. 2001).

Primary nutrients required by microorganisms for proper composting are carbon, nitrogen (N), phosphorus (P), and potassium (K). All the four composts had optimum values and it was noted that the N, P and K values decrease after composting process. The carbon content of the wastes decreased during composting indicates a higher mineralization of organic matter (Crawford 1983). The final nitrogen content of compost is dependent on the initial nitrogen present in the waste and the extent of decomposition.

The carbon and nitrogen (C/N) ratio provided is an indication of degree of decomposition. Researchers have suggested various ideal C/N ratios ranging from 12 to 25 (Jimenez & Garcia 1992, Erhart & Burian 1997, Brewer & Sullivan 2013), but the optimal value is often dependent on the initial feedstock (Benito et al. 2005, Epstein 1997). The C/N ratio values lower during composting of all four solid waste materials. In this study the C/N ratios for EM_{KC}, EM_{LC} and EM_{WHC} were in range, but the EM_{PC} has slightly higher value.

Enhanced organic matter decomposition in the presence of Effective Microorganisms resulted in lowering the C/N ratio. In general, a low C/N ratio accelerates the rate of decomposition, but may cause a loss of nitrogen as ammonia gas and a rapid depletion of the available oxygen supply, leading to foul smelling conditions. But EM controls the foul smell and the process was odour free (Sekaran et al. 2005).

Adsorption studies: This work examined the feasibility and efficiency of EM based composts to remove basic dye crystal violet from the aqueous solution. The results obtained from the adsorption of crystal violet dye by EM_{KC}, EM_{PC}, EM_{LC} and EM_{WHC} are illustrated in Fig. 5. From the results obtained, the percentage removal for the composts EM_{KC}, EM_{PC}, EM_{LC} and EM_{WHC} were 89.55, 86.36, 86.23 and 77.46 respectively. The removal of dyes from aqueous solution was due to the presence of organic carbon in the compost. The pH of compost did not pose a significant effect on the adsorption process because the dye pH was in neutral range. The compost, natural humus substance has rich organic functional groups of carboxyl, hydroxyl and others which are responsible for the adsorption process (Joanna Kyziol-Komosiñska et al. 2011). So the EM based compost of EM_{KC}, EM_{PC}, EM_{LC} and EM_{WHC} has the potential to remove the crystal violet dye from aqueous solution. The detailed characterization of the adsorption behaviour of all the composts is the future scope of present investigation.

CONCLUSION

This experimentation was done in an effort to restructure the system of solid waste management by investigating small-scale composting with Effective Microorganisms. The following conclusions were drawn from this study,

- From this analysis, the composting parameters for EM_{KC}, EM_{LC}, EM_{PC} and EM_{WHC} were in similar patterns and shown that the prepared composts fulfil all the parameters necessary for quality compost.
- The kitchen, leaf, paper and water hyacinth wastes used in this evaluation provided a better environment for EM to grow and produce greater quality compost. Cow dung and Effective Microorganisms play a significant role in stabilizing the mixture and accelerate the composting process.

- The recycling of water hyacinth waste as compost will reduce water pollution. Kitchen, leaf and paper waste recycling lead to reduction of solid waste generation.
- The composts were rich in NPK and their C/N ratio was below 25 which indicate their agronomic importance as a soil conditioner and manure. It was quite evident that, the physico-chemical characteristics of composts showed the better quality.
- The EM based composts of EM_{KC}, EM_{LC}, EM_{PC} and EM_{WHC} were matured at 30, 36, 39 and 45 days respectively.
- The adaptation of Effective Microorganisms in composting process significantly promotes cost effective and stress free method for converting organic wastes into value-added products.
- Apart from the conventional use of compost, it could be employed as an alternative, eco-friendly and low-cost adsorbent for the dye removal from water and wastewater.

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