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Bio composting of Municipal Solid Wastes employing earthworms *Eisenia fetida* and *Eudrilus eugeniae*

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Abstract

The MSW was composted with different Earthworm species to identify the suitable earthworm species for Eco-friendly and scientific management of MSW. Earthworm species of Eudrilus eugeniae and Eisenia fetida were collected from Kodaikanal forest soil, brought to Alwarkurichi and reared in cages under controlled environmental conditions till attaining full grown stage. These two earthworm species were introduced into the raw MSW collected from Alwarkurichi town Panchayat and studied the changes in physico-chemical and biological characteristics during the course of decomposition of MSW. There were six treatments taken up for this study, out of which two treatments had been made with 50 numbers of each earthworm species and another two treatments with 100 numbers of each earth worm species. The 5th treatment was made by adding 50 numbers of each earthworm species. An experimental control was also maintained to compare the efficacy of various treatments. During the decomposition of MSW by these earthworm species, there was an increase, in size, number of cocoons, number of young ones and number of adult earthworms. This study was observed with gradual increase in pH, E.C. nitrogen, phosphorus, potassium and continuous decrease of total carbon and C: N ratio during the composting period. The bacterial and fungal populations were minimum at the initiation of composting, reached the maximum at the middle period and attained stable population on maturation. The actinomycetes population steadily increased during the process of decomposition and reached maximum and stable population on completion of decomposition. The micronutrients content had shown a steady increase from the beginning to the end. The heavy metals concentration decreased during the period of composting. The compost obtained from the MSW treated with Eudrilus eugeniae in 100 numbers possessed most favorable physico-chemical and biological characteristics when compared to the other treatments in this study.

Keywords: Bio-composting, *Eisenia fetida, Eudrilus eugeniae*, C:N ratio, compost maturity.

Introduction

Waste is a term denoted for the unwanted materials thrown out on streets and roads. Waste is a common term for all kind of unwanted materials. The substances or objects, which are either disposed of or proposed to be disposed of or forced to be disposed of by the provisions of national law are termed as wastes [1]. In Indian cities, the average per capita waste generation is about 500gms per day[2]. Wastes are residues which are generated during the extraction and processing of raw materials to get intermediate and final products. The remains left over during consumption of final products can also be called as waste. The term waste excludes recyclables or reusables being generated during production, utilization or consumption[3]. Municipal solid Waste (MSW) constitutes household waste, construction and demolition debris, sanitation residue, and waste from streets. MSW is mainly generated from domestic kitchen and commercial complexes. With the increase of urbanization and change in socio-economic system, lifestyle and food habits, the amount of municipal solid waste has been increasing rapidly over years and its composition is getting changed. MSW is a common term used to denote trash or garbage, which consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint and batteries[4]. MSW is common term for domestic and commercial waste and their contribution is relatively small in the total solid waste stream in developed countries[5], whereas its contribution to the total waste in Nigeria is relatively more[6]. Actinobacteria is the most widely used microbe which is efficient and capabable of producing antibiotics and other compounds of biotechnological importance[7]. The composting is the most effective and eco-friendly method among the various available methods for the disposal of MSW. The composting is bio-degradation of green MSW and it is a recyclable process. The end product of composting is the good organic manure that can be used in agricultural production which aids to promote Organic Farming.

The end product obtained by the bio-degradation of organic matter by utilizing various species of worms, usually earthworms to produce a heterogeneous mixture of decomposed organic manure including bedding materials and vermicast. This end product is called Vermi Compost. The other terms commonly used to denote the vermicompost are worm castings, worm humus or worm manure [8]. At present the only way of obtaining earthworm for soil improvements is field

collection which is laborious and costly[9]. The normal weight of indigenous *Lampito mauritti* and exotic *Eudrilus eugeniae* are about one gram. Normally, the number of earthworms doubles within 40-50 days. But, the Chinese earthworms *Eisenia fetida* and African earthworm *Eudrilus eugeniae* can multiply up to thrice within 45-50 days. The length of various earthworm species ranges from 10 mm to 300 mm. In case of all the earthworm species, segments in the oesophageal region contain muscular commissural vessels which connect the top and bottom vessels that function like hearts to pump the blood (these are called aortic arches). Earthworm has five pairs of hearts, which may be more or less[10].

This study was undertaken with an objective of identifying suitable organism to treat the MSW for its scientific management and conversion into an economic product in order to find solution for environmental degradation due to accumulated garbage. It has been proposed to take up this study by introducing different earthworm species into raw compost to compare their efficiency in breakdown of organic matter with a view to identify a suitable earthworm species for the treatment of MSW to convert it into valuable organic manure and its utilization for sustainable crop production.

Material and Methods

Processing of Municipal solid waste: The MSW composed of bio-degradable waste and non bio-degradable waste were collected from Alwarkurichi town Panchayat. The mixed waste was segregated into biodegradable and non-biodegradable fractions. A portion of biodegradable waste was shade dried, powdered and sieved through 2 mm sieve for further chemical analysis.

Proximate analysis of solid waste: The powdered and sieved MSW was subjected to the determination of physico-chemical parameters in standard protocols. The methods followed for the physico-chemical analysis of powdered and sieved MSW were, pH and EC followed the method of Falton et al.[11], temperature and total carbon[12], for the estimation of total nitrogen [13] total phosphorus and total potassium[14]. The micronutrients and heavy metals were analyzed by atomic absorption spectrophotometer. In addition, the population of bacteria, fungi and actinomycetes were enumerated using the standard methods.

Study Area: The earthworm species *Eisenia fetida* and *Eudrilus eugeniae* were collected from Kodaikanal forest soil and the study of treatment of MSW with these earthworm species was carried out at Manonmaniam Sundaranar University, Sri Paramakalyani Centre of Excellence in Environmental Sciences, Alwarkurichi, Tirunelveli District, Tamil Nadu, India. This study was conducted by designing 6 treatment in completely randomized design with the inoculation of *Eisenia fetida* and *Eudrilus eugeniae* earthworm species in different numbers. The place of collection of earthworm species and study location are marked in figure 1.

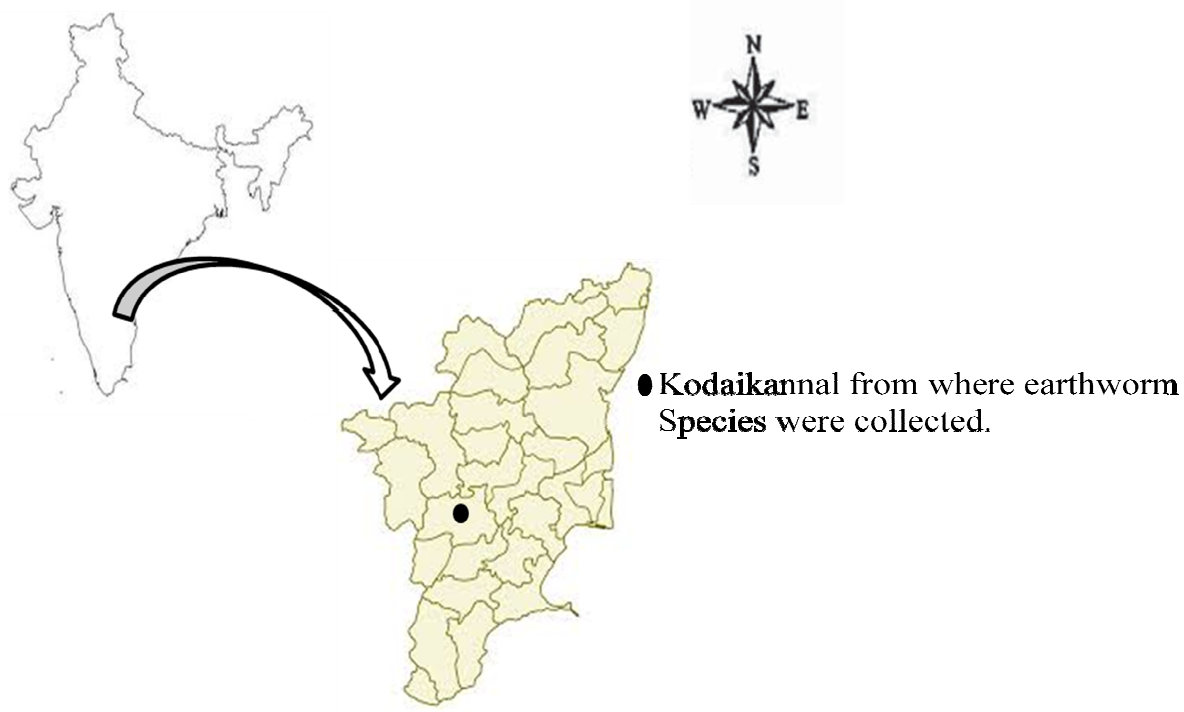

Figure-1a
Kodaikannal forest- place of soil sample collection

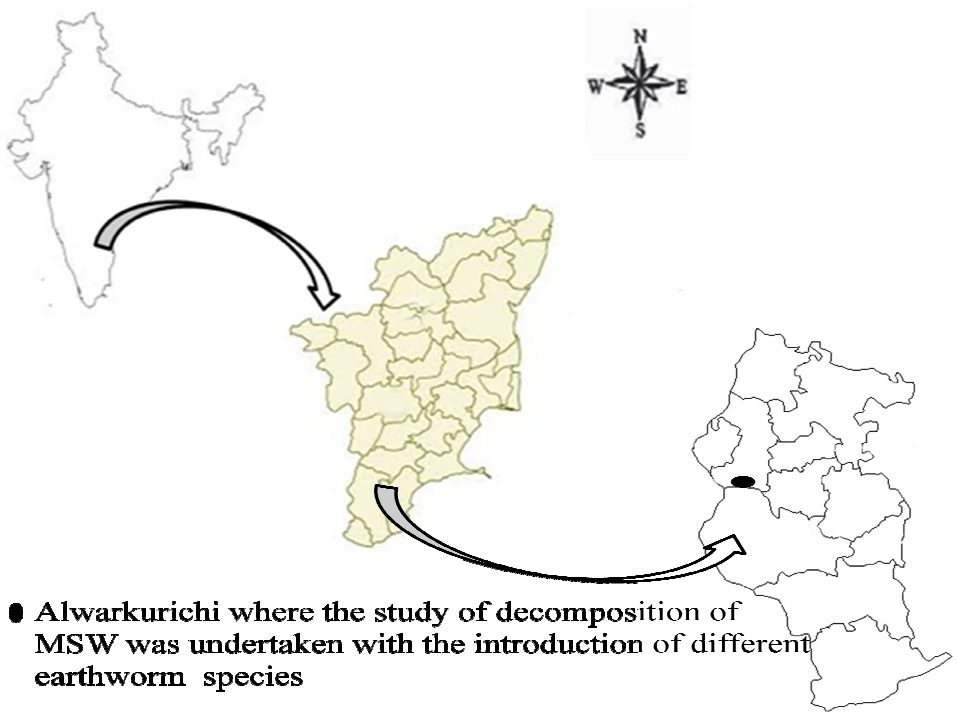

Figure-1b
Alwarkurichi-study site

Treatments: In this study, 6 treatments had been set up for the investigation of the rate of decomposition of MSW by employing different species of earthworms. The earthworms were introduced into 100 Kg. of MSW in each treatment. The earthworms *Eisenia fetida* and *Eudrilus eugeniae*, numbering each 50 and 100 were used to make four treatments. The fifth treatment was made by adding 50 numbers of each earthworm species together. An untreated row of MSW was also maintained as experimental control. The details of treatments are, T_1 (100 kg of MSW-Control), T_2 (100kgMSW+ 50 numbers of *Eisenia fetida* earthworms), T_3 (100kg MSW+100 numbers of *Eisenia fetida* earthworms), T_4 (100kg MSW+50 numbers of *Eudrilus eugeniae* earthworms), T_5 (100kg MSW+100 numbers of *Eudrilus eugeniae* earthworms) and T_6 (100kg MSW+ 50 numbers of *Eisenia fetida* earthworms +50 numbers of *Eudrilus eugeniae* earthworms). These treatments were allowed to undergo decomposition for 60 days. After 60 days, the compost samples were collected and analysed at Tamil Nadu Agricultural University, Coimbatore.

Statistical analysis: The statistical analysis was done using Microsoft excell 2007 and data were analyzed through ANOVA to determine significance of differences (0.05 level).

Results and Discussion

Biological Changes during Composting of MSW: Biology of Earthworm Species: During the composting period (0^{th} day to 60^{th} day), the size and number of earthworms increased. It was also observed the increase in number of cocoons and young ones during that period (table 1). The reproduction of earthworms during composting led to the availability of eggs, cocoons and earthworms in different stages such as young ones and adults.

Changes of Physico-Chemical Characteristics in Composted MSW: Changes in pH, EC phosphorus and temperature in Composted MSW: The pH is an index of compost maturity. At the initiation of composting lowest pH 6.20 was measured from the treatment T_5, and observed highest pH 6.40 in T_1. The pH observation from all these treatments showed that ideal pH 7.45 was in existence in the matured compost from the treatment T_2. All the physico-chemical changes were significant during composting ($P<0.05$ level). The Electrical conductivity is the ability of ions in the compost to conduct electricity. At the initiation of composting, the EC values were highest 1.62 dSm^{-1} for the treatment T_2 and T_5 and lowest, 1.50dSm^{-1} for the treatment T_4. The highest 3.45 dSm^{-1} EC was shown by T_3 and lowest 2.78 dSm^{-1} EC by T_6 on completion of decomposition. The treatment T_3 was measured with lowest 0.10% phosphorus content at the beginning of composting and measured highest 0.15% phosphorus content from the treatment T_4. The total phosphorus contents were measured from the sample of matured compost of all the treatments and observed highest phosphorus 0.34 % concentration in the compost of treatment T_6 followed 0.33 % by the treatment T_4 (table 2). The lowest 0.26% phosphorus content was observed from the treatment T_3. The decomposition process continued up to 60^{th} day, when the

MSW got decomposed fully and the compost attained maturity in all the treatments. The matured compost from the treatment T_2 recorded highest 38°C temperature followed 37°C by the treatments T_1 and T_5 and recorded lowest temperature 35°C from the treatment T_4. The total phosphorus content and temperature values were gradually increased significantly ($P<0.05$).

Khalil et al.[15], reported that the pH increased at the beginning of composting of municipal sewage sludge and then decreased to near neutrality at the end of decomposition process. The pH of all the treatments in this study ranged between 7.45 and 8.05 and the existence of favorable pH was found to have similarity with the findings of Khalil et al.[15]. Cardnas and Wang 1980[16] and Campell[17] suggested that the EC of compost samples varied from 2.40 to 7.70 dSm^{-1} in 50 to 60 days old compost. Brinton[18], found that the electrical conductivity is a measure of soluble salts in the compost such as sodium, chlorine, potassium, nitrate, sulphate and ammonia. The EC value for all the six treatments taken up in this study were found to be well within the range of favorable EC values as reported by Campell, 1997[17]. Elango et al., 2009 [19], reported that the total phosphorus content gradually increased during composting process and water solubility of phosphorus decreases with humification so that phosphorus solubility during the decomposition was subjected to further immobilization. The phosphorus transformation during decomposition of MSW by earthworm species in this study was found to be identical with the findings of Elango et al.[19].

Changes in carbon, nitrogen, C: N ratio and potassium in the composted MSW: The carbon contents were measured from the samples collected from all the six treatments after completion of 60 days of decomposition and found to be highest 13.50% in the treatment T_4 and lowest 11.50% in the treatment T_2. The carbon content values were significantly ($P<0.05$) decreased during the decomposition of MSW by the action of earthworm species. The initial nitrogen content was highest 0.43% in the treatment T_5 and it was lowest 0.38% in T_1. The concentration of nitrogen was highest 0.76% in the matured compost of treatment T_5 and the treatments T_1 and T_3 were measured with lowest 0.55% nitrogen concentration. The potassium concentration ascends right from the beginning of decomposition to the end of decomposition. The treatment T_3 had shown highest 0.42 % potassium concentration and the treatment T_5 showed lowest 0.38 % potassium in the matured compost.

The carbon is the building blocks of complex organic compounds and it is a structural element in all the complex organic materials. The breakdown of complex organic compounds and its transformation into simpler compound are accompanied with the reduction in carbon concentration in the matured compost. Cabrera et al.[20], reported that part of the carbon is lost due to the evolution of CO_2 and the remaining loss is due to assimilation of carbon by the microorganisms. The carbon concentration had been declining continuously while progressing the decomposition and attained fairly stable concentration in the matured compost in all the treatments and the findings of this study matches with the findings of Cabrera et al.[20]. The nitrogen concentration was directly proportional with number of days of decomposition in case of all the six treatments. The increase in nitrogen concentration is due to the breakdown of complex organic compounds and release of simple soluble nitrogen. On progress of decomposition, the nitrogen concentration continued to be increased and reached fairly constant values in the matured compost. Gaur[21] reported that the macro and micro nutrients were increased during composting, due to the loss of organic carbon content as CO_2. The continuous increase of total nitrogen and total potassium in all the treatments under study had been found to be identical with the findings of Gaur[21].

Table-1
Changes in population of earthworms during the period of composting

Characteristics	50 earthworm		100 earthworms		50+ 50 earthworms	
	0^{th} day	60^{th} day	0^{th} day	60^{th} day	0^{th} day	60^{th} Day
Small	0	12	0	30	0	35
Big	50	55	100	112	100	114
Egg	0	22	0	52	0	48

Table-2
Change in pH, EC and total phosphorus during the decomposition of MSW

Treatments	pH		EC (dsm^{-1})		Temperature (^0C)		Total Phosphorus (%)	
	0^{th} day	60^{th} day	0^{th} day	60^{th} day	0^{th} day	60^{th} day	0^{th} day	60^{th} day
T_1	6.40*	7.90	1.52	2.85	36	37	0.13	0.28
T_2	6.32	7.45	1.62	3.12	35	38	0.12	0.30
T_3	6.25	7.80	1.60	3.45	37	36	0.10	0.26
T_4	6.35	8.05	1.50	2.85	36	35	0.15	0.33
T_5	6.20	7.85	1.62	3.05	38	37	0.11	0.29
T_6	6.35	7.69	1.57	2.78	37	36	0.14	0.34

*Values are expressed as mean compared with control.

The initial C:N ratio was highest 66.65 in the treatment T_1 followed 63.85 by the treatment T_2. The lowest 59.19 C:N ratio was observed from the treatment T_5 (table 3). The treatment T_5 was observed with lowest 15.65 C: N ratio and the highest C:N ratio 23.64% was observed from the treatment T_1 of matured compost samples. The narrow C: N ratio of the compost sample collected from the treatment T_5 could reveal that the compost from this treatment attained highest maturity and the earthworm *Eudrilus eugeniae* in 100 numbers was more efficient in the biodegradation of MSW than the other treatments.

Changes in bacterial, fungal and actinomycetes count in the composted MSW: The bacteria are naturally present in the organic matter and it is also present in the intestine of the earthworms. The bacterial population proliferated under the prevalence of favorable substrate which is required for its growth and multiplication (figure 2). The bacterial population was lowest 8.00×10^5 CFU/g in the treatment T_1 and enumerated highest 11.00×10^5 CFU/g bacterial count from the treatment T_4 at the beginning of composting. The enumerated bacterial count from the samples of matured compost had shown the highest 18.00×10^5 CFU/g population by the treatment T_4 followed 17.00×10^5 CFU/g by the treatment T_6. The lowest bacterial count 14.00×10^5 CFU/g was observed from the treatment T_1. The decomposition of organic matter is a dynamic process by the activities of succession of bacterial population (Bhardwaj, 1999) [22]. The existence of low population at the initial stages and fairly stable population in the matured compost were found to have similarity with the findings of Bhardwaj, 1999[22].

The fungal population was highest 9.00×10^2 CFU/g in the treatment T_2 and it was lowest 6.00×10^2 CFU/g in T_4. The fungal population increased up to 30th day and then started declining and reached stable fungal count on completion of decomposition. The increase of fungal population was significant ($P<0.05$) during the decomposition of MSW (figure 3). Actinomycetes are the microorganisms dominating at acidic pH and its population varies with time of composting. The actinomycetes population had been enumerated at regular intervals in all the treatments from initiation of composting to completion of decomposition. The increase of actinomycetes population had continued up to the end of decomposition and attained stable count in the matured compost in all treatments. The highest 11.00×10^3 CFU/g actinomycetes count was observed from the matured compost sample drawn from the treatment T_3 followed 10.00×10^3 CFU/g (figure 4) by T_6 and enumerated lowest 6.12×10^3 CFU/g count from T_4.

Table-3
Change in carbon, nitrogen, C:N ration and potassium during the decomposition of MSW

Treatments	Total carbon (%)		Total nitrogen (%)		C:N ratio		Total potassium (%)	
	0th day	60th day	0th day	60th day	0th day	60th day	0th day	60th day
T_1	25.10*	13.00	0.38	0.55	66.65	23.64	0.23	0.39
T_2	24.90	11.50	0.39	0.58	63.85	19.83	0.21	0.39
T_3	25.20	12.45	0.40	0.55	63.00	22.64	0.24	0.42
T_4	24.75	13.50	0.41	0.63	60.37	21.43	0.22	0.40
T_5	25.45	11.90	0.43	0.76	59.19	15.65	0.21	0.38
T_6	25.15	12.95	0.42	0.68	59.88	19.04	0.22	0.40

*Values are expressed as mean compare with control

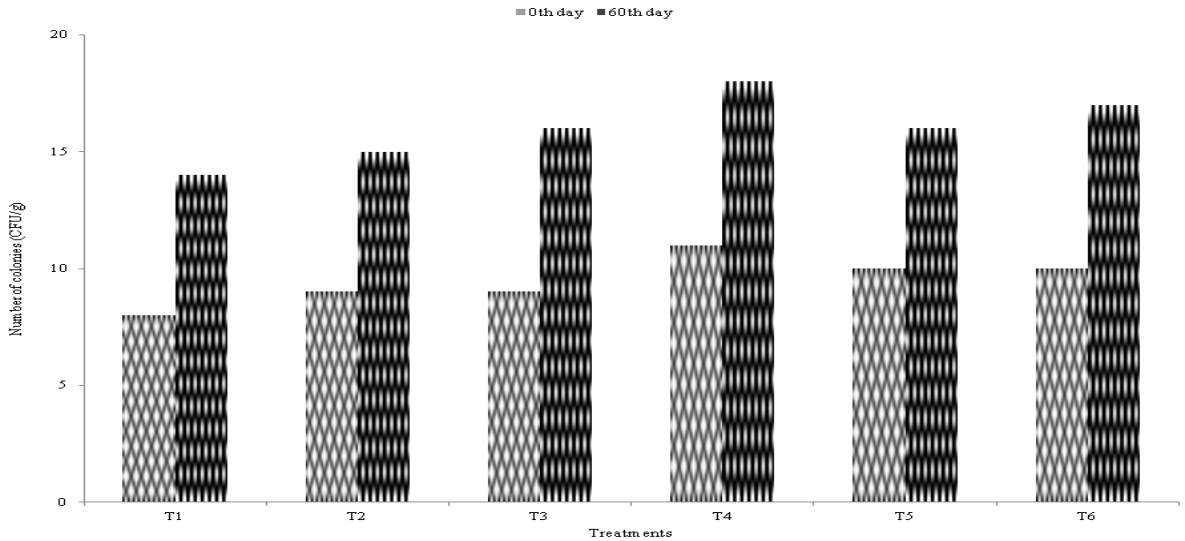

Figure-2
Changes of bacterial population during the decomposition of MSW

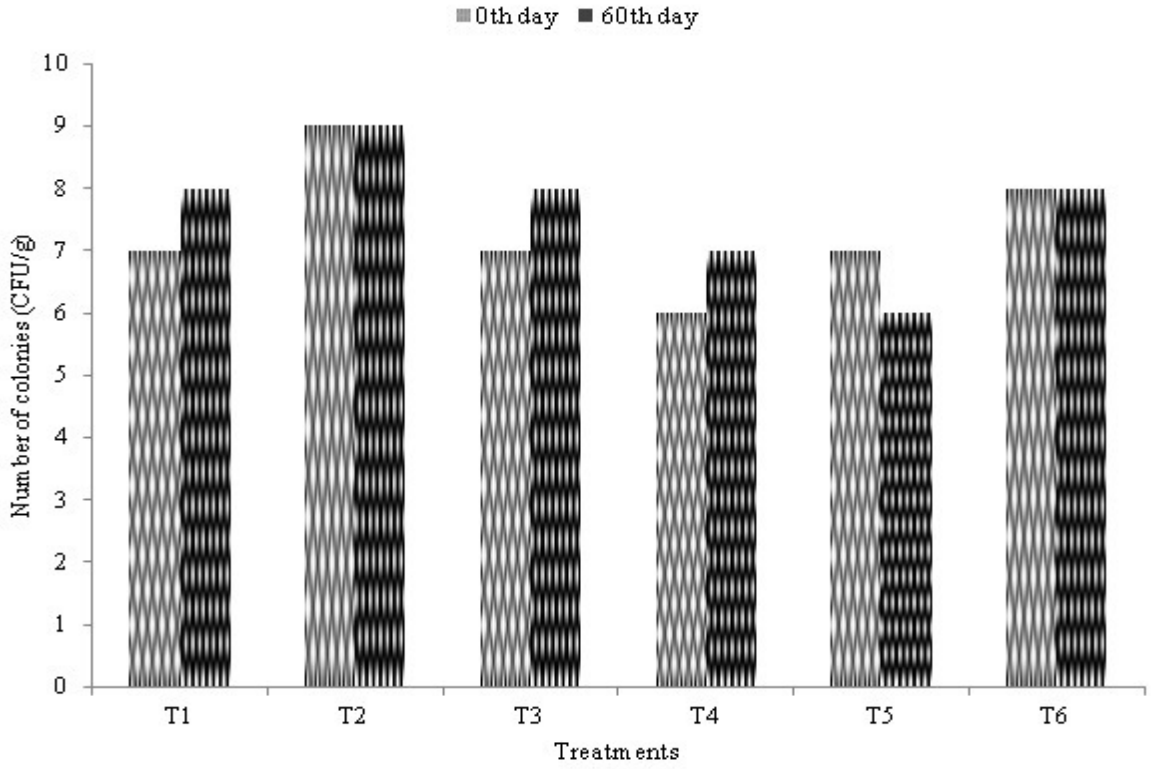

Figure-3
Changes of fungal population during the decomposition of MSW

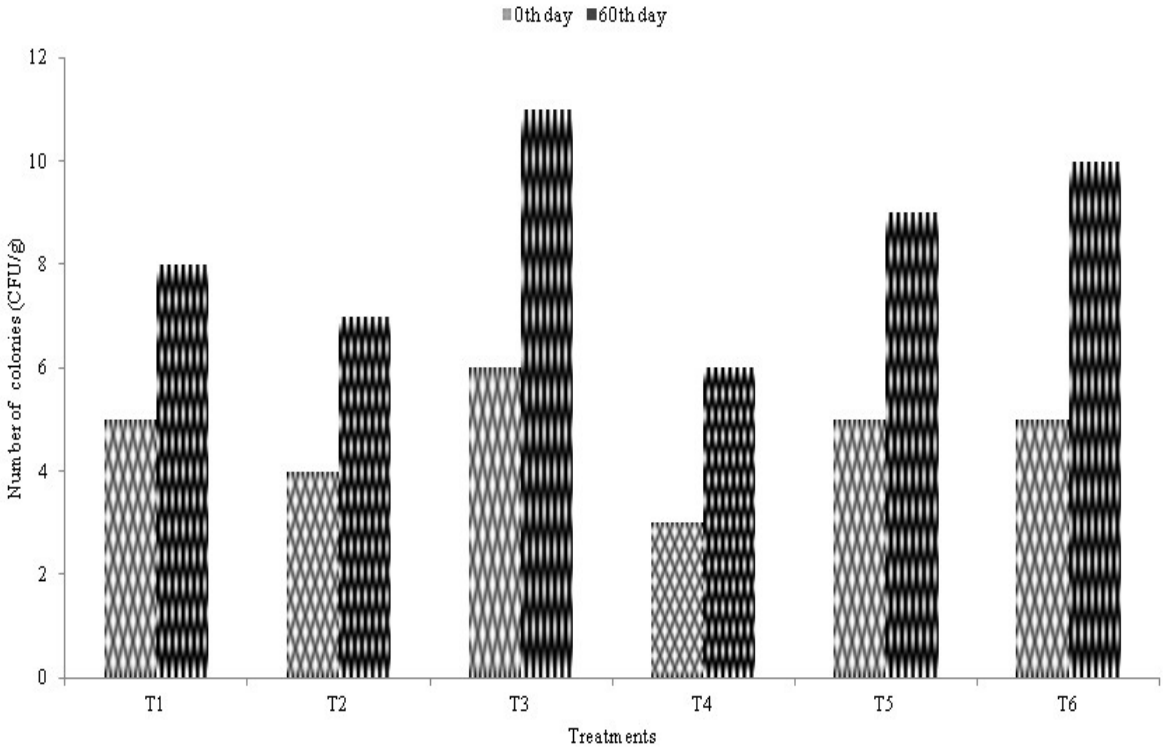

Figure-4
Changes of actinomycetes population during the decomposition of MSW

Changes in micro nutrients and heavy metals in the composted MSW: The concentration of Copper (Cu) was highest 5.10mg/kg in T_6 and lowest 2.25mg/kg in T_3 at the beginning of composting and highest concentration 6.10mg/kg of Cu was measured from the matured compost sample of treatment T_6. In case of Zinc (Zn), the highest concentration was observed at the beginning 12.20 mg/kg and end 13.50 mg/kg of decomposition from the treatment T_6 and lowest concentration at beginning 8.80 mg/kg and at the end 9.80 mg/kg from T_3. The highest 4.15 mg/kg concentration of Manganese (Mn) was determined from the matured compost sample of treatment T_6 and lowest 2.90 mg/kg concentration from T_1. The lowest 5.20 mg/kg concentration of Fe was measured from treatment T_4 at the initiation of composting and highest 9.35 mg/kg concentration was observed from the matured compost samples of the treatment of T_1 (table 4). . The lowest concentration of lead 41.75 mg/kg in T_2, Cadmium 2.20mg/kg in T_5, Chromium 25.25 mg/kg in T_1 and Nickel 27.50 mg/kg in T_3 were observed at the initiation of composting. The concentration of Pb, Cd, Cr and Ni in the matured compost were lowest 38.85 mg/kg in T_1 1.90 mg/kg in T_1 23.80 mg/kg in T_1 and 24.68mg/kg in T_3, respectively (table 5).

The micronutrients concentration in the end product is one of the major factors to determine the manure value of the compost. The possession of ideal concentration of all the essential micronutrients in all the treatments had shown that the matured compost obtained from all the treatments could be used as valuable manure for crop production. The highest concentration of Cu-6.10 mg/kg, Zn-13.50 mg/kg Mn - 4.15 mg/kg was measured from the matured compost samples of the treatment T_6 and Fe-9.35 mg/kg from T_1. The heavy metal concentration in the end product should not exceed the prescribed limits when the end product (compost) is proposed to be used as organic manure in crop production. The prescribed Indian standards for lead, cadmium, chromium and nickel are 100, 5.0, 50 and 50 mg/kg respectively. Even the highest concentration in none of the treatment exceeded the permissible limit of heavy metals standard and hence the compost obtained from the biodegradation of MSW was found to be ideal for field application to raise economic crops.

Conclusion

The biological composting is an effective method for the scientific management of MSW and to tide over the problem of menace due to garbage and its ill effects on land degradation, water pollution and air pollution. The findings of this study revealed that the use of earthworms for the decomposition of MSW could bring good results in converting the waste (MSW) into useful end product (Compost). The bio-composting of MSW with the use of various earthworm species reduces the volume of MSW and paves a way to add value to the MSW by means of converting into useful organic manure. The use of earthworm species for the decomposition of green organic waste nullifies the effect of pollution on land, water and air. While examining the favorable physical, chemical and biological characteristics possessed by the compost obtained from the decomposition of MSW inoculated with different earthworm species in varying numbers, it was found that the MSW inoculated with *Eudrilus eugeniae* in 100 numbers played a pivotal role in the biological break down of green organic matter when compared to various other treatments. So, it can be concluded that *Eudrilus eugeniae* in 100 numbers can be effectively employed for the scientific handling and Eco-friendly management of Municipal Solid Waste. Since, it is an eco-friendly method for the effective management of MSW; it will help to sustain the natural environment without any damage and to sustain crop production by way of application of good organic manure and which in turn aid to preserve the natural resources without any irreversible damage or degradation.

Acknowledgement

We acknowledge the technical helps of the Tamil Nadu Agriculture University Coimbatore.

Table-4
Changes in micro nutrients during the decomposition of MSW

Treatments	Micronutrients (mg/kg)							
	Cu		Zn		Mn		Fe	
	0^{th} day	60^{th} day	0^{th} day	60^{th} day	0^{th} day	60^{th} day	0^{th} day	60^{th} day
T_1	4.75	5.30	10.25	11.30	2.00	2.90	8.00	9.35
T_2	2.75	3.20	11.00	12.10	2.75	3.50	5.50	6.50
T_3	2.25	2.95	8.80	9.80	3.00	3.80	5.25	5.90
T_4	2.90	3.48	10.00	11.30	3.70	4.05	5.20	6.58
T_5	4.00	4.50	11.25	12.45	3.75	4.10	6.40	7.32
T_6	5.10	6.10	12.20	13.50	3.90	4.15	6.10	7.00

*Values are expressed as mean compared with control

Table-5
Changes in heavy Metal concentration during the decomposition of MSW

Treatments	Heavy metals (mg/kg)							
	Pb		Cd		Cr		Ni	
	0^{th} day	60^{th} day	0^{th} day	60^{th} day	0^{th} day	60^{th} day	0^{th} day	60^{th} day
T_1	42.00	38.85	3.10	2.90	25.25	23.80	32.30	31.00
T_2	41.75	40.05	3.05	2.95	33.90	32.00	32.75	29.50
T_3	57.22	56.65	3.25	3.10	27.90	26.50	27.50	24.68
T_4	61.90	60.50	2.70	2.45	33.85	31.20	33.90	30.08
T_5	55.75	53.00	2.20	1.90	35.72	33.50	32.95	32.50
T_6	58.25	56.60	2.90	2.55	33.65	31.50	29.80	28.00

*Values are expressed as mean compared with control

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