Ingenious Method Towards Sustainable Decentralized Solid Waste Management

Naresh K Sharma, C.Sivapragasam, S.Vanitha , K.Ganeshmoorthy, S.Dilipkumar S.Saivishnu, A.M.Muhil

Abstract: ***Solid waste management is a huge environmental threat not just in context to Indian Scenario, but globally as well. It is reported that on average around 1.5 lakh tones of solid waste is generated per day in India of which only 20% is treated and managed safely, the rest is dumped on land or burnt both which are highly toxic to human and animal health. At several waste processing sites in India, the fresh mixed waste received each day, is first manually separated to remove plastics and other non-biodegradable contents, this exposes the laborers to a very unhygienic working conditions and exposes them to deadly microbes and stench.. In the present work, we have developed an ingenious way which handles mixed waste with minimal manual intervention and protects the health of laborers while generating good quality manure. The mixed waste is directly fed in to the bio bins where due to microbial action, the biodegradable components are composted, the treated waste is then separated in to compost and non-biodegradable components using a bench top trommel. It was found that Bioinoculum combined with cow dung quickly achieved the compost of mixed organic waste with minimal maintenance in contrast to vermi-composting. From this study, it is observed that the mixed municipality waste could be treated and managed effectively, safeguarding the health of laborers and the generated compost is of good quality which can be used for crop cultivation or gardening.***

Keywords: mixed domestic solid waste, waste processing, manual waste segregation, vermi-composting, bioinoculum, trommel

I. INTRODUCTION

In India, currently there is not even a single state which achieves complete collection, treatment and processing of solid waste, in fact only 22% of the 1.43 lakh metric tonnes (MT) of solid waste generated each day in India is processed. The remaining 88% of the solid waste (which includes refuse from residential, commercial, institutional, construction sites, municipal services and processing plants; excluding faecal waste) remain unprocessed and are dumped on open land [1]. A recent survey shows that states like Tamilnadu, Andhra Pradesh, Haryana and West Bengal don't even process 10% of their municipal solid waste [2]. The waste dumped on open land poses severe risks of disease transmission, air pollution and contamination of surface and ground water through percolation of leachates. With new cities spurting and mega cities expanding, it is estimated that 300 million MT of solid waste would be generated per year in India [3] posing a severe environmental concern without suitable treatment and processing techniques. The Municipal Solid Waste Rules (Management and Handling, 2016) mandates that every municipal authority segregates, treats and scientifically processes the collected solid waste, a Central Monitoring Committee was also formed to investigate the overall implementation [4]. Despite these efforts, the solid waste management is still one of the major environmental problems. The Indian solid waste characteristics includes around 51% of compostable or organic waste, 10% of recyclable materials and around 40% of inert wastes [3] unlike the solid waste from western countries having less organic content to it. In the current scenario, the mixed waste collected from various sources reaches the dump site, where the waste is first manually segregated to remove plastics and other non-biodegradable components as this may hinder the microbial action and delay or inhibit the composting process [5]. The manually segregated waste is then separated on a trommel into sizes suitable for shredding and then subjected to composting. There are various approaches to waste processing which includes (i) waste to compost (Aerobic/Anaerobic composting and vermi composting) (ii) waste to energy process (Refuse Derived fuel / Palletisation and Bio methanation). The major gaps identified and addressed in this work are to (i) reduce manual separation of fresh waste which has highly offensive odour and exposes the health of workers to deadly diseases (ii) identify and implement effective composting technique for mixed solid waste collected at Kalasalingam Academy of Research and Education (KARE), Tamil nadu, India. An ingenious approach has been conceived and tested to improve the efficacy of composting and drastically reduce manual segregation. In this work, the fresh mixed is directly subjected to composting without the need of pre-manual separation, here different combinations of cow dung, bioinoculum and vermi-worms were tested to identify the

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***** Correspondence Author

Naresh K Sharma*, Biotechnology, Kalasalingam Academy of Research and Education, Tamilnadu, INDIA.

Sivapragasam C, Civil Engineering, Kalasalingam Academy of Research and Education, Tamilnadu, INDIA.

Vanitha S, Civil Engineering, Kalasalingam Academy of Research and Education, Tamilnadu, INDIA. E

Ganeshmoorthy K, Civil Engineering, Kalasalingam Academy of Research and Education, Tamilnadu, INDIA.

Dilipkumar S, Civil Engineering, Kalasalingam Academy of Research and Education, Tamilnadu, INDIA.

Saivishnu S, Civil Engineering, Kalasalingam Academy of Research and Education, Tamilnadu, INDIA.

Muhil A M, Civil Engineering, Kalasalingam Academy of Research and Education, Tamilnadu, INDIA.

effective method to compost the waste. The composted waste which is now free from odour and deadly microbes can then be separated to manure and non-biodegradable components. Much of the organic waste more than 70 mm size which would otherwise be rejected by trommel are also composted in our approach when the fresh waste is directly composted in contrast to the existing method where the fresh waste is pre-separated first manually and then by trommel before shredding and composting. This work highlights the importance of direct composting of fresh waste to safe guard the health of labourers and use of bio-inoculum for effective and sustainable solid waste management.

II. MATERIALS AND METHODS

A. Existing Solid Waste Treatment Method

In the existing method of mixed solid waste management, the fresh mixed solid waste is manually separated to remove plastics which otherwise hinders the composting process. The manually separated waste then goes to a trommel where wastes of specific sizes are sorted (say, using a 70 mm or 100 mm mesh). The wastes less than the mesh size are shredded and composted using aerobic composting or vermi composting. Usually organic wastes greater than mesh sizes are also removed by the trommel and these wastes do not undergo composting as they still are mixed with non-biodegradable waste greater than 70 mm size which results in loss of energy. The various steps involved in the management of solid waste is illustrated in the Fig.1

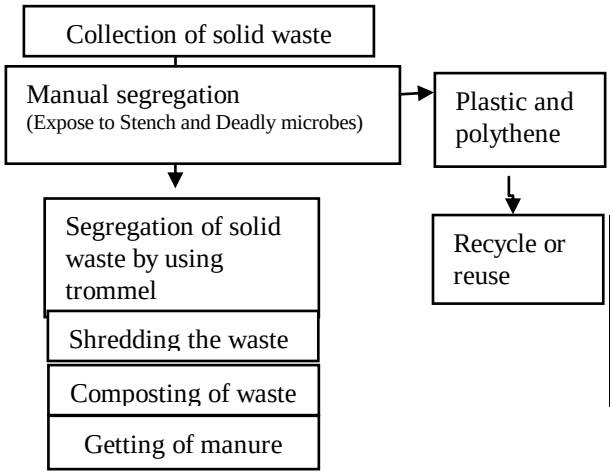

Fig 1: Steps followed at solid waste processing sites

B. Ingenious approach towards solid waste management.

In the new approach of solid waste management presented here, two gaps were identified in the existing treatment method and addressed herewith. The fresh mixed solid waste is directly exposed to composting which reduces the health risks of the labourers and the entire organic waste is decomposed which would otherwise get wasted in separation by trommel. Several combinations of composting methods have been tested with various proportions of cow dung, bioinoculum and vermi-worms. These composting methods were tested on 3 kg of mixed solid waste collected from the Kalasalingam Academy of Research and Education, Tamil nadu, India. The steps involved in the ingenious approach of solid waste processing is detailed in Fig. 2.

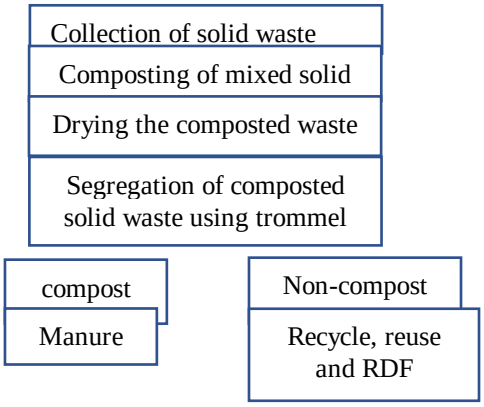

Fig 2: Steps involved in the ingenious approach of solid waste management

C. Size Analysis

The size analysis was done on the fresh mixed waste collected from the premises of Kalasalingam Academy of Research and Education (KARE), Tamilnadu, India. The sizes of various wastes were measured using a standard Vernier scale and average values reported from three grabs of waste samples collected on three different days.

D. Composting

Composting was carried directly on mixed solid waste without any manual or machine pre-segregation containing all the mixed waste (bio and non-biodegradable) components. Composting were performed using two different combinations of bio-inoculum (i) Vermicomposting + Bioinoculm and (ii) Cow dung + Bio inoculum. The description of each of these bins is reported in the Table: I:

TABLE I: DESCRIPTION OF COMPOSTING EXPERIMENTAL METHODS TESTED ON MIXED SOLID WASTE

Bio-bins Notation	Description
Bin A	Control (only mixed waste without any addition of cow dung, bio-inoculum or vermin-worms)
Bin B	3 kg waste + 3 kg cow dung + 40 earth worms
Bin C	3 kg waste + 3 kg cow dung + 500 ml of bio-inoculum twice each week

The experiment was performed in duplicates and average values reported. The experiments were carried on for 15 days until the biodegradable matter were visibly composted and no odour was observed.

E. Molecular Formula

Molecular formula of the solid waste calculated using the methods described in Municipal Solid Waste Management Module II [6]. The moisture content of the solid waste was carried using the methods mentioned in APHA, 2005 [7].

F. pH and Conductivity

The pH and conductivity of all the samples was measured using digital pH and conductivity metre (Systronics, 2012).

G. Trommel Design and Fabrication

The trommel is designed based on the analysis of the particle sizes present in the mixed solid waste.

The trommel is designed for hand rotation with the base stand of height 2 feet and the rotating drum covered by mesh of 2 mm with the inclination of 30°.The length of the rotating drum is 1 m. The trommel is designed to separate the manure through the mesh and the non-degradable waste on the other side of drum by the inclination of the rotating drum. The trommel was fabricated from the scraps found in the KARE workshop.

I. RESULT AND DISCUSSION

A. Size Analysis.

The mixed waste collected from the premises of Kalasalingam Academy of Research and Education, was analysed and separated into various categories based on the sizes. The average of three different waste composition collected during different days is reported in Table II. It could be observed that the sample represented a mixture of all types of waste usually generated from households. Various types of plastics of different densities, food and vegetable waste, paper and cardboard waste were found in the sample. The sizes of waste ranged from less than 1 cm to waste larger than 25cms which included polythene bags and milk plastic bags.

TABLE II: SIZE ANALYSIS OF FRESH MIXED WASTE SAMPLES

Sr.no	Size range (cm)	Example
1	20-25	Milk packed, masala covers
2	15-20	Grass, masala covers, papers
3	10-15	Kitchen waste, food waste
4	10-12	Masala covers ,shampoo cover, etc
5	5-10	Paper, polythene plastic covers
6	1-5	Coffee cups, onion waste, food waste, etc

B. pH and conductivity

The *Ph* and conductivity of the samples were analysed on 15th day of start of the experiment. It could be seen that the wastes after compost had Ph values close to neutral range (Table III). Also the conductivity values (Table IV) showed was close to 1 ms/cm and no significant difference in Ph and conductivity were observed between vermi-composting and bioinoculum based treatments.

TABLE III: pH VALUES

Types of composting	pH (±0.5)
Control	7.5
Cow dung and vermicomposting	7.8
Cow dung and bio inoculum	7.90

TABLE IV: CONDUCTIVITY VALUES

Types of composting	Conductivity (±0.5 ms/cm)
Control	1.101ms/cm
Vermicomposting	1.510ms/cm
Cow dung and bio inoculum	1.360ms/cm

The compost microorganisms operate best under neutral to acidic condition with pH in the range of 5.5 to 8 [8].

C. Composting.

There are several reports and experimental documentations on composting of fresh waste using different methods [9-10]. The characteristics of mixed waste greatly influences the composting process; the composition however, depends upon wide range of factors like food habits, lifestyle and local climatic changes. The composting experiments were done using Bioinoculum, cow dung and vermi – worms. Various bins were taken to accommodate approximately 3kgs of mixed waste without pre segregation and experiments were performed till a visible change of organic waste in to compost was observed. Of the various bins studied, it could be seen that the bins with bio inoculum and cow dung achieved the degradation process quicker (at 12th day) while significant changes were observed in vermicomposting only after 15 days. Moreover, during the experiment it was observed that vermi worms were very sensitive to the changes in temperature, moisture and therefore required careful maintenance in contrast to cow dung and bio inoculum bins. The overall observation from the bins is reported in the Table. V. After 15 days of composting the samples were dried in sunlight and fed to trommel for separating the composted and non-biodegradable matter.

TABLE V: OBSERVATION OF BIN BINS WEEKLY

Week	A1/A2 bin (Control)	B1/B2 bin (vermicomposting + waste)	C1/C2 bin (Bioinoculum+ cowdung +waste
1st week	Waste	Cow dung + waste	Cow dung + waste
2nd week	There were no observable change	Adding of earth worms	Adding of bio inoculum
3rd week	There were no observable change	Reduce in smell and weight and colour	Reduce in smell

After composting,the mixed waste was kept for 2 days under sun drying for easy separation of non-biodegradeable and bio-degradeable waste by using of trommel as shown in fig 3.

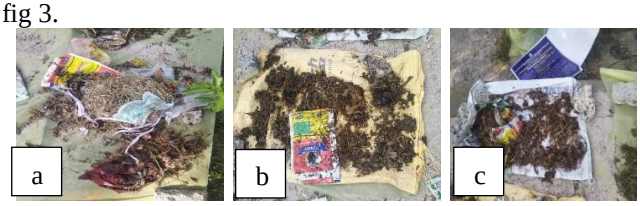

Fig 3: Sun drying of composted waste (a) control (b) Vermi-composting and (c) cow dung and bio-inoculum

D.Trommel Segregation and Manure

After composting and drying, the waste was segregated into biodegradable and non-bio degradable fractions using a 2 mm mesh sized trommel. The trommel could be rotated by both manually or using a motor belt. The biodegradable fraction could be used as manure while the non-bio degradable fraction could be recycled, reused and used as refuse derived fuel in many industries. The photo image of the separated manure is shown in Fig.4.

Fig 4: Photo image of the generated manure by using the ingenious approach of solid waste processing

E. Molecular Formula

The molecular formula for the manure generated from the waste is calculated using [6]. This method is based primarily on the moisture content of the waste and calculated based on the wet and dry weight of the waste. The wet and dry weight of different categories of solid waste is given in Table VI. From the Table VII moisture

content of various categories of solid waste can be observed, it is seen that food and yard waste had high moisture content; a significant portion of which contributes to manure production. The typical fraction of each element such as carbon, nitrogen, hydrogen, oxygen and ash present in a typical domestic solid waste found in India was used [6] as shown in Table VIII. Using the element fraction values and moisture content values of the waste, the molecular formula for the manure was calculated. The fraction of each element in the solid waste sample is given in Table IX, similarly the weight of each element (with and without water) in the solid sample was calculated and given in Table X.

TABLE VI WET AND DRY WEIGHTS OF DIFFERENT SOLID WASTE

Component	Wet weight (g)	Dry Weight(g)
Food Waste	26.3	4.872
Paper	8.43	8.162
Plastic	8.57	8.216
Yard	6.32	4.973
Total	50	26.223

$$M = \frac{Ww - Dw}{Ww} \times 100$$

M=Moisture Content

W_w=Wet Weight

D_w=Dry Weight

TABLE VII MOISTURE CONTENT FOR THE SOLID WASTES

Component	Moisture Content (%)
Food Waste	81.74
Paper	4.13
Plastic	3.18
Yard	21.31

TABLE VIII: COMMON FRACTION OF EACH ELEMENT IN TYPES OF WASTE

Component	C	H	O	N	Ash
Food Waste	0.480	0.064	0.376	0.026	0.050
Paper	0.435	0.060	0.440	0.003	0.060
Plastic	0.600	0.072	0.228	-	0.100
Yard	0.478	0.060	0.350	0.034	0.045

TABLE IX: COMMON FRACTION VALUES OF EACH ELEMENT

Component	C	H	O	N	Ash
Food Waste	2.34	0.32	1.83	0.13	0.24
Paper	3.55	0.49	3.59	3.59	0.49
Plastic	4.93	0.59	1.87	1.87	0.82
Yard	2.38	0.30	1.89	1.89	0.22
Total	13.2	1.7	9.18	9.18	1.77

Weight of Water = 50 – 26.223 = 23.78 g

Weight of H present = 23.78g $*$ (2 ÷18)

= 2.64 g

Weight of O present = 23.78 g $*$ (16 ÷18)

= 21.14

TABLE X: WEIGHT OF ELEMENT WITH AND WITHOUT WATER

Element	Weight w/o water (g)	Weight w/ water (g)
C	13.2	13.2
H	1.7	4.34
O	9.18	30.32
N	0.32	0.32
Ash	1.77	1.77

Molar Composition of the element present in solid waste is determined by dividing each component by its respective molar weight as shown in Table XI. The mole ratio was determined by dividing the number of moles of each element by the lowest number of moles (here the value of sulphur was used). The molar ratio thus obtained is shown in Table XII. The chemical formula for this particular solid waste sample is $C_{183.33}H_{283.33}O_{95}N_{3.83}$ without water & $C_{183.33}H_{723.33}O_{315.83}N_{3.83}$ with water. The heavy metals present in the manure were not determined in the present study. However, with the molecular formula obtained it is clear that the generated manure is suitable for crop cultivation or gardening.

TABLE XI: MOLAR COMPOSITION

Element	Atomic Weight	Moles w/o water	Moles w/ water
C	12	1.1	1.1
H	1	1.7	4.34
O	16	0.57	1.895
N	14	0.023	0.023

TABLE XII: MOLAR RATIO

Element	Mole ratio w/o water	Mole ratio w/ water
C	183.33	183.33
H	283.33	723.33
O	95	315.83
N	3.83	3.83

III. CONCLUSION

From the various methods, bio inoculum and cow dung was observed to effectively treat the municipal mixed waste in 15days. Bio inoculum proved to be an effective means to treat mixed waste and required minimum maintenance in contrast to vermicomposting. The treated mixed waste could be separated from non-biodegradable component using trommel with least manual intervention without risking the health of the labourers. The molecular formula and chemical characteristics shows that the compost is suitable for crop irrigation while the non-biodegradable fractions could be recycled or used as refuse derived fuel.

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AUTHORS PROFILE

Naresh Kumar Sharma is an Associate Professor at Kalasalingam University in Department of Biotechnology. He completed his PhD from IIT Madras. His research interests include bioremediation and wastewater treatment.

Sivapragasam C is a Professor in Department of Civil Engineering, Kalasalingam Academy of Research and Education. He completed his PhD from NUS Singapore and has published several papers in the area of Artificial Intelligence in Water resources, Genetic Programming and Hydraulics. His h-index and i10 index are 11 and 12 respectively.

Vanitha S is an Associate Professor in Department of Civil Engineering, Kalasalingam Academy of Research and Education. She completed her PhD in the area of Genetic Programming and environmental engineering. Her h-index and i10 index are 4 and 1 respectively.

Ganeshmoorthy K is an undergraduate student in the Deparmtent of Civil Engineering at Kalasalingam Academy of Research and Education.

Dilipkumar S is an undergraduate student in the Deparmtent of Civil Engineering at Kalasalingam Academy of Research and Education.

Saivishnu S is an undergraduate student in the Deparmtent of Civil Engineering at Kalasalingam Academy of Research and Education.

Muhil A M is an undergraduate student in the Deparmtent of Civil Engineering at Kalasalingam Academy of Research and Education.