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Perfect home composting of biodegradable waste resources for reducing carbon foot print and climate change associated with global warming – a microbiological approach

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Abstract

Huge amounts of organic biodegradable waste resources are thrown on dumping yards in India and neighboring Asian countries every day. It is estimated that 40-50% of total solid waste collected daily is biodegradable in India. Mumbai, a 1% population of the country, generates about 2500 MT of biodegradable waste. The African continent is no exception to this colossal wastage of natural resources. Barring few countries in the developed world where these waste resources are handled appropriately and environmentally friendly and converted to good quality compost, the story is the same worldwide. This waste resource amounting to millions of metric tonnes is one of the key sources of biomethane escaping in the environment. It is also directly responsible for global warming and associated climatic changes. However, the waste resource generators have been permitted to wash off their hands in not taking care of small amounts of wastages. The result is huge sprawling dumping yards in civilized areas Small measures taken by individuals can make vast changes in the situation. The main reason for this centralized issue is that the decentralized generation of the waste resource is not tackled at that level. This method has two key factors. The method is based entirely on bacterial decomposition without involving any insects. It is also fast and can achieve conversion in 24 to 72 hours. A sincere approach supported by technological improvisation will make it successful and prevent huge amounts of bio-methane from escaping into the environment, which would certainly slow down global warming significantly and help arrest climate changes to a perceptible level. It would also be in tandem with the law of conservation of matter. The generation of pure organic manure will help in recovering the degrading topsoil layer of the country. A perfectly sustainable solution can be offered if all individuals play their part.

Keywords

Solid waste resource, Recycling, Home composting, Global warming, Climate change, Bio-methane, Aerobic composting, Segregation, Bacterial composting, Insect-free composting, Responsible citizens

Imprint

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1 Introduction

Solid waste resource management is a big challenge faced by urban local bodies all over the world. A good discipline in civilized society in the developed world has helped solve this issue satisfactorily, mainly through source segregation and proper scientific disposal. Many European countries like Sweden, Norway, Switzerland, Denmark, Germany, France, and England have effectively handled these segregated resources encouraging their recycling and reducing pollution levels significantly. However, the overall lack of civil discipline in Asian and African countries backed with huge populations has complicated this issue in the developing world. Increasing populations with changing lifestyles have further intensified the issue.

Municipal solid waste (MSW) landfills are listed as the third-largest source of human-related methane emissions in the United States, accounting for approximately 14.1% of these emissions in 2017 [1]. Simultaneously, methane emissions from landfills represent a lost opportunity to capture and use a significant energy resource. Thickly populated countries like India and China produce gigantic amounts of solid waste daily, causing extensive dumping yards [2]. Indian population has grown from 376 million in 1950 to 1380 million in 2019 (as of December 15, 2019), which amounts to a rise of 367% in about 69 years. An average annual raise of 5.3% with a starting figure of

376 million will impact all sectors of life. The unorganized sector of municipal solid waste has been taking its toll on environmental pollution [3].

The population of six metro cities in India viz. Mumbai, Kolkata, Delhi, Chennai, Hyderabad, and Bengaluru have been estimated as 137.8 million in December 2019 (23+58.6+19.9+11.1+12.2+13 million respectively) [4]. They generate 43000 metric tones of solid waste daily. Considering that these cities account for about 10% of the total Indian population, a simple extrapolation puts the daily solid waste figure 430,000 Metric tonnes [5]. Most of the studies carried in the last few years have suggested that more than 50% of solid waste is organic and biodegradable. Two hundred thousand metric tonnes of biodegradable waste will be a potentially good source for generating 40000 metric tonnes of good quality organic matter if handled scientifically. Annually, this figure touches 14 million tonnes of organic manure on a national level [6].

A country which is by and large an agricultural country, it is of paramount interest that we develop means to convert the biodegradable waste into good quality organic manure by composting and make sure that it reaches the nearest farm immediately, which [7] is true not only for India but also for other countries too [8]. Since India's urea consumption stands at 30 million tonnes annually, this organic manure's importance can easily be underlined [9]. We can replace half the quantity of urea if all the citizens play their role. Organic manure has an added advantage of increasing productivity through improved soil microbiological properties and nitrogen sources [10]. Hence it should be supported. Its use will also help in promoting organic farming in the country. The impact of chemical pesticides has been experienced the world over. Therefore, organic farming is the need of the hour [11]. There are success stories in Europe. It has been shown that simple, inexpensive methods can help convert biodegradable waste into usable compost [12]. There are university education programs in Europe that play a leading role in awareness and helping people to compost their waste [13],

The present scenario is very disappointing and harmful in the long term for resource recycling concerning biological waste management. Millions of tonnes of unsegregated solid waste are reaching dumping yards daily. Though indeed, nature will eventually take care by degrading this waste over some time, the route taken for such degradation would be disastrous [14]. Huge accumulations of biodegradable waste materials on dumping yards develop anaerobic conditions quickly, and bio-methane starts escaping into the environment. Every metric tonne of biodegradable waste can, on average, generate about 20 to 40 Kg of methane. It also contaminates the generated manure with heavy metals and plastic materials. Dumping of huge quantities of un-segregated solid waste becomes important to point sources of major greenhouse gas. Hence the contribution of mismanaged solid waste sector is directly responsible for global warming and resulting climate change. It also produces contaminated manure which is bound to have long-term effects on soil fertility and eventually poses a problem in crop yields [15].

The scientific solution to this problem is relatively simple. However, it involves the need to change the mental attitude. Indian citizens have been trained to throw the waste in municipal vehicles for more than a few decades. Waste generators were never made responsible for processing it. Suddenly, asking such people to segregate their waste and treat it is not appreciated by a large population section. Why should I do it? That is the key question asked by people. "My waste, my responsibility" is to be understood and implemented by everyone, and this would take probably two generations time in the developing world. Continuous efforts are required to be done to create awareness in society at various levels. These efforts are to be supplemented with developing simple methods which can encourage people to process the waste at their level. The increasing need felt by leading educational institutes to strive for Zero Garbage Campus is a ray of hope that people are now thinking seriously.

The steps suggested to reduce dumping yards and thereby reduce the environmental pollution are as follows:

- Reducing waste as much as possible. This step is highly relevant for biodegradable waste. The quantum of well-cooked food wasted in marriages and celebrations, seminars, restaurants, hostel messes, and even in households is so large that one wonders whether citizens in this country ever understand the importance of food. How easily one insults his spouse, mother, farmer, and Mother Earth, who take tremendous efforts in reaching that food to his or her dish! We must stop this waste at once. The same thing applies to clothes, shoes, electronic goods, and household goods. We must buy minimum things and reuse them as much as possible.

- Segregation at the waste resources source in five different kinds, viz., biodegradable, glass, metal, recyclable plastics, and landfill.
- Processing of biodegradable waste resources at household and community levels to prevent their entry into dumping yards. Household and small community biodegradable waste can be handled by composting. We are presenting here a simple and environmentally friendly method for home composting. The same method can be used for smaller communities like multistory buildings, small restaurants, schools, colleges, and small offices and establishments. Biogas plants can handle large quantities of biodegradable wastes generated in big restaurants, vegetable markets, and slaughterhouses. Bhabha Atomic Research Centre has developed Nisargruna technology for this purpose.
- Collection of other kinds of waste resources separately and send them for recycling.
- Create a sanitary landfill for non-recyclable materials. It is expected that only 10 to 15% of the present quantities would only reach sanitary landfills after segregation at the source.
- The household biodegradable waste consisting of unused portions of fresh vegetable residues, fruit peels, rotten vegetables and fruits, and non-edible parts of non-vegetarian food cannot be reduced and inevitable in any kitchen. Although composting is an age-old process, we have developed an innovative method based on bacterial degradation, fast, odorless, and insect-free. Since it is insect-free and odorless, we feel that it would be widely accepted and help biodegradable waste resources' decentralized processing.

2 Methods and materials

2.1 Home composting

It is expected that, on average, a family of four members will generate 600 -800 g of vegetable and fruit waste daily. Two plastic buckets of 50 L capacity with a tight-fitting lid were taken to handle this quantity of biodegradable waste. A good number of holes of 0.5 to 1 mm were drilled at the bottom. Similar holes were drilled on the lid to permit excess water to escape. A 2" thick sponge cut to size was placed at the bottom of each bucket. A thin layer of coconut husk was spread on this sponge. 3 kg fresh organic manure and 200–300 g of coco peat or sawdust in each bucket were added and mixed thoroughly. This mixture's moisture level was adjusted to 60% water holding capacity (WHC) of organic manure. Coco peat which is obtained in powder form by fermenting coconut husk can absorb much moisture.

Initially, 4 l water was needed to reach 60% WHC. 200 g of powdered jaggery (a sweet sugar-like product made from sugarcane in Asian countries) was added to each bucket and mixed with the manure. If jaggery is not available, sugar may be used. About 500 ml of homemade fresh buttermilk (diluted probiotic yogurt) in each bucket was sprayed, and buckets were left undisturbed for 4days. During this incubation period, they were covered with lids. A bacterial consortium was developed in each bucket (Figure. 1). The buckets were ready to receive the biodegradable waste resources. These buckets had to be used on alternate days. This experiment is continuing for the last five years without any significant break. The waste resource added to each bucket on alternate days varied from 500 to 1000 g. These waste resources were collected once a day, chopped into as fine pieces as possible (Figure 2), and mixed. Nothing should be visible on the surface. Initially, additional small quantities of organic manure were needed to cover the residues on the surface. Afterward, when a good build-up of culture and manure started forming, this addition was discontinued. Liquid waste residues were never added to these buckets. The manure was removed occasionally when the buckets were full, sieved through 20 meshes net, and analyzed as per IS 500 standards. Most of it has been used as a culture for individual households in neighboring areas interested in this experiment. Some of it has been used for the home garden. The experiment will continue in the future too.

2.2 Community composting

Five larger bins of size 200L were used for this purpose. The culture development was the same as per home composting. Every day about 45 to 50 Kg finely chopped (manually) waste resource was added in alternate five bins for one year. Every week each bin was used once as the Institute works only for five days a week.

2.3 Sample collection

A composite sample of compost was collected after thorough mixing of the samples collected from composting units. Sample collection was done as per the procedure laid out for drawing a sample of fertilizers in the Fertilizer (Control) Order 1985.

2.4 Organic manure analysis

Physical and certain chemical parameters of the sample were studied at the in-house laboratory of Symbiosis Centre for Waste Resource Management (SCWRM) of Symbiosis International (Deemed University), Pune. The sample was then cross-checked at that the National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited Fertilizer Control Laboratory, Pune of Department of Agriculture, Government of India, for confirmation of results. The parameters studied were in terms of pH, color, odor, particle size, moisture percent by weight, bulk density, electrical conductivity, total organic carbon, total nitrogen (as N), total phosphorous (as P2O5), water-soluble potash (as K2O), Carbon to nitrogen (C:N) ratio, and micronutrients such as zinc (as Zn) and copper (as Cu). All the analytical methods followed by the Fertilizer Testing Laboratory were NABL approved for the specifications laid out by The Fertilizer (Control) Order 19857 for city compost.

3 Results and discussion

Household waste resource generated in kitchens is never considered significant for any life activities. However, it is a very important resource for various elemental cycles for Mother Earth. Five years' data collection of kitchen waste generated from a household of four members is given in Table 1.

Table 1
Quantity of waste resource added every year and manure recovered in home composting

Year	Bucket 1 Kg	Bucket 2 Kg	Manure recovered Kg
2015	200	180	75
2016	210	180	80
2017	190	250	80
2018	180	250	70
2019	180	170	65
Total	960	1030	370

In community composting, the waste resources were available for about 200 days in a year as the Symbiosis International (Deemed University) work for these many days in a year. The total waste resources processed were about 9000 kg, and 2200 kg manure was recovered.

There is not much variation in daily generation from the given household. The characterization of waste shows only limited variation as eating habits do not change easily. It is expected that the food habits of any family do not significantly change. Occasionally some variations might happen in the type of food eaten, and quantities may drop to zero during vacations or increase when guests are there. However, overall conditions remain more or less unchanged. Table 1 reveals that a family of four generates daily 1 kg of waste resource in the kitchen and can generate about 75 kg of good quality organic manure annually, which would help them prevent their contribution of 400 kg of contaminated waste to the dumping yard. There is also the counter contribution of 75 kg organic manure to the agricultural sector. In a civilized society, every individual can lower his carbon footprint print by adopting this method - in community composting involving a community of about 3000 students, the annual waste processed was about 9 MT. Suppose households and communities can handle their waste in this manner. In that case, a large fraction of waste will not reach dumping yards.

The bacterial consortium analysis showed the domination of Bacillus species in the organic waste decomposition. The decomposition is an exothermic process and generates a good amount of heat. After the addition of the fresh waste, the unit's core temperature had reached a maximum of 60C for few hours. Bacillus domination in the consortium, therefore, is not surprising. Bacillus pumilus, Bacillus stratospheric, Bacillus amyloliquefaciens, Bacillus subtilis were predominantly present. The other bacteria present in the consortium were belonging to Serratia, Pseudomonas, Sphingobacterium, and Lactobacillus. Although bacteria completely dominated the consortium, few fungal species were also found to be consistently present. They included Aspergillus niger, Mucor, Rhizopus, and Candida tropicalis.

It must be emphasized that fine chopping of biodegradable waste resources plays an important role in faster degradation of it as bacterial consortium can access it more effectively. The mixing of the waste in the subsurface layer also is a very important step. It avoids flies, fruit flies completely, and the unit remains completely insect-free. The rate of degradation is also faster. We have observed in-home and community composting takes about 48 to 72 hours for complete degradation. The process of being odor-free is conducive for people to adapt easily.

The organic manure generated in home composting should be as per norms laid down by FCO. The specifications for various parameters are listed in Table 2. The organic manure analysis against parameters and specifications as per FCO guidelines is given in Table 2.

Table 2
The organic manure analysis against parameters and specifications as per FCO guidelines

Sr. No.	Parameter	Specification as per FCO		Home	Community
1	Moisture content by weight	Max	25.00	20.00	30.52
2	Color	Dark brown to black		black	black
3	Odor	Absence of foul odor		absent	absent
4	Particle size (-4 mm Sieve)	Min	90%	95	82.63
5	Bulk density (g/cm3)	Min	1.00	2.55	2.05
6	Total Organic Carbon % by weight	Min	12.00	16.75	23.78
7	Total nitrogen (as N) % by weight	Min	0.80	0.82	0.66
8	Total Phosphorus (as P2O5) % by weight	Min	0.40	0.46	0.78
9	Total soluble potash (as K2O) % by weight	Min	0.40	0.80	2.40
10	C:N ratio	Less than	20.00	20.42	35.83
11	pH		6.50 - 7.50	7.30	8.10
12	Conductivity (ds/m)	Less than	4.00	2.85	3.76
13	Zinc (as Zn) mg/kg	Max	1000.00	ND	1.19
14	Copper (as Cu) mg/kg	Max	300.0	ND	5.41

Both home compost and community compost were reasonably satisfactory. Out of the two processes, home composting is looking to be more efficient, yielding better results. It underlines those small-scale composting yields better results as parameters can be easily controlled at the individual household level, encouraging common people to undertake this process and reduce the waste quantity reaching dumping yards. The community composting will be successful depending on effective source segregation. If that fails, as we have seen several times, the quality of manure and degradation process is adversely affected.

Major hurdles experienced by any civilized society in home composting are

a) The mental attitude that waste processing is not their responsibility.

b) An associated foul odor and insect menace

c) What to do with the organic manure generated

We have sincerely tried to cross all these hurdles through a scientific sense and experimentation, which has yielded insect-free bacterial composting of household biodegradable waste generated in the kitchen. If we can stop the quantum of cooked food in wastage, the process remains insect-free. Though insects in the composting process play an important role, the family's mindset fails to understand this. Hence, by avoiding cooked food waste, if we can achieve this, then why not? It will also save the colossal losses of precious food. Simple procedural steps of chopping the vegetable and fruit waste into as small pieces as possible and making sure that they are not exposed during composting can achieve faster odor-free and complete degradation resulting in good quality manure. We hope that responsible citizens take up this simple issue and help reduce climate changes associated with global warming. Figure 1 discusses about free bacterial culture developed in a bucket for home composting in details. Where, biodegradable waste chopped into smaller pieces for ease of degradation are shown in Figure 2.

Fig. 1. Insect free bacterial culture developed in a bucket for home composting

Fig. 2. The biodegradable waste chopped into smaller pieces for ease of degradation

4 Conclusions

Solid waste resource management is a big challenge faced by urban local bodies all over the world. A good discipline in civilized society in the developed world has helped solve this issue satisfactorily, mainly through source segregation and proper scientific disposal. Composting is an age-old method that plays an important role in maintaining biogeochemical cycles of various elements and sustaining the living world. Various life forms are involved in composting process. Earthworms, bacteria, and fungi are the key organisms. They work in tandem. However, the civilized human population poses challenges to the composting process. Though no one wants the dumping yard, their actions are not very helpful or conducive. Simple procedural steps of chopping the vegetable and fruit waste into as small pieces as possible and making sure that they are not exposed during composting can achieve faster odor-free and complete degradation resulting in good quality manure. We have observed in-home and community composting takes about 48 to 72 hours for complete degradation. The process of being odor-free is conducive for people to adapt easily.

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Conflict of Interest

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