IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 9, Issue 5 Ver. I (May. 2015), PP 20-29
www.iosrjournals.org

A Review on Composting of Municipal Solid Waste

K.R. Atalia[1], D.M. Buha[1], K.A. Bhavsar[2], N.K. Shah[1]
[1] *Department of Chemistry, School of Sciences, Gujarat University, Ahmedabad, Gujarat, India*
[2] *Department of Environmental Science, School of Sciences, Gujarat University, Ahmedabad, Gujarat, India*

Abstract: *Municipal Solid Waste management is becoming a critical problem in most of the megacities of the world as waste volume continues to rise, which leads to the loss of resources and increased environmental risks. Municipal Solid Waste consists of more than 40 percent of organic waste, so composting most of this waste would be the best way to reduce the quantity to one fourth resulting in nutrient rich soil amendment. Composting is an age old practice for the biological conversion of organic waste to humus like substance which can enhance physical, chemical and biological soil properties. For the assurance of an effective solid waste management, implementations of appropriate solid waste treatment strategies are vital. This can be enhanced through the utilization of technologies that are most economically efficient, sustainable and ecofriendly.*
Keywords: *Composting, C/N ratio, Microbial Community, Microorganisms, Municipal Solid Waste (MSW),*

I. Introduction

Waste is the outcome of human activity which is produced since humans started living in smaller and larger societies. In modern times, the size of the town and cities are increasing at a very fast rate and therefore solid waste generated daily has a very high magnitude and therefore its collection and disposal is necessary, to maintain good hygienic condition in the society. Waste, in general is a derogatory term which implies something unwanted, useless, pejorative and filthy. The term waste is very complicated to define, as concepts, views or attitudes towards waste are usually very subjective and often exceedingly distinctive and conflicting.

Solid Waste Management (SWM) systems exist in most of the urban centre's since last few decades. However, these systems have yet to emerge as a well-organized practice. Although, the solid waste characteristics in different urban centers vary significantly, there is a meager effort to tailor the system configuration to the waste characteristics [1].

Waste management has become a critical area of practice and research due to the increasing concerns of environmental pollution and resources shortage [2]. Most of solid waste management professionals recognize that there is no single, simple solution to solid waste problems. Instead an integrated approach, combining the elements of multiple techniques, is used in an increasing number of cases [3, 4].

Municipal solid waste (MSW) is largely made-up of kitchen and yard waste, and its composting has been adopted by many municipalities [5]. Composting MSW is seen as a method of diverting organic waste materials from landfills while creating a product, at relatively low cost that is suitable for agricultural purposes [6, 7]. This trend may be attributed to economic and environmental factors, such as municipal landfill capacity; costs associated with landfilling and transportation of materials; adoption of legislation to protect the environment; decreasing the use of commercial fertilizers; increasing the capacity for household waste recycling and improved quality of compost products [5, 8, 9, 10]. Composting MSW reduces the volume of the waste, kills pathogens that may be present, decreases germination of weeds in agricultural fields, and destroys malodorous compounds [11].With rising interest in organic agriculture, the production of organic-grade MSW compost for agriculture is also gaining popularity because of its positive effect on biological, physical, and chemical soil properties [12]. In many countries, a large proportion of municipal waste is not disposed properly posing a potential environmental threat due to presence of pathogens and toxic pollutants [13, 14]. In Ahmedabad about 3500 metric tons of solid waste is generated on a daily basis. Currently more than 1600 metric tons of waste is collected under the "Door or Gate to dump project" and transported to processing plant/landfield.

The solid waste expresses highly diversified nature at physicochemical and biological aspects which is highly influenced by socioeconomic localities. The microbial diversity studies are important in order to understand the microbial ecology in the ecosystem. The microbial community remains one of the most difficult to characterize because of their immense phenotypic and genotypic diversity. The term "diversity" as used today, spans from a molecular to a global level of biological organization and defined as "the variety of species in ecosystems, as well as the genetic variability within each species" and it is therefore the range of significantly different kinds of organisms and their relative abundance in natural assemblage and habitat. The biodiversity can be regarded as the amount and distribution of individual species information in a natural community and thus a representative estimate of microbial biodiversity is a prerequisite for understanding the functional activity of microorganisms in ecosystem [15].

Currently, more than 130 million tons of waste per year is incinerated at over 600 plants [16]. Thermal processes with advanced emission controls are proven technology but more costly than controlled landfilling with landfill gas recovery; however, thermal processes may become more viable as energy prices increase. Because landfills produce CH_4 for decades, incineration, composting and other strategies that reduce landfilled waste are complementary mitigation measures [16].Composting has become a preferred method for municipalities and industries to recycle a variety of organic byproducts in order to apply them as soil conditioners and amendments [17].

Problems due to solid waste in urban areas

Solid waste causes lots of health and noise pollution problems in urban areas. The major problems of solid waste in urban areas are as follows:

- The biggest threat to a locality is the fact that the waste is a breeding ground for flies, insects, bacteria, fungus and many such microorganisms which could spread diseases which become worse during the rainy season and the contamination might end up in the drinking water.
- Bad odor is created around all garbage areas, making an unbearable environment.
- Poor waste pickers pose a serious threat to public health.
- Animals like cats, dogs, goats and cow come to the garbage in search of food and end up spreading the garbage around the bins.
- The economical factor is also affected as the market value of a particular area decreases if there is a badly maintained waste area nearby as this is aesthetically bad.
- Overall waste leaves a bad impression and poses a threat to the environment in the form of epidemic diseases such as cholera, malaria, etc. [18].

Classification of Municipal Solid Waste

MSW can be broadly categorized into five broad categories

(a) Biodegradable waste:
Food and kitchen waste, green waste (vegetables, flowers, leaves fruits), paper (can also be recycled).

(b) Recyclable material:
Paper, glass, bottles, cans, metals, certain plastics, etc

(c) Inert waste:
Construction and demolition waste, dirt, rocks, debris.

(d) Composite waste:
Waste clothing, tetra packs, and waste plastic such as toys.

(e) Domestic hazardous waste (also called "household hazardous waste") & toxic waste:
Medication, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, shoe polish.

Waste Management Techniques

Waste management includes collection, transportation, processing, treatment, recycling or disposal of waste materials to reduce their adverse effects on human health or amenities. The type of waste management techniques that should be applied for proper management of waste depend on the composition of waste. Although composting is the appropriate for all organic wastes: wastes such as plastic metals and glasses are better handled through recycling. Waste management technique take place in many ways viz., landfill, incineration, pyrolysis and gasification, composting and anaerobic digestion [19].

Landfilling

In many metropolitan cities, open, uncontrolled and poorly managed dumping is commonly practiced, giving rise to serious environmental degradation. More than 90% of MSW in cities and towns are directly disposed of on land in an unsatisfactory manner. Such dumping activity in many coastal towns has led to heavy metals rapidly leaching into the coastal waters. [20, 21, 22, 23, 24, 25, 26, 27]. In the majority of urban centers, MSW is disposed of by depositing it in low-lying areas outside the city without following the principles of sanitary landfilling. Compaction and leveling of waste and final covering by earth are rarely observed practices at most disposal sites, and these low-lying disposal sites are devoid of a leachate collection system or landfill gas monitoring and collection equipment [23, 28]. As no segregation of MSW at the source takes place, all of the wastes including infectious waste from hospitals generally find its way to the disposal site. Quite often, industrial waste is also deposited at the landfill sites meant for domestic waste [29].

Thermal treatment techniques of MSW

The destruction of MSW using heat energy is called thermal treatment. Although there are many thermal processes, incineration is the most widely used at present.

Incineration

Incineration of waste (with energy recovery) can reduce the volume of disposed waste by up to 90%. These high volume reductions are seen only in waste streams with very high amounts of packaging materials, paper, cardboard, plastics and horticultural waste. Recovering the energy value embedded in waste prior to final disposal is considered preferable to direct landfilling assuming pollution control requirements and costs are adequately addressed. Typically, incineration without energy recovery (or non-autogenic combustion, the need to regularly add fuel) is not a preferred option due to costs and pollution. Open-burning of waste is particularly discouraged due to severe air pollution associated with low temperature combustion.

Pyrolysis and gasification

These are methods for managing wastes by heating under controlled conditions to produce low to medium heating fuel gases, tars, char and ash; under a high temperature with limited oxygen [30]. Usually, the process takes place in a sealed vessel under a high pressure. Whereas pyrolysis converts the solid wastes into solid, liquid and gas products, gasification converts organic materials into a syngas (CO and H_2). The effect of pyrolysis to the environment is loss of biodiversity, desertification and emission of acid and green-house gases. Generally, the use of pyrolysis and gasification for waste management is uncommon in developing countries because of the expense of equipment. Another reason why pyrolysis and gasification may not be sustainable is the emission of green house gases during thermal treatment.

II. Composting

Composting is seen as a key process in the waste hierarchy and has an important role in reducing the volume of biodegradable municipal solid waste going to landfill. Composting is a biological process which converts heterogeneous organic wastes into humus like substances by mixed microbial population under controlled optimum conditions of moisture, temperature and aeration (Fig. 1). It is the aspect of control that separates composting from natural rotting or decomposition processes which occur in an open dump, sanitary landfill, or unmanaged waste pile [31]. In composting, microorganisms convert organic materials such as manure, sludge, leaves, fruits, vegetables and food wastes into product like soil humus [32, 33]. Through composting organic waste materials are decomposed and stabilized into a product that can be used as soil conditioner and/or organic fertilizer [34]. Decomposers include bacteria, actinomycetes and fungi that are widespread in nature. These are indigenous to soil, dust, fruit and vegetable matter and waste of all sorts, so special organisms are not required [35]. Controlled decomposition occurs as a result of activities of these naturally occurring microorganisms.

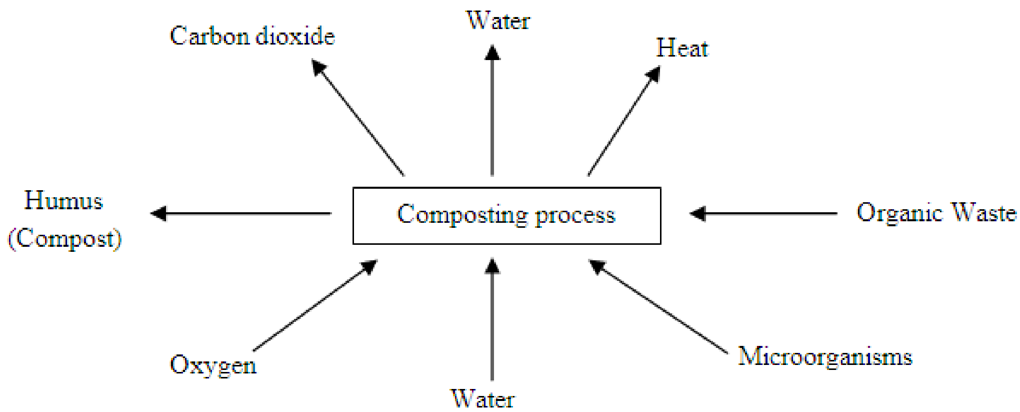

Fig. 1: Composting Process

Composting can be considered as microbial farming, so they need energy, food, and habitat. These microorganisms require carbon as energy source and nitrogen to build proteins. Bacteria produce enzymes to break down complex carbohydrates into simpler forms [36], and use them as food. Composting process continues until the remaining nutrients are consumed by the last microorganisms and most of the carbon is converted into carbon dioxide and water [32]. The nutrients that become available during decomposition remain in the compost within the bodies of dead microorganisms and in humus.

There are two fundamental types of composting aerobic and anaerobic:

Aerobic

Composting is the decomposition of organic wastes in the presence of oxygen, products from this process include CO_2, NH_3, water and heat. This can be used to treat any type of organic waste but, effective composting requires the right blend of ingredients and conditions. These include moisture contents of around 40-60% and carbon to nitrogen ratios (C/N) of 25-30:1. Any significant variation inhibits the degradation process. Generally wood and paper provide a significant source of carbon while sewage sludge and food waste provide nitrogen. To ensure an adequate supply of oxygen throughout, ventilation of the waste, either forced or passive is essential. [37].

Anaerobic

Composting is the decomposition of organic wastes in the absence of oxygen, the products being methane (CH_4), CO_2, NH_3 and trace amounts of other gases and organic acids. Anaerobic composting was traditionally used to compost animal manure and human sewage sludge, but recently is has become more common for some municipal solid waste (MSW) and green waste to be treated in this way [37].

2.1 Stages of Composting

A large variety of mesophilic, thermotolerant and thermophilic aerobic microorganisms predominantly bacteria, actinomycetes, yeasts and fungi are involved in the specialized biodegradation process [38].

The process of biocomposting occurs into three phase. (a) the mesophilic phase, (b) the thermophilic phase, which can last from a few days to several months (c) the cooling and maturation phase which lasts for several month. The length of the composting phases depends on the nature of the organic matter being composted and the efficiency of the process, which is determined by the degree of aeration and agitation. At the start of composting the mass is at its ambient temperature and usually slightly acidic. Soluble and easily degradable carbon sources, monosaccharides, starch and lipids are utilized by microorganisms in the early stage of composting. The pH decreases because organic acids are formed from these compounds during degradation. In the next stage microorganisms start to degrade proteins, resulting in the liberation of ammonia and increase in the pH. As the temperature increases, thermophilic microbes develop. These consist of only a few genera of bacteria e.g. *Bacillus subtilis*, fungi e.g. *Aspergillus fumigatus*, and actinomycetes e.g. *Streptomyces spp*. [39]. After the easily degradable carbon sources have been consumed, more resistant compounds such as cellulose, hemicellulose and lignin are degraded and transformed into humic acid, fulvic acid and phenolic intermediate metabolites [40]. The humified substances are divided into following groups: humin (not soluble in water at any pH), humic acids (soluble in water under alkaline conditions) and fulvic acids (soluble in water under all pH conditions) [41]. The humification of biocompost is a result of complex symbiotic and synergetic microbial interaction finally resulted into humifying earthy fragrances to an ideally compost.

2.2 Composting Systems

2.2.1 Open Windrows

This is the least sophisticated technique which involves placing a mixture of organic waste materials into long, narrow piles approximately six feet high by twelve feet wide and as long as it is necessary. The composting process depends upon a good supply of oxygen, therefore air must be able to move through the windrow. This will depend upon the size and shape of the windrow, the porosity of the material, and its water content. Feedstock material is usually shredded to ensure the correct porosity. A windrow constructed of low density materials such as leaves can be much larger than a windrow constructed of wet dense manure. Anaerobic areas can occur near the centre of the windrow if it is too large, too dense or too wet, and these areas will release odors when the windrow is turned. On the other hand, small windrows lose heat quickly and may not achieve high enough temperatures to kill pathogens and weed seeds. Turning releases trapped heat, water vapour and gases and also mixes the materials, breaks up large particles and restores the pore spaces eliminated by decomposition and settling. Turning also exchanges the material from the outside of the windrow with that from the interior. This helps to ensure that all material receives equal exposure to the air at the surface and to the high temperatures inside the windrow thereby providing a uniform treatment process. The compost process may take 4 to 6 weeks and finally the compost is ready to use as a fertilizer.

2.2.2 Aerated static pile

This system involves supply of ambient air through mechanical means and requires no turning of the organic mixture once the pile is formed. By controlling air mechanically, this process allows the use of larger piles. For composting under this method, an air plenum is constructed and the organic mixture is placed in piles on top of the air plenum. Piles are built as high as the equipment allows, normally it is kept eight to twelve feet high. Aerated static piles can be constructed individually or in extended piles. Individual piles, constructed all at once, allow the composting to occur in batches. Extended piles consist of a series of cells created over the course of many days and stacked against each other to form one long rectangular pile. A temperature sensor placed within the pile works in conjunction with the blower to control temperature and oxygen concentration within the pile.

2.2.3 In-vessel composting

It involves confining the compost process to a variety of containers or vessels. Different in-vessel systems use a variety of methods to accelerate the composting process. These systems usually include provisions for aeration, mixing, temperature control, and containment of odors. In-vessel, systems generally are the most costly of the three major technologies because of its high construction costs. Most of these are proprietary systems that also require greater operation and maintenance expenses and a higher skill level to operate. Once a recipe has been established, the mixture will be incorporated into the compost technology chosen; either windrow, aerated static pile, or in-vessel composting. These technologies are designed to accelerate the decomposition process of organic materials. The management levels of these processes will either speed up or slow down the decomposition process, ultimately influencing the quality and cost of the product.

2.2.4 Controlled Microbial Composting (CMC) (covered windrow)

The Controlled Microbial Composting® (or CMC®) process was developed by the Luebke family in Austria and involves the production of compost in covered windrows (1.2 x 1.8 m approx. x any length) over a 6-8 week period [42]. The feedstocks are carefully chosen to include a balance of well structured materials and should have a C/N ratio of around 30. They are mixed, water is added if necessary and covered with a waterproof, breathable membrane. The windrows are monitored daily for CO_2, moisture levels and temperature and the windrows are turned with a purpose-built compost turner every time the temperature exceeds 60 ºC. This often means that the windrows are turned daily at the start of the process. Compost maturity is estimated by measuring temperature and CO_2 emission from the windrows.

2.2.5 Vermicomposting

Vermicomposting is the result of combined activity of microorganisms and earthworms. Earthworms will break down sewage sludge and other organic wastes [43]. The 'tiger' or 'brandling' worm *Eisenia foetida* has received most attention, and work at Rothamsted showed that it could grow well in a wide range of wastes including pig and cattle solid and slurries, horse manure and potato waste [44]. Worms are useful in converting agricultural wastes into useful soil conditioners, but also the worms can be harvested and processed into a nutritious protein feed supplement for fish, poultry and pigs. *E. foetida* prefers a pH of 5, temperatures <35 ºC, and it will not enter poultry waste with high ammonia content. Batch systems treating up to 2 tons of waste in worm beds to a depth of one meter have been tested, but are labour intensive. The amount of soluble P, K and Mg appears to be increased, and worm-processed animal wastes have been shown to be suitable as plant growing media. Vermicomposting has been used in Hyderabad, Bangalore, Mumbai and Faridabad. Experiments on developing household vermicomposting kits have also been conducted. However, the area required is larger, when compared to dry composting [23, 27, 45, 46, 47, 48, 49].

2.2.6 Biominearlization

The plant requires major and minor nutrients in form of soluble minerals for their growth and development which are absorbed by root system from fertile well mineralized compost soil. In ecosystem various mineral biocycles are conducted by natural biodegradation processes. The plant contributes various waste products to soil environment in form of carbohydrates, celluloses, hemicelluloses, lignins, pectins, lipids and immobilized minerals. Similarly an animal contributes various waste products to ecosystem in form of carbohydrates, proteins, lipids, chitins, carotenes and insolubilized minerals.

The natural biomineralization of various animal and plant products and byproducts for compost humus formation is a complicated and long term process to contribute excellent manurization and to develop soil fertility.

Biomineralizer is the fermentative product developed under the latest scientific concept of biotechnology for the enrichment of multi-inoculant of potent microbial community for the biodegradation and biomineralization of insoluble bio-waste products to generate plant accessible macro and micro nutrients under highly diversified natural ecosystem within shortest time duration.

2.3 Factors affecting the composting process

The rate of microbial activity or degradation in the composting mass depends on certain important physical and chemical factors which should be considered in the design and operation of a composting process.

2.3.1 Microorganisms

Microorganisms decompose or oxidize the organic compounds to simple, stabilized end products, with the production of heat. During the process oxygen is consumed and carbon dioxide, water and often ammonia are released. The heat energy is partially used for cell synthesis of the microorganisms. However, the heat production is sufficient to raise the temperature up to the thermophilic range. It should be noted that different parts of the composting mass may, at the same time, achieve either mesophilic or thermophilic temperatures and the duration of these phases also may be different. The shape of the temperature curve depends on the initial waste materials being composted and the composting methods [50]. However, in a controlled reactor system the variation in temperature distribution can be improved.

Biological waste materials contain a large number of many different types of bacteria, fungi, mould and other living organisms. High-temperature compost appears to be a promising source for isolation of new thermophilic organisms as well as heat-stable enzymes of industrial value [51].

Gotaas (1956) concluded that more species of bacteria are involved in aerobic decomposition than in anaerobic fermentation. The main microorganisms responsible for biological degradation in composting are bacteria, actinomycetes and fungi of mesophilic and thermophilic groups.

Nakasaki et al., (1985) observed that the rate of composting sewage sludge was mainly controlled by the degradability of solid substrates and not by the kinds of microorganisms inhabiting the compost. However, inoculants are needed for special kinds of waste such as wool waste and hazardous waste.
The most commonly used microorganisms for MSW composting is illustrated in Table 1.

Table 1. Types of microorganisms used in MSW composting

Types	Species	Reference
Bacteria	*Bacillus casei,*	[54]
	Lactobacillus buchneri	
Fungi	*Candida rugopelliculosa*	
	Trichoderma	
	White-rot fungi	
Bacteria	*Pseudomonas*	[55]
	Azotobacter	
	Azospirillum Micrococcus	
Actinomycetes	*Streptomyces*	
	Actinomyces	
Fungi	*Trichoderma*	
	Alternaria	
	Penicillium and Aspergillus	

2.3.2 Aeration

Composting systems are distinguished on the basis of oxygen usage (aerobic vs. anaerobic). Aerobic decomposition, in contrast to anaerobic types, is quicker, progresses at higher temperatures, and does not produce foul odors. While anaerobic decomposition may be conducted with minimal operator attention and the operation may be sealed from the environment. However, the most modern composting operations attempt to maintain an aerobic environment [31]. Mixing the compost pile at intervals aerates it, but it is often difficult to determine the exact periods to turn the pile. Aeration conducted in excess is usually not harmful to the composting process, except that an optimum temperature is harder to maintain and excessive evaporation may cause moisture to become a limiting factor. An oxygen level from 10 to 30% has been reported optimum by Willson, (1989) and Gaur, (1997).

The air supply needs for temperature and moisture control typically are ten or more times greater than those for biological decomposition, so that when these needs are met, biological oxygen demands also will be safely satisfied [58]. Several systems have been applied to provide aeration for composting. The main systems are mechanical turning and forced aeration via air blower or fan. Forced aeration composting is usually applied to static windrow, static pile and to most of the reactor systems.

Mohee et al., (1998) investigated composting of bagasse and found that maximum degradation rates were obtained for airflow rates of 0.12 kg dry air/kg dry compost, while keeping temperatures below 50°C. Wiley, (1957), studied the effect of different aeration rates in continuously mixed reactors containing approximately 16 kg of garbage mixture with a moisture content of 52-58 percent. The effect of aeration was evaluated from the temperature curve during composting.

To control the aeration rate a number of strategies have been designed and practiced for the composting process. These range from simple manual control systems to more sophisticated computer control system using temperature, oxygen or carbon dioxide feedback as the controlling variables and air supply as the manipulated variable [61]. However, the control system should be able to satisfy peak, average and minimum aeration requirements [62].

2.3.3 C/N Ratio

The carbon to nitrogen (C/N) ratio is one of the important factors affecting the composting process as well as the properties of the end product. A C/N ratio between 25 and 30 is usually considered as the optimum ratio for composting. However, recent studies have shown that composting can be carried out effectively at a lower C/N of 15 [63]. Composting at low C/N ratios will reduce the requirement of bulking agent for adjusting the initial C/N ratio of a food waste composting mixture. Different initial mix ratios will ensure different C/N ratios to obtain optimum mix ratio for composting. During composting microorganisms utilize the C as a source of energy and the N for building cell structure. Microorganisms utilize C and N at a ratio of about 30:1.

The mineralizable solid carbon of each solid waste component was assumed to comprise the readily, the moderately and the slowly (or refractory) hydrolysable carbons, each hydrolyzing at different rates to aqueous (water soluble) carbon. Aqueous carbon mineralizes to CO_2 at rapid rates that are not rate-limiting to the process [64].

Most of the nitrogen in compostable materials is readily available. However, some of the carbon may be bound up in compounds that are very resistant to biological degradation, such as lignin. As not all of their carbon will be readily available, a higher initial C/N ratio than 30:1 can often be adopted [65].

Turan and Ergun, (2008), recommended the use of natural zeolite together with expanded perlite in municipal solid waste composting processes that produced mature and stable compost.

High or low C/N ratios can be adjusted by adding high nitrogen or carbon rich wastes, respectively. Sawdust, wheat straw, grass clippings, dry leaves, etc. are examples of carbon-rich materials, whereas poultry manure, slaughterhouse waste, sewage sludge, etc. are nitrogen-rich. The C/N ratio decreases during the composting process as carbon is lost in the form of carbon dioxide. A C/N ratio of 20 has been widely accepted as optimum for composting [52].

Singh, (1987), reported that the decomposition of organic waste increased considerably when the C/N ratio was narrowed down to 30 through the addition of urea-N. Witter and Real, (1987), observed excessive loss of N during the composting of manure at a lower C/N ratio.

2.3.4 Temperature

High temperature maintained during composting serves to promote efficiency and effectiveness of compost by accelerating the process and by destroying pathogenic microorganisms. High temperature of compost pile, in conjunction with satisfactory levels of other important composting factors, indicates the likelihood of successful composting. While low temperatures retard composting, and may even halt the process. Low temperatures are indicative of reduced microbial activity and could indicate a lack of oxygen or inadequate moisture conditions. The critical temperature, which limits composting, has yet to be defined [31]. However, Gaur, (1997) suggested that a temperature of 55 to 60 °C should be maintained up to three days for efficient composting.

The onset of temperature rise in the first stage of composting was almost independent of the process conditions [69]. High temperatures (above 50°C) are essential for the destruction of pathogenic organisms and undesirable weed seeds. The preponderance of information on the effects of temperature on composting suggests that optimum decomposition takes place between 55°C and 60°C.

Although there is some variation in the optimum temperature range due to variations in waste materials and operational practices, in most of the cases it is reported as 55°C to 60°C. But, according to Gotaas, (1956), the optimum temperature range is 50-70°C, around 60°C usually being the most satisfactory for successful composting. To avoid temperatures greater than 60°C which weaken the microbial mass suppressing decomposition, heat output and moisture removal, an enhanced heat removal in a controlled fashion (e.g. feedback control) is necessary [70]. During the initial stages of composting the active microbial population grows exponentially until the available substrate or other factors limit growth [71].

McKinley and Vestal, (1984), concluded that temperature seems to be the dominant physicochemical parameter which controls the microbial activity during the composting process and the decomposition ceases or extremely reduced at temperatures exceeding 60°C.

2.3.5 pH

Beulah Gnana Ananthi and Partheeban, (2001), stated that the composting municipal solid waste involves managing conditions to accelerate the biological decomposition of some of its organic components. The report stated that the conditions for efficient biological decomposition of organic waste depend on optimum pH (6.0-7.5).

Metabolic activities affect the pH of compost under process. Deamination of protein rapidly increases the pH due to ammonia. Conversely, production of organic acids during the decomposition of carbohydrates and lipids decrease the pH. On average, pH of inputs is somewhat acidic while finished compost is neutral.

Considerable changes in pH value occur during the composting process. In the beginning, the formation of organic acids and carbon dioxide lower the pH value to approximately 5.0 or less, whereas as the process progress the pH value reaches up to 8.0 to 8.5 [74]. The pH of compostable material influences the type of organisms involved in the composting process. Fungi tolerate a wider pH range than bacteria do. The optimum pH range for most bacteria is between 6.0 and 7.5, whereas for fungi it can be between 5.5 and 8.0. Most of the waste materials available for composting are within the above pH range and hence pose no problem of pH control. The pH level desired for microbial activity is between 5.0 and 7.0. However, for composting an optimum pH of 5.5 to 8.5, with little variation, is recommended in most of the literature.

2.3.6 Moisture

Moisture content is very important for composting and it may become the limiting factor if not monitored. Excess water interferes oxygen accessibility, while too little hinders diffusion of soluble molecules and microbial activity, slowing down the rate of composting. Moisture content of 40 to 60 percent has been found optimum for good composting process [56, 57]. While a moist mixture is necessary to sustain the biological decomposition vital to the composting process, dry compost is easier to manipulate and store without causing a nuisance. Only after composting has been completed, drying could be considered as a necessary prerequisite for storage or sale [31].

In aerobic composting, high moisture content must be avoided because water displaces air from the interstices between the particles and gives rise to anaerobic conditions. On the other hand too low moisture content deprives the organisms of the water needed for their metabolism and inhibits their activity.

Excessive moisture can have several adverse effects on the subsequent processes after the final decomposition phase. Finstein and Miller, (1985), stated that the final compost should be dry, since it decreases weight and bulk, improves materials handling, processing operation, storage and transport.

2.3.7 Particles size

Particles size affects oxygen movement into the pile, as well as microbial and enzymatic access to the substrate. Smaller size particles of organic material increase the surface area available for microbial attack. However, very small particles pack tightly together; preventing movement of air into the composting heap and movement of carbon dioxide out of the heap. Large size particles reduce surface area for microbial attack which slows down or may stop composting process altogether [76]. Bulky organic materials should be chopped or shredded to reduce particle size to the range of 1-5 cm. On the other hand if too small, the organic materials should be mixed with a bulking agent like wood chips or tree bark. A particle size of 5 cm is appropriate for heaps employed to natural air flow, while 10 mm size is suitable for the composting systems having forced air supply [57].

III. Effect Of MSW Compost On Soil Microbial Biomass

Compost is rich in organic matter and is an important source for plants nutrient [77]. Nutrients present in compost are also used by the soil microbial biomass. Incorporation of organic materials, such as MSW compost, in soil promotes soil microbiological activity. Consequently, compost promotes directly or indirectly changes in soil biological properties. Several studies have been conducted to evaluate the effect of MSW compost on soil microbial biomass. Soil microbial biomass is very closely related to the soil organic matter content in many arable agricultural soils [78].

IV. Conclusion

In order to meet the challenges of municipal solid waste management there is a need to develop a better technology or method through which the waste can be converted into useful material. The biodegradable organic waste can be processed into ecofriendly organic manure. Organic manure nourishes the soil fertility, increases the soil aeration and also minimizes environmental pollution. Now, it has been realized throughout the world that the use of chemical fertilizers and other chemicals is harmful to soil productivity and also a cause of water and air pollution. Municipal solid waste is suitable for composting because of the presence of high percentage of biodegradable organic matter, acceptable moisture content and C/N ratio in the waste. Composting has a lot of benefits like: reduce landfill space, reduce surface and groundwater contamination, reduce methane emissions, reduce transportation costs , reduce air pollution from burning waste, provide more flexible overall waste management, enhance recycling of materials and can be carried out with little capital and operating costs. It is an environmental friendly, wealth creating and sustainable method rather than directly dumped into earth and is useful to convert organic waste to useful products.

References

[1]. Kumar S., Mondal A.N., Gaikwad S.A., Sukumar Devotta and Singh P.N., Qualitative Assessment of Methane Emission Inventory from Municipal Solid Waste Disposal Sites: A Case Study, Atmospheric Environment, 38, 2004, 4921-4929.
[2]. Brewer L. J., Maturity and stability evaluation of composted yard debris. M.S. Thesis, Oregon State University, Corvallis, USA, 2001.
[3]. Uif S. Systems analysis of waste management-the ORWARE model, transport and compost sub-models. Ph.D. Dissertation, Swedish university of agricultural sciences, Uppsala, Sweden. USA, 1998.
[4]. Fromme W. R., Characterization of changes occurring in natural organic matter during the composting of a synthetic compost and a municipal solid waste, Ph.D. Dissertation, University of Cincinnati, Cincinnati, USA, 1999.
[5]. Otten L., Wet–dry composting of organic municipal solid waste: current status in Canada, Can. J. Civil Eng., 2001, 124–130.
[6]. Eriksen G., Coale F., Bollero G., Soil nitrogen dynamics and maize production in municipal solid waste amended soil, Agron. J., 91, 1999, 1009–1016.
[7]. Wolkowski R., Nitrogen management considerations for landspreading municipal solid waste compost, J. Environ. Qual., 32, 2003, 1844–1850.
[8]. He X., Traina S., Logan T., Chemical properties of municipal solid waste compost, J. Environ. Qual. 21, 1992, 318–329.
[9]. Hansen T., Bhander G., Christensen T., Bruun S., Jensen L., Life cycle modeling of environmental impacts of application of processed organic municipal solid waste on agricultural land (EASEWASTE), Waste Manag. Res., 124, 2006, 153–166.
[10]. Zhang M., Heaney D., Henriquez B., Solberg E., Bittner E., A four-year study on influence of biosolids/MSW cocompost application in less productive soils in Alberta: nutrient dynamics, Compost Sci. Util., 14 (1), 2006, 68–80.
[11]. Jakobsen S., Aerobic decomposition of organic wastes 2. Value of compost as fertilizer, Resour. Conserv. Recy, 13, 1995, 57–71.
[12]. Iglesias-Jimenez E., Alvarez C., Apparent availability of nitrogen in composted municipal refuse, Biol. Fert. Soils 16, 1993, 313–318.
[13]. Darby H.M., Stone A.G. Dick R.P., Compost and manure mediated impacts on soil borne pathogens and soil quality, Soil Science Society of America Journal, 70, 2006, 347-358.
[14]. De Araujo A.S.F., De Melo W.J., Singh R.P., Municipal Solid Waste compost amendments in agricultural soil: changes in microbial biomass, Reviews in Environmental Science and Bio/Technology, 9, 2010, 41-49.
[15]. Ovreas L., Torsvik V., Microbial diversity and community structure in two different agricultural soil communities, Microbial Ecology, 36, 1998, 303-315.
[16]. Bogner J.M., Waste Management, in Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change", Cambridge University Press, Cambridge, United Kingdom and New York, USA, 2007.
[17]. Butler T.A., Sikora L.J., Steinhilber P.M. and Douglass L.W., Compost Age and Sample Storage Effects on Maturity Indicators of Biosolids Compost, Journal of Environmental Quality, 30, 2001, 2141-2148.
[18]. Singh Jagbir, and Ramanathan AL., Solid Waste Management Present and Future challenges (IK. International Publishing House Pvt. Ltd, New Delhi, 2010).
[19]. Taiwo Adewale M. Composting as a sustainable waste management technique in developing countries, Journal of Env. Sci & Tech., 4 (2), 2011, 93-102.
[20]. Mor S., Ravindra K., Visscher A.D., Dahiya R.P., Chandra A., Municipal solid waste characterization and its assessment for potential methane generation: a case study, Journal of Science of the Total Environment, 371 (1), 2006, 1–10.
[21]. Siddiqui T.Z., Siddiqui F.Z., Khan E., Sustainable development through integrated municipal solid waste management (MSWM) approach – a case study of Aligarh District. In: Proceedings of National Conference of Advanced in Mechanical Engineering (AIME- 2006), Jamia Millia Islamia, New Delhi, India, 2006, 1168–1175.
[22]. Sharholy M., Ahmad K., Mahmood G., Trivedi R.C., Development of prediction models for municipal solid waste generation for Delhi city. In: Proceedings of National Conference of Advanced in Mechanical Engineering (AIME-2006), Jamia Millia Islamia, New Delhi, India, 2006, 1176–1186.
[23]. Gupta S., Krishna M., Prasad R.K., Gupta S., Kansal A., Solid waste management in India: options and opportunities. Resource, Conservation and Recycling 24, 1998, 137–154.
[24]. Das D., Srinivasu M., Bandyopadhyay M., Solid state acidification of vegetable waste, Indian Journal of Environmental Health, 40 (4), 1998, 333–342.
[25]. Kansal A., Prasad R.K., Gupta S., Delhi municipal solid waste and environment – an appraisal, Indian Journal of Environmental Protection, 18 (2), 1998, 123–128.
[26]. Chakrabarty P., Srivastava V.K., Chakrabarti S.N., Solid waste disposal and the environment – a review, Indian Journal of Environmental Protection, 15 (1), 1995, 39–43.
[27]. Khan R.R., Environmental management of municipal solid wastes, Indian Journal of Environmental Protection, 14 (1), 1994, 26–30.
[28]. Bhide A.D., Shekdar A.V., Solid waste management in Indian urban centers. International Solid Waste Association Times (ISWA) (1) 1998, 26–28.
[29]. Datta M., Waste Disposal in Engineered Landfills. Narosa publishing house, New Delhi, India, 1997.
[30]. Heimlich J.E., Hughes K.L. and Christy A.D., Integrated Waste Management. OSU Extension, Ohio, 2005.
[31]. Roger S.W., Jokela E.J., Smith W.H., Recycling composted organic wastes on Florida forest lands. Dept. of Forest Resources and Conservation, Florida Cooperative Extension Services, University of Florida, USA, 1991.
[32]. Rynk R., On-farm Composting Handbook. Northeast Regional Agricultural Engineering Service, Coop. Ext., NRAES-54 Ithaca, USA, 1992.
[33]. Reinikainen O., Herranen M., Different methods for measuring compost stability and maturity. Soil Sci. Soc. Amer. J., 55, 1999, 1020-1025.
[34]. Ahmad R., Use of recycled organic waste for sustainable maize (Zea mays L.) Production. Ph.D. Thesis, Institute of Soil & Environmental Sciences, University of Agriculture, Faisalabad, Pakistan, 2007.
[35]. Rodrigues M.S., Composted societal organic wastes for sustainable wheat (Triticum aestivum) production. Ph. D. Thesis, Wye College, University of London, 1996.
[36]. Hamdy H.S., Purification and characterization of the pectin lyase produced by Rhizopus oryzae grown on orange peels. Ann. Microbiol., 55 (3), 2005, 205-211.
[37]. Guanzon Yvette B., Holmer Robert J., Composting of Organic Wastes: A Main Component for Successful Integrated Solid Waste Management in Philippine Cities, 2000.
[38]. Boulter Jeanine I., Trevors Jack T., Boland Greg J., Microbial studies of compost: bacterial identification and their potential for turfgrass pathogen suppression, World Journal of Microbiology and Biotechnology, 18, 2002, 661-671.

[39]. Strom P. F., Effect of temperature on bacterial species diversity in thermophilic waste composting, Applied and Environmental Microbiology, 50, 1985, 899-905.
[40]. Tuomela M., Vikman M., Hatakka A., Itavaara M., Biodegradation of lignin in a compost environment: a review, Bioresource Technology, 72, 2000, 169-183.
[41]. Aiken G.R., Mcknight D.M., Wershaw R. L., MacCarthy P., An introduction to humic substances in soil, sediment and water: Geoc hemistry, Isolation and Characterization, Wiley, 1985, 1-9.
[42]. Diver S., Controlled Microbial Composting and Humus Management: Luebke Compost. Appropriate Technology Transfer for Rural Areas, Fayetteville, Arkansas, USA. 2001.
[43]. Neuhauser E.F., Kaplan D.L., Malecki M.R., and Hartenstein R., Materials supporting weight gain by earthworms, Eisenia foetida, in waste conversion systems, Agricultural Wastes, 2 (1), 1980, 43-60.
[44]. Edwards C.A., Burrows I., Fletcher K.E., and Jones B.A., The use of earthworms for composting farm wastes. In J. K. R. Gasser (ed.). Composting of Agricultural and Other Wastes. Elsevier Applied Science Publishers, London, 1985, 229-241
[45]. Ghosh C., Integrated vermin – pcsciculture – an alternative option for recycling of municipal solid waste in rural India, Journal of Bioresource Technology 93, 2004, 71–75.
[46]. Bezboruah A.N., Bhargava D.S., Vermicomposting of municipal solid waste from a campus, Indian Journal of Environmental Protec tion, 23 (10), 2003, 1120–1136.
[47]. Jha M.K., Sondhi O.A.K., Pansare M., Solid waste management – a case study, Indian Journal of Environmental Protection, 23 (10), 2003, 1153–1160.
[48]. Sannigrahi A.K., Chakrabortty S., Beneficial management of organic waste by vermicomposting, Indian Journal of Environmental Protection, 22 (4), 2002, 405–408.
[49]. Reddy S., and Galab S., An Integrated Economic and Environmental Assessment of Solid Waste Management in India – the Case of Hyderabad, India, 1998.
[50]. Epstein E., The Science of Composting, Technomic Publishing Company, Lancaster, Pennsylvania, USA, 1997.
[51]. Oshimaa B.T and Moriyab T., A Preliminary Analysis of Microbial and Biochemical Properties of High-Temperature Compost, Annals of New York Academy of Sciences, 1125, 2008, 338-344.
[52]. Gotaas H.B., Composting: Sanitary disposal and reclamation of organic wastes, World Health Organization, Monograph 31, Geneva, Switzerland, 1956.
[53]. Nakasaki K., Sasaki M., Shoda M. and Kubota H., Characteristics of mesophilic bacteria isolated during thermophilic compostin g of sewage sludge, Applied and Environmental Microbiology, 49 (1), 1985, 42-45.
[54]. Wei Z., Xi B., Zhao Y., Wang S., Liu H., Jiang Y., Effect of inoculating microbes in municipal solid waste composting on char acteristics of humic acid, Chemosphere, 68, 2007, 368- 374.
[55]. Rebollido R., Martínez J., Aguilera Y., Melchor K., Koerner I., Stegmann R., Microbial populations during composting process of organic fraction of municipal solid waste, Applied Ecology and Environmental Research, 69 (3), 2008, 61-67.
[56]. Willson G.B., Combining raw materials for composting. Biocycle, 1989, 82-85.
[57]. Gaur A.C., Bulky organic manures and crop residues. In: Tandon H.L.S., Ed., Fertilizers, Organic Manures, Recyclable Wastes a nd Biofertilizers, FDCO, New Delhi, India, 1997, 37-51.
[58]. Kuter G.A., Hoitink H.A.J. and Rossman L.A., Effects of aeration and temperature on composting of municipal sludge in a full scale vessel system, Journal water Pollution Control Federation, 57 (4), 1985, 309-315.
[59]. Mohee R., White R.K. and Das K.C., Simulation Model for Composting Cellulosic (Bagasse) Substrate s, Compost science & Utilization, Spring 1998, 83-92.
[60]. Wiley J.S., Progress report on high-rate composting studies: Proceedings of the 12^{th} Annual Purdue industrial Waste Conference, Lafayette, Purdue University, 1957.
[61]. Haug R.T., The Practical Handbook of Compost Engineering, Boca Raton, Lewis Publishers, 1993.
[62]. Hameedaa B.G., Harini O.P., Rupela S.P. and Wani W.G., Growth promotion of maize by phosphate solubilizing bacteria isolated from composts and macrofauna, Microbiological Research, 2008, 234-242.
[63]. Kumar M., Ou Y.L and Lin J.G., Co-composting of green waste and food waste at low C/N ratio, Waste Management, 2010, 602-609.
[64]. Komilis D.P. and Ham R.K., Carbon dioxide and ammonia emissions during composting of mixed paper, yard waste and food waste, Waste Management, 2006, 62-70.
[65]. Tucker P., Co-Composting Paper Mill Sludges with Fruit and Vegetable Wastes University of Paisley, National Society for Clean Air and Environmental Protection as part of the Biffaward Programme of Research and Development into Sustainable Waste Management, 2005.
[66]. Turan G. and Ergun O.N., Improving the Quality of Municipal Solid Waste Compost by using Expanded Perlite and Natural Zeolite, Clean, 36 (3), 2008, 330-334.
[67]. Singh C.P., Preparation of high grade compost by an enrichment technique. I. Effect of enrichment on organic matter decomposition, Biological Agriculture and Horticulture, 5 (1), 1987, 41-49.
[68]. Witter E. and Real J.M.L., Monitoring the composting process using parameters for compost stability. In Compost: Production Quality and Use, Elsevier Applied Science, London, 1987, 351-358.
[69]. Chang J.I., Tsai J.J. and Wu K.H., Thermophilic composting of food waste, Bioresource Technology, 97, 2006, 116-122.
[70]. MacGregor S.T., Hoitink H.A.J. and Rossman L.A., Composting process control based on interaction between microbial heat output and temperature, Applied and Environmental Microbiology, 41 (6), 1981, 1321 -1330.
[71]. Marugg C., Grebus M., Hansen R.C., Keener H.M. and Hoitink H.A.J., A kinetic model of the yard waste composting process, Comp ost Science and Utilization, 1993, 39-51.
[72]. McKinley V.L and Vestal J.R., Biokinetic analysis of adaption and succession: Microbial activity in composting municipal sewa ge sludge, Applied and Environmental Microbiology, 47 (5), 1984, 933-941.
[73]. Beulah Gnana Ananthi G. and Partheeban P., Solid waste Management Proceedings of ENVIRO 2001, National conference on control of Industrial Pollution and Environmental Degradation ,at PSG college of Technology, Coimbatore, India, 2001, 375-381.
[74]. Techobanoglous G., Theisen H. and Eliassen R., Solid Wastes Engineering Principles and Management Issues, Mcgraw Hill Limited, New York, 1977.
[75]. Finstein M.S. and Miller F.C., Principles of composting leading to maximization of decomposition rate, odour control and cost effectiveness, Composting of Agricultural and other Wastes, Elsevier Applied Science Publishers, London and New York, 1985, 13-26.
[76]. Zia M.S., Khalil S., Aslam M., Hussain F., Preparation of compost and its use for crop-production. Sci. Tech. Develop., 22, 2003, 32-44.
[77]. GallardoLara F., Nogales R., Effect of the application of town refuse compost on the soil–plant system: a review, Biol Waste, 19, 1987, 35–62.
[78]. Houot S., Chaussod R., Impact of agricultural practices on the size and activity of the soil microbial biomass in a long term field experiment, Biol Fertil Soils, 19, 1995, 309–316.