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RESEARCH ARTICLE

COMPOSTING OF MUNICIPAL SOLID WASTE: A SUSTAINABLE WASTE MANAGEMENT TECHNIQUE IN INDIAN CITIES – A REVIEW

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ABSTRACT

Attending sustainability in waste management require an option that employs environmental friendliness. The generation of municipal solid waste is increasing year by year and there are many options for handing and disposing of these wastes. Composting is the natural biological process in which degradable part of waste is transformed to a stable material with excellent characteristics for application on soils. Thus it requires a pretreatment such as removal of big fractions and other contaminants that could affect the composting process and final quality of compost. Such type of technique must be effective efficient and less costly Agricultural application of composted Municipal Solid Waste, as nutrient source for plants and as soil conditioner, is the most cost effective option of MSW management. Municipal solid waste (MSW) compost is increasingly used in agriculture as a soil conditioner but also as a fertilizer. Proponents of this practice consider it an important recycling tool since MSW would otherwise be land filled and critics are concerned with its often elevated metal concentrations. In this review, we show the state of art about the composting of Municipal solid waste (viz. Kitchen waste) and its application in agriculture.

INTRODUCTION

Waste management has become a critical area of practice and research due to the increasing concerns of environmental pollution and resources shortage (Brewer, 2001). 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 (Uif, 1998; Fromme, 1999).

Waste Management Techniques

Waste management is the collection, transportation, processing, treatment, recycling or disposal of waste materials to reduce their adverse effects on human health or amenties. 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 placein many ways viz., landfill, incineration, pyrolysis and gasification, composting and anaerobic digestion (Adewale *et al.,* 2011).

Land filling

Land filling is an economical method of waste materials in developing countries involving pitching refuses into a depression, abandoned, mining void, excavated land, or borrowed pits (Daskalopoulos *et al.,* 1998, Adewale *et al.,* 2011).

Open Dump System/ordinary landfill

This disposal of waste material is in pits, excavated land, canal, sloping land scape, or flat surface without covering the waste. From time to time open dumps burn leading to air pollution. Other environmental implication of landfill are the sites eyesore, windblow of litters along the landscape, presence of faecal matters, intrusion of vermin such as mice and rats, odor, smoke with resultant effects on human health (Adewale *et al.,* 2011).

Sanitary Land fill

The engineering means of disposing solid waste uses thin layers, compacted in to the smallest practical volume and cover with inert ash at the end of each working day. Environmental effects of sanitary landfill are production of Landfill Gases (LFGs), lichates and leaving heavy metals. LFGs are produced when methogens are decomposed primarily in to methane and Carbon di oxide and other gases such as CO, N2, alcohols, Hydrocarbons and organosulphur compounds (EL-Fadel *et al.,* 1997, Adewale *et al.,* 2011).

Incenaration

Incinerations refers to high temperature combustion of waste in a high efficiency furnace to produce staem and ash (EPA, 1995). The banifits of incineration are a major reduction in waste volume and production of energy in form of electricity and heat production (Seo *et al.*, 2004) However, the problems of waste incineration cannot be overemphasized in the light of the following: construction and start up cast of facility, which could be too expansive for developing countries (Rand *et al.*, 2000, Adewale *et al.*, 2011).

Composting

Composting is the regulated decomposition of organic matter to produce a final product called compost; it is used in waste management as a method to recover organic waste (Haight 2006). The composting process entails managing and accelerating the biological and oxygen demanding process as a mixture of organic materials pass through a series of stages that are characterized by increases in temperature and bacterial types leading to a stable organic material called compost (Haight and Taylor 2000). Composting of organic waste is recognized as an effective method to manage this waste type as it aims to recovers organic waste in the waste stream and produces a useful end-product (Hoornweg 1999). Composting may be defined as part of a sustainable resource management strategy (Richard, 1992; Golueke and Diaz, 1996; Faucette, 2004). It is essential to encourage recycling, the only sustainable waste management practice which avoids the existence itself of wastes by transforming possible waste materials into a series of products (Campbell, 1990). With sustainable transformation of wastes into organic fertilizers, composting would complement sustainable agriculture (Cathcart *et al*., 1986). The sustainable agriculture and the use of compost can be considered as essential activities for a sustainable society (Sinha and Heart, 2002). Hence, sustainability considerations are major driving forces for composting technologies. Improvements in composting process control will help increase the efficiency and economic viability of the related technologies, and thus contributing to agricultural and societal sustainability (Molla, 2005).

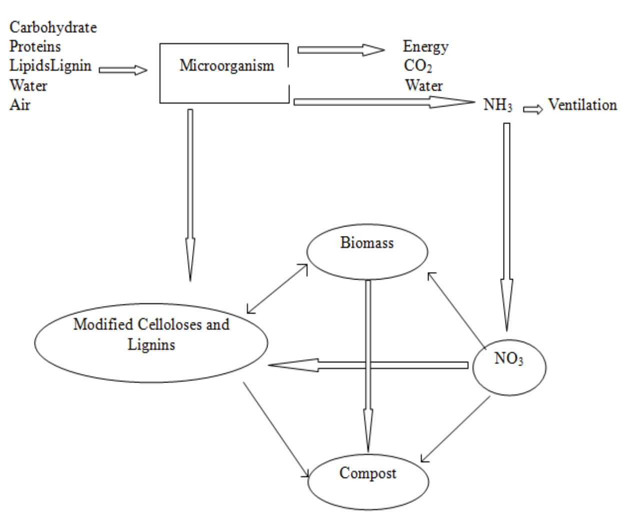

Fig. 1. Schematic Diagrame of Composting Process (Source: Teira, 2003)

Composting can meet multiple objectives, including reduction of odor, recycling of nutrients to soils, and management of livestock wastes through an integrated approach (Haug, 1980, 1986; Miller, 1991; Hansen *et al.*, 1993; Alpert *et al*., 2002; Park *et al.*, 2004). Thus, composting offers a potential for producing a usable product from the organic fraction of solid waste and is thus a form of recycling. Composting can also produce combustible fuel for energy recovery (Brodie, 1996). By itself, composting is not a solution to all waste problems; however it can serve as a valuable component in a waste management plan (Lasoff, 2000). It advances the goals of decomposing putrescible material, decreasing volume, weight and water content, producing a stabilized process residue, and inactivating pathogenic organisms (Godden, 1983; Hoitink and Keener, 1992; Finstein and Hogan, 1992; Szmidt and Fox, 2001).

Factor affecting composting Process

Many factors can affect composting processes, including temperature, moisture, gas flow and many other physical, chemical and biological variables (Beck, 1984; Ljung and Glad 1994; Ekinci, 2001).

C/N ratio

C/N ratio is a traditional parameter, which has been used to evaluate the compost maturity and stability as it defines the agronomic quality. The composting process results in the fall of C/N ratio because the microorganism activities: the conservation of nitrogen and transformation of carbon to CO2 and humic substances. During active aerobic growth, living organisms use about 25 to 35 units of carbon for every unit of nitrogen (Gotaas, 1956). Poincelot (1975) verified that the C/N ratio within the range between 25 and 35 is the most desirable for rapid and efficient composting. If excess carbon is available (a higher C/N ratio), rapid cell growth will cause a depletion of available nitrogen and a temporary slowdown in cellar growth. The ideal C/N ratio or well-matured compost is about 10, but it is usually difficult to achieve by composting (Mathur, 1991).

pH value

The pH value of compost is looked as an indicator of process of decomposition and stabilization. The change of pH value during composting is quite predictable (Miller, 1993; Benito, 2003; Page, 1982): it drops slightly early in processing, and then rises rapidly to approximately 8.5 because of ammonification. The pH value settles to between 7.5~8.0 as the compost stabilizes. Sanchez-Monedero (2001) found that pH value varies within 7.0 ~8.0 in 4 composting mixtures (wide range feedstock) in 20 weeks. But pH value is not an absolute reliable indicator of maturity and stability. Campell (1992) found that the pH value of compost stopped at 6.7 after 6 weeks.

Nitrogen element related

Nitrification or ammonification process has been studied extensively as a maturity and stability index for composting (Finstein and Mille, 1985; Bernal *et al*., 1998). NH4+-N/NO3--N ratio is a clear indicator of nitrification (Haug, 1993).

According to Haug (1993), high ammonia concentration is usually found in the early stages of composting as organic nitrogen is decomposed; the ammonia concentration is eventually reduced through volatilization or oxidation to the nitrate form; thus the presence of nitrate and absence of ammonia are indicative of a stabilized condition.

Electricity Conductivity (EC)

A low electric conductivity could be an indicator of complex nutrients and therefore desirable. The decrease of EC in the composting process is the direct consequence of the increased concentration of nutrients, such as nitrate and nitrite. EC is a measure of soluble salt content. Undesired salt levels can be harmful to germinating seeds and plants when compost is applied as growing medium. The desired ranges may not apply when compost is used as an amendment because of the diluting effect of mixing the compost with soil ().

Oxygen/Aeration

Gas exchange supplies oxygen and removes carbon dioxide, heat, and water vapor. The significance of supplying oxygen is that aerobic respiration generates heat at a rate sufficient for self-heating (Cooney *et al.*, 1968; Atchley and Clark, 1979; Rynk, 1991; Sesay, 1998). A number of researchers considered oxygen or carbon dioxide levels as feedback variables (Jeris and Regan, 1973a, b; Nakasaki and Shoda, 1987; DeBertoldi *et al.,* 1988; Haug, 1993, 1996; Vinci, 1996; Bodelier and Laanbroek, 1997; Richard *et al.,* 1999; Zhang, 2000; Ekinci, 2001). With a known flow rate, measurement of carbon dioxide or oxygen should be sufficient to define the rate of degradation (Jeris and Regan, 1973a).

Moisture/Water Content/Temperature

Sufficient moisture in the solid waste is required for maximum efficiency of microbial stabilization (Dirksen and Dasberg, 1993; Iriarte and Ciria, 2001). Water is both required for and produced by microbial activities. A major part of the composting process is the loss of water, as a result of evaporation as the process progresses (Stentiford, 1996). Moisture also affects porosity and gas diffusivity and is removed via vaporization (evaporative cooling), as driven by microbial heat generation (Dean *et al.*, 1987; Oppenheimer, 1997). The moisture content of the compost affects the structural properties of the materials, the thermal properties of the materials as well as the rate of biodegradation (Stentiford, 1996; Nakasaki *et al.*, 2004, 2005).

The temperature of compost is a function of the accumulation of heat generated metabolically and, simultaneously, the temperature is a determinant of metabolic activities (MacGregor *et al.,* 1981). It is a critical variable in the composting process and a number of studies have addressed heat and mass transport in composting processes (Finger *et al.,* 1976; Characklis and Gujer, 1979; Luong and Volesky, 1983; Incropera and DeWitt, 1985; Macky and Derrick, 1986; Kishimoto *et al.,* 1987; Bach *et al.*, 1987; Nakasaki and Akiyama, 1988; Richard and Walker, 1989; Keener *et al.*, 1992; VanderGheynst *et al.*, 1997; Hall, 1998; Ekinci, 2001; Nakasaki *et al.*, 2004, 2005).

The Microbiology of Composting

Composting is a complex biological process that involves the combined activities of many individual microorganisms. Two classes of microorganism are considered regarding to the temperatures at which they can grow: mesophiles and thermophiles. Mesophiles are organisms that grow optimally at temperatures from 20.0 to 35.0°C. Organisms that are best adapted to temperatures between 50.0 and 60.0°C are known as thermophiles. They can tolerate and survive at minimum temperatures of 30.0 to 40.0°C and maximum temperatures of 80.0 to 90.0°C (Swatek 1967; Lyles 1969; Henis 1987; Lester and Birkett 1999). Bacteria, fungi, and actinomycetes are the three principle microbial species associated with the decomposition of organic matter, which can be categorized as readily, moderately, and highly resistant degradable matter (Stentiford 1993; Eklind et al. 1997). Different microbial communities predominate at various stages: mesophilic, thermophilic, cooling, and stabilization, of the composting process; each microbial community is adapted to a particular type of organic material and environment (Gray et al. 1971a; Ryckeboer et al. 2003).

Compost Phases

Composting characteristically is an ecological succession of microbial populations almost Invariably present in wastes.The succession begins with the establishment of composting conditions. “Resident” (indigenous) microbes capable of utilizing nutrients in the raw waste immediately begin to proliferate. Owing to the activity of this group, conditions in the composting mass become favorable for other indigenous populations to proliferate. composting proceeds in three stages, namely (1) an initial lag period (“lag phase”), and (2) a period of exponential growth and accompanying intensification of activity (“active phase”) that (3) eventually tapers into one of final decline, which continues until ambient levels are reached (“curing phase” or “maturation phase”) (Luis F. Diaz et al.,2004).

Lag Phase

The lag phase begins as soon as composting conditions are established. It is a period of adaptation of the microbes characteristically present in the waste. Microbes begin to proliferate, by using sugars, starches, simple celluloses, and amino acids present in the raw waste. Breakdown of waste to release nutrients begins. Because of the accelerating activity, temperature begins to rise in the mass. (Luis F. Diaz *et al.*, 2004).

Active Phase

The transition from lag phase to active phase is marked by an exponential increase in microbial numbers and a corresponding intensification of microbial activity. This activity is manifested by a precipitous and uninterrupted rise in the temperature of the composting mass. The rise continues until the concentration of easily decomposable waste remains great enough to support the microbial expansion and intense activity. Unless countermeasures are taken, the temperature may peak at 70°C or higher. The activity remains at peak level until the supply of readily available nutrients and easily

Table 1. Summary of agricultural studies of MSW compost. (Source: Hargreaves J.C. et al., 2007)

MSW source	Soil type/pH/E.C. (dS/m)	Crop	Rate (Mg ha-1)	Comments	Reference
Source-separated from Netanya sewage treatment plant, Israel	Sand/7.5/8.5	Wheat	0.03, 0.06, 0.12	Increase yield, downward movement of P observed, pot experiment	Bar-Tal et al. (2004)
Calcutta city wastes, India	Clay/5.5/2.7–2.8	Rice	5.9–6; 40	Increased yield, pH (field experiment); high rates did not affect microbiology of soil (pot experiment)	Bhattacharyya et al. (2003a,b)
Castel di Sangro, Italy	Clay/8.3	N/A	12–24	Increased enzyme activities but no effect of community structure 6 years after application	Crecchio et al. (2001, 2004)
Not stated	Sand/6.4	Maize	0, 63, 126, 189 (fw)	First year N immobilization	Eriksen et al. (1999)
Valdemingomez MSW treatmentplant, Madrid, Spain	Sandy loam/6.4/7.0 (2001)	Barley	20 and 80	Increased microbial metabolism in soil; long-term increased buffering capacity of soil	Garcia-Gil et al. (2000, 2004)
Gesenu MSW treatment plant,Perugia, Italy	Sandy loam/7.7; clay silt loam/7.8	N/A	~ 50	Increased soil Zn concentrations in both soils, pot experiment	Giusquiani et al. (1988)
Gesenu MSW treatment plant, Perugia, Italy	Clay loam/8.3	Corn	30, 90, and 270	Increased enzyme activities despite adding three times the heavy metals limit specified by Italian law	Giusquiani et al. (1994)
Valdemingomez urban solid waste treatment plant, Madrid, Spain	Sandy clay loam/6.1/10	N/A	15, 30, and 60	Increased water holding capacity, pH, soil Zn and Cu concentrations, pot experiment	Hernando et al. (1989)
Santa Cruz de Tenerife, Canary Islands, Spain	Clay loam/5.8/16	Ryegrass	10, 20, 30, 40, and 50	High rates can provide sufficient N for ryegrass, E.C. increased with rate, soil P retention decreased, pot experiment	Iglesias-Jimenez and Alvarez (1993) and Iglesias-Jimenez et al. (1993)
Not stated	Clay loam/7.7/0.8	Spinach	0, 20, 40, 60, and 80	Increased yield, increased P, Mn, Pb, Na, and Cl uptake, pot Experiment	Maftoun et al. (2004)
Truman, MN (OTVD French technology) and Buffalo, MN (Buhler Swiss technology)	Sandy loam/5.8	Corn	90 and 270	Composts highly variable year to year	Mamo et al. (1999)
Source-separated Lunenburg regional recycling and composting facility, NS, Canada	Sandy loam/potatoes: 5.8, sweet corn: 6.5	Potatoes and sweet corn	Potatoes: 21.7, 43.4, and 65.1; sweet corn: 7.5, 15, and 22.5 (half these amounts were applied the second year)	pH increased, compost supplied similar amount of P as mineral fertilizer	Mkhabela and Warman (2005)
Cupello engineering, Italy	Clay/7.4	Alfalfa and cocksfoot	Alfalfa: 150, cocksfoot: 60	Organic carbon increased	Montemurro et al. (2006)
Sevilla city wastes (fraction <30mm), Spain	Sandy clay loam/7.8	Clover	100 (2 applications)	Increased N, Zn, Cu, Ni, and Cr uptake, pot experiment	Murillo and Cabrera (1997)
Lunenberg regional recycling and composting facility, NS, Canada	Sandy loam/4.55; gravelly loams/4.53, 4.80	Blueberries	35, 70, and 140 (2 applications)	Increased soil Mn at high rate, increased leaf Ni at high rate	Murphy and Warman (2001)
Agrisoil compost	Very gravelly loam/7.2–7.6	Tomatoes; squash	24 and 48	Increased soil concentrations of Cd, Cu, Pb, Ni, and Zn, fruit uptake was not observed	Ozores-Hampton and Hanlon (1997)

decomposed materials begins to dwindle. (Luis F. *Diaz et al.*, 2004).

Maturation or Curing Phase

Eventually, the supply of easily decomposable material is depleted, and the maturation stage begins. In the maturation phase, the proportion of material that is resistant steadily rises and microbial proliferation correspondingly declines. Temperature begins an inexorable decline, which persists until ambient temperature is reached. The time involved in maturation is a function of substrate and environmental and operational conditions (i.e., as brief as a few weeks to as long as a year or two) (Luis F. Diaz *et al.*, 2004).

Utilization of MSWC in agricultural land

Soil organic matter plays a major role in maintaining soil quality Pedra *et al.,* (2007). In addition to supplying plant nutrients, the type and amount of soil organic matter influences several soil properties Arau´jo *et al.,* (2008). Utilization of MSWC in agricultural land Increase the soil organic matter improves soil properties, enhances soil quality, reduces soil erosion, increases plant productivity and soil microbial biomass. Thus, in the regions where organic matter content of the soil is low, agricultural use of organic compost is recommended for increasing soil organic matter content and consequently to improve and maintain soil quality. Apart of increasing soil organic matter content, application of organic compost can affect soil quality by: (a) Decreasing the need of chemical fertilizers and pesticides (b) Allowing for more rapid growth in plants Bulluck and Ristaino (2002) (c) Sequestering C in soil that has received compost application; (d) Improving tillage and workability of soil; (e) Increasing soil microbial biomass and activity Bulluck and Ristaino (2002 Arau´jo and Monteiro (2006). Recently, RocaPerez *et al.,* (2009). Soil ecology is increasingly being used to evaluate soil quality. It is thought that soil microbiological properties are most sensitive to changes in the soil environment (Pankhurst *et al.,* 1997; Crecchio *et al.,* 2001). Biomass N, C, and S showed increases in the soil immediately after compost addition and for up to 1 month, while biomass P showed an increasing trend for 5 months (Perucci, 1990). Application of 2.5, 10, 20, and 40 Mg ha#1 MSW compost increased soil microbial biomass C and soil respiration(Bundela *et al.,* 2010)

Effect of MSW compost amendments on soil microbial biomass

Compost is rich in organic matter and is an important source plants nutrient GallardoLara and Nogales (1987). 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 Houot and Chaussod (1995). In view of the fact that, it is through the microbial biomass mineralization of important organic elements take place, microbial activity is very closely related with soil fertility Frankenberger and Dick (1983). Thus, the application of MSW compost affected the soil content of C and N, and ultimately soil microbial biomass and activity. On the other hand, according with heavy metals quantity and bioavailability in MSW compost and MSWC amendment in soil may affect soil microbial biomass (Bundela *et al.,* 2010).

Conclusion

In the present review composting of municipal solid waste could be seen as an option of waste management in indian cities. It is environmental friendly, wealth creating and sustainable. This technique has been used for bioremediation of polluted sites. Effect of Hms on soil microbes depend upon soil as well as municipal solid waste characteristic and its application rates. Thus physico-chemical analysis of municipal solid waste compost is necessary before its application in to agricultural land.

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