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Original Research Paper

Studies on Aerobic Compost from the Solid Waste Generated in Coimbatore City, Tamilnadu, India

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ABSTRACT

Waste is an unavoidable secondary product of human activities. Economic development, urbanization and improving living standards in cities, have led to an increase in the quantity and complexity of generated waste. The generated solid waste from Coimbatore city was sorted in to organic waste and various types of aerobic compost such as Rapid compost, Windrow compost, Pit method of compost and Vermicompost were prepared by adding raw materials of different composition. Their physical and chemical characteristics, macro and micronutrient content were evaluated in the field and laboratory. This paper highlights the comparative study between the various types of aerobic composts prepared. pH, electrical conductivity, temperature, total organic carbon (TOC), total nitrogen, phosphorus, potassium and C/N ratio were estimated, and their impact on soil is elaborately discussed in the paper.

INTRODUCTION

Expeditious growth of population and industrialization degrades the urban environment and places serious stress on natural resources, which undermines equitable and sustainable development. Inefficient management and disposal of solid waste is an obvious cause of degradation of the environment in most cities of the succeeding world. Municipal Corporations of the developing countries are not able to hold the increasing quantities of waste, which results in uncollected waste on roads and in other public places. There is a need to work towards a sustainable waste management system, which requires environmental, institutional, financial, economic and social sustainability. This study explores alternative approaches to Municipal Solid Waste (MSW) management and estimates the cost of waste management in Coimbatore city, Tamilnadu, India. Aerobic composting was a substitute innovative method and it means that composting with air. The opposite of this is without air, which is anaerobic composting. The organic matter is turned into compost by microorganisms living in the composting material (biomass). Giving these microorganisms the correct environment means they can work rapidly and effectively. Due to environmental concerns, composting has become an increasingly popular method for handling organic waste, manure and other organic materials as it is an inexpensive, simple and environmentally friendly process. The main decomposition and stabilization process of the organic material within a compost pile is the biological reaction which is a heat-generation and dehydrating-environment process (Erykson 2003, Haug 1993). When the temperature rises, another important heat-generation process is the chemical or oxidation reaction which may be modelled by a single Arrhenius reaction (Bari & Koenig 2006).

Aerobic compost under the correct conditions creates a lot of heat; this can kill all sorts of seeds and pathogens. Efficient aerobic compost does not emit foul ammonia like smell (Nag 2009). Aerobic compost reduces the biomass to usable compost quicker than its anaerobic counterpart in nature; the aerobic process is most common in areas such as the forest floor, where droppings from trees and animals are converted into relatively stable organic matter. This decomposition does not smell when adequate oxygen is present. We can try to imitate these natural systems when we plan and maintain our landscapes. As we learn more about the biology and chemistry of composting, we can actually fasten the decomposition process. When carbon is oxidized to CO_2, a great deal of energy is released as heat. For example, if a gram of glucose molecules is dissimilated under aerobic conditions, 484 to 674 kilogram calories (kcal) of heat may be released (Ayalon et al. 2010). If organic material is in a large enough pile or arranged to provide some insulation, temperatures during decomposition may rise to over 170°F. At temperatures above 160°F, however, the bacterial activity decreases (Deborah et al. 1992).

There are varieties of bacteria that work in the compost pile. Each type needs specific conditions and the right kind of organic material. Some bacteria can even decompose organic material at temperatures below freezing. These are called psychrophilic bacteria, and although they work best at around 55°F, they continue to work down to 0°F. As they work, they give off small amount of heat. If conditions are right, this heat will be enough to set the stage for the next group of bacteria, the "Mesophylic," or middle range temperature bacteria. Mesophylic bacteria thrive from 70°F to 90°F, but just survive at temperatures above and below (40°F to 70°F, and 90°F to 110°F). In many backyard piles, these mid range bacteria do most of the work. However, if conditions are right, they produce enough heat to activate the "Thermophilic," or heat loving bacteria. Thermophilic bacteria work fast. Their optimum temperature range is from 104°F to 160°F. High temperatures destroy pathogenic bacteria and protozoa, and weed seeds, which are harmful to health and agriculture when the final compost is used on the land. Aerobic oxidation does not stink. If odours are present, either the process is not entirely aerobic or there are materials present arising from other sources than the oxidation which have an odour. Aerobic decomposition or composting can be accomplished in pits, bins, stacks or piles, if adequate oxygen is provided. To maintain aerobic conditions, it is necessary to add oxygen by turning the pile occasionally or by some other method. (Dubey 1993)

MATERIALS AND METHODS

Since anaerobic composting is a leisurely process and due to outrush of noxious gases, aerobic composting methods like windrow composting, rapid composting, pit method of composting and vermicomposting were taken for investigation and composts were prepared.

Windrow method: Windrow composting consists of placing the mixture of raw materials in long and narrow piles which are turned on a regular basis. The turning operation mixes the composting materials and enhances passive aeration. The windrow size was 1.5m height, 1.5m width and 3.5m length. To enhance the rate of decomposition, turnings were given daily to the raw materials in the pile at the starting time and was considerably reduced as the time prolongs and height of the windrow reduces to 0.75m. Moisture content was uniformly maintained between 40% to 50%.

Rapid composting method: While traditional composting procedures take as long as 4-8 months to produce finished compost, rapid composting methods afford possibilities for turning down the processing period up to three weeks. Here a temporary shed was constructed over the elevated pit to protect the compost from heavy rainfall. The pit dimension was 1m height, 1.5m wide and 3m length. The ratio of waste to effective microorganisms was 100MSW: 1EM. The material brought from the pre-processing unit of about 500kg was spread evenly in the pit in layers of 15cm. On each layer about 0.25kg of effective microorganisms were spread. Sufficient quantity of water was sprinkled over the material in the pit to wet it. The pit was filled in this way, layer by layer. The material was turned four times during the month throughout the process. At each turning the material was assorted thoroughly, moistened with water.

Preparation of effective microorganism: The following micro organisms were cultured in the laboratory in liquid form and mixed with lignite in the ratio 1:4 to obtain powder form: i) *Bacillus specious*, ii) *Bacillus megatireium*, iii) *Pseudomonas straita*, iv) *Trichoderma virdi*, v) phosphate solubilizing bacteria.

Vermicomposting: Vermi stands for process facilitated by worms. Earthworms eat soil and various kinds of organic matter which undergo complex biochemical changes in the intestine which are then excreted in the form of granular casts of earthy smell. Earthworms excreted together with their cocoons and undigested food are called vermicastings. The species best suited for the generation of manure by this method are *Eudrilus euginae* and *Eisenia fetida*. The earthworm culturing was done in elevated pits of 1.5m wide, 1m height and 4m length, which can accommodate around 2000 worms and 4 tons of Municipal Solid Waste (MSW). Culturing of earth worms is done in moist places with shelter to avoid direct sunlight. To ensure protection from predators, pits are lined and covered with mesh. Sand dust, coconut shell, broken bricks were used as a base. Cow dung is an ideal feed for worms.

The worms that feed actively assimilate only 5%-10% and the rest is excreted as loose granular mounds of vermicastings on the surface, generally away from the food source. These have to be brushed aside and collected into separate trays. The collected castings have to be left overnight in conical heaps for the worms to move at the bottom. The top of the cones which are free from worms were collected and lightly air dried. The dried vermicastings were sieved through a 3mm mesh to separate cocoons and young ones from the vermincastings. The dried castings are ready for use as manure. The ratio is 1000kg of MSW: 5kg of earth worms. The material brought from the preprocessing unit of 1000kg was spread evenly in the pit in a layer of 25cm. On each layer about 1kg of earthworm was fed. Sufficient quantity of water was sprinkled over the material in the pit to wet it. The pit was filled in this way layer by layer.

Pit method of composting: The pit was dug below the ground level in summer season to study the impact on soil due to composting. The site selected for the compost pit was near to the cattle shed and a water source. A temporary shed was constructed over it to protect the compost from heavy rainfall. The pit dimensions were, 1m deep, 1.5m wide and 1.5m length (www.compost.com). The ratio was 2.5 MSW: 2 cowdung :1sawdust (Kalamdhad & Kazmi 2008). The material brought from pre-processing unit of 10 kg of solid waste was spread evenly in the pit in layers of 10-15cm. On each layer slurry made with 8kg cow dung, 4kg of saw dust and 0.25 kg of inoculum taken from a 15 day old composting pit was spread. Sufficient quantity of water was sprinkled over the material in the pit to wet it. The pit was filled in this way layer by layer.

RESULTS AND DISCUSSION

Moisture content for all the four types of compost was uniformly maintained at 40%-50% during the experimental phase. pH, electrical conductivity and temperature were analysed daily. Total organic carbon, total nitrogen, phosphorus and potassium were analysed in the laboratory. pH, electrical conductivity, temperature and moisture content were determined for the final compost. Table 1 shows the value of all the parameters for the four types of prepared compost. pH, electrical conductivity and temperature vary significantly with respect to the number of days for decomposition. Total organic carbon, organic nitrogen, phosphorus and potassium were also estimated in the laboratory.

Moisture content: Fig. 1 represents the variation of moisture content for the all the composts with respect to retention time. Moisture content for all the four types of compost was uniformly maintained at 40%-50% during the experimental phase. Moisture content is one of the most important factors for biological reaction within a compost pile. Haug (1993), Lin et al. (2008), Kuwahara et al. (2009) and Nakasaki et al. (2004) suggested that the optimal moisture content for biological activity is between approximately 40 and 60 percent of the compost's weight. The critical moisture content range for supporting spontaneous combustion is around 20 to 45 percent; above this range there is moisture sufficient for the evaporation process to cool the temperature, and below it, there is insufficient moisture to sustain the biological reaction. Normally, the composting process operates with a moisture content range of between 40 and 70 percent (Haug 1993).

pH: Fig. 2 represents the variation of pH for the all the compost with respect to retention time. In successful composting, the initial phase is followed by high-rate composting at pH values above neutral. A combination of temperature above 40°C and pH below 6 severely inhibits the composting process. The pH value changes during composting, due to changes in the chemical composition. In general, the pH falls below neutral in the beginning due to the formation of organic acids and later raises above the neutral because acids are consumed and because ammonium is produced (Beck-Friis 2007).

Electrical conductivity: Fig. 3 represents the variation of electrical conductivity for all the compost with respect to the retention time. Electrical conductivity is used to measure the amount of nutrients in the compost that are in the form of salts. Electrical conductivity is a measure of the salt concentration in the soil solution. Electrical conductivity has been shown to increase with increased manure/compost application rates. (Kalamdhad & Kazmi 2008) reviewed the effects of municipal solid waste compost on soil properties and concluded that while municipal solid waste compost could induce salinity damage, the effects were likely to be much less than from sewage sludge applied at the same loading rate. (Ekinci et al. 2004) reported municipal compost causing salinity problems that could threaten the production of sensitive horticultural crops. Compost is mixed with a set amount of water, and an electrical conductivity meter measures how much electricity moves through the water. Elec-

Table 1: Physical and Chemical parameters of various types of compost.

Parameters	Windrow compost	Rapid compost	Vermicompost	Pit method of compost
Moisture content	20%	23%	24%	21%
Colour	Black	Black	Black	Black
Odour	No foul odour	No foul odour	No foul odour	No foul odour
pH	7.5	7.4	7.2	7.4
EC	4.596 mhos/cm	3.5 mhos/cm	3.87 mhos/cm	3.24 mhos/cm
Particle size	Passing thru 4mm sieve	Passing thru 4mm sieve	Passing thru 4mm sieve	Passing thru 4mm sieve
Retention time	60 days	28 days	40 days	36 days
Organic carbon	0.3%	0.18%	22%	0.38%
Total nitrogen	0.005%	0.006%	0.7%	0.001%
Total phosphorus	0.07%	0.01%	0.8%	0.12%
Total potassium	0.4%	0.18%	0.7%	0.2%
C/N ratio	60	30	31	38

tricity moves better through solutions high in salts, so the higher the EC reading the saltier the product. Since nutrients occur in compost as salts, high EC may also indicate high levels of nutrient content. Electrical conductivity seems to be raised during the middle of the maturity period of the compost.

Temperature: Fig. 4 represents the variation of temperature for all the type of compost. In aerobic composting, proper temperature is important; heat is released in this process. Since the composting material has relatively good insulation properties, a composting mass large enough (3' × 3') will retain the heat of the exothermo-biological reaction and high temperatures will develop. High temperatures are essential for destruction of pathogenic organisms and undesirable weed seeds (Ekinci et al. 2004) When the temperature rises, another important heat-generation process is the chemical or oxidation reaction which may be modelled by a single Arrhenius reaction (Miller & Finstein 1989). Also, decomposition is more rapid in the thermophilic temperature range. The optimum temperature range is 135°-160°F. Since few thermophilic organisms actively carry on decomposition above 160°F, it is undesirable to have temperatures above this for extended periods. Eggs of parasites, cysts and flies have survived in compost stacks for days when the temperature in the interior of the stack is around 135°F (Zeman et al. 2002). Since a higher temperature can be readily maintained during a large part of the active composting period, all the material should be subjected to a temperature of at least 150°F for safety (Bach et al. 2007). Sometimes compost operators avoid prolonged high temperatures because the nitrogen loss is greater at high temperatures because ammonia vaporizes, which takes place when the C:N ratio is low. But there are other ways of minimizing nitrogen loss than operating at a lower temperature. The advantages of destroying pathogenic organisms and weed seeds, controlling flies, and providing better decomposition outweigh any small nitrogen loss due to high temperatures. A drop in temperature in the compost pile before the material is stabilized can mean that the pile is becoming anaerobic and should be aerated. High temperatures do not persist when the pile becomes anaerobic. The temperature curve for different parts of the pile varies somewhat with the size of the pile, the ambient (surrounding) temperature, the moisture content, the degree of aeration, and the character of the composting material. To maintain high temperatures during decomposition, compost must be aerobic. The size of the compost pile or windrow may be increased to provide higher temperatures in cold weather or decreased to keep the temperatures from becoming too high in warm weather (Smars 2002). Experience shows that turning to release the heat of compost piles, which have become so hot (170°-180°F) that the bacterial

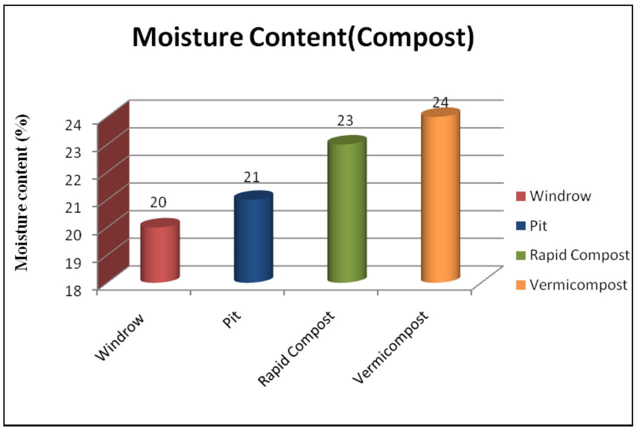

Fig. 1: Variation of moisture content on compost.

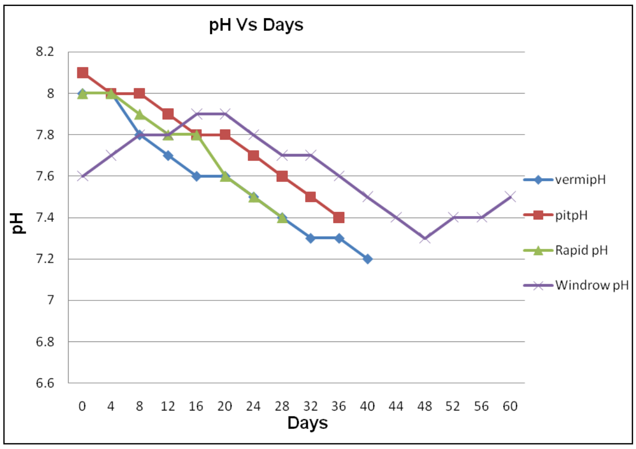

Fig. 2: Variation of pH on compost.

activity is inhibited, is not very effective. When the material is actively decomposing, the temperature, which falls slightly during turning, will return to the previous level in two or three hours. Also, it is impossible to bring about any significant drop in temperature by watering the material without water logging the mass (Abdelhadi et al. 2013).

Windrow compost raises upto a temperature of 70°C and simultaneously decreases, where other type of compost shows only minor variation with respect to retention time. Variations in moisture content between 30% and 75% have little effect on the maximum temperature in the interior of the pile. The initial temperature rises a little more rapidly when the moisture content is 30% to 50% than when it is 70%. Studies show an important and significant correlation between the moisture content and the temperature distribution within the pile. When the moisture content is high, temperatures near the surface will be higher, and the high temperature zone will extend nearer to the surface than when the moisture content is low.

C/N ratio: Fig. 5 indicates the C/N ratio for the compost prepared. C/N ratio seems to be higher for windrow compost and lower for vermi compost. The course of decomposition of organic matter is affected by the presence of carbon and nitrogen. The C:N ratio represents the relative proportion of the two elements. Actually, the ratio of available carbon to available nitrogen is the important relationship because there may be some carbon present, so resistant to biological attack that its presence is not significant. Organisms that decompose organic matter use carbon as a source of energy and nitrogen for building cell structure (Barrington et al. 2002, Lin et al. 2008). They need more carbon than nitrogen. If there is too much carbon, decomposition slows when the nitrogen is used up and some organisms die. Other organisms form new cell material using their stored nitrogen (Schulze 1962). In the process, more carbon is burned. Thus the amount of carbon is reduced while nitrogen is recycled. Decomposition takes longer, however, when the initial C:N ratio is much above 30 (Axelsson 2008). In the soil, using organic matter with excess carbon can create problems. To complete the nitrogen cycle and continue decomposition, the microbial cells will draw any available soil nitrogen in the proper proportion to make use of available carbon. This is known as "robbing" the soil of nitrogen, and delay availability of nitrogen as a fertilizer for growing plants, until some later season when it is no longer being used in the life-cycles of soil bacteria. Organisms use about 30 parts carbon for each part of nitrogen, an initial C:N (available quantity) ratio of 30 promotes rapid composting and would provide some nitrogen in an immediately available form in the finished compost. Researchers report optimum values from 20 to 31. A majority of investigators believes that for C:N ratios above 30 there will be little loss of nitrogen. University of California, studies on materials with an initial C:N ratio varying from 20 to 78 and nitrogen contents varying from 0.52% to 1.74%, indicate that initial C:N ratio of 30 to 35 was optimum. These reported optimum C:N ratios may include some carbon which was not available. Composting time increases with the C:N ratio above 30 to 40. If unavailable carbon is small, the C:N ratio can be reduced by bacteria to as low a value as 10. 14 to 20 are common values depending upon the original material from which the humus was formed. These studies showed that composting a material with a higher C:N ratio would not be harmful to the soil, however, because the remaining carbon is so slowly available, that nitrogen robbery would not be significant. The optimum ratio in soil organic matter is about 10 carbons to 1 nitrogen, or a C:N ratio of 10:1 (Liang et al. 2003). This is the ratio of total carbon to total nitrogen (C:N) in the sample. The C:N ratio typically decreases during composting if the starting C:N ratio is > 25, but may increase if the starting C:N ratio is <15 and nitrogen is lost during the composting process. Composts with C:N > 30 will likely immobilize nitrogen if applied to the soil, while those with C:N ratio < 20 will mineralize organic nitrogen to inorganic (plant-available) nitrogen.

Organic carbon: Fig. 6 indicates the organic carbon content in the aerobic compost. Vermicompost has the higher organic carbon content when compared to other types of compost. Carbon will be in the organic form unless the sample has a pH > 8.3 or is known to contain carbonates. Compost organic matter typically contains around 54% organic carbon.

Total nitrogen: Fig. 7 indicates the total nitrogen content of the aerobic compost prepared. Ammonium levels decrease as the maturity of the compost increases. Ammonium levels may be high during initial stages of the composting process, but will decrease as maturity increases. Organic nitrogen is determined by subtracting the ammonium and the nitrate nitrogen (an optional test) from the total nitrogen. However, since nitrate nitrogen levels are generally very low, total nitrogen minus ammonium nitrogen will give a good estimate of organic nitrogen in most composts. The composition of raw starting materials, as well as, process conditions will affect the total nitrogen (N) content of compost. The organic nitrogen in compost is that bound only in organic matter, while the total nitrogen content is typically defined as the sum of organic and inorganic forms (ammonium-N, nitrite-N, and nitrate-N). The organic N content of compost can be significantly lower than the total N content and, therefore the C:N ratio often must be calculated from the total N content of the material. A total N level between 0.75% and 2.5% is normal. Values below this range often indicate a high mineral content in the compost (OM less than 20%). This may indicate that it has been diluted with soil or that the composting process has proceeded to an advanced stage and that some amount of soil material was included in the original compost recipe. Starting materials low in N may also be a contributing factor. Nitrogen contents above 2.5% are most often associated with high organic matter levels (>60%), and/or nitrogen-rich starting components. The amount of total nitrogen (organic and inorganic) that is in the finished compost is usually lower then the raw manure. This could be due to several reasons. One reason is simply due to the rate of carbon amendment to the compost. In order to compost optimally, a Carbon to Nitrogen ratio (C:N ratio) of about 30 - 35:1 should be attained. By adding carbon materials to the manure will result in a dilution of the amount of nitrogen in the final mix. The production of ammonia is caused by high levels of nitrogen, which is indicated by a low C:N

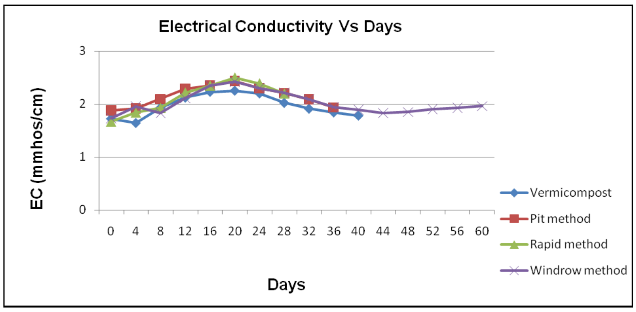

Fig. 3: Variation of EC on composts.

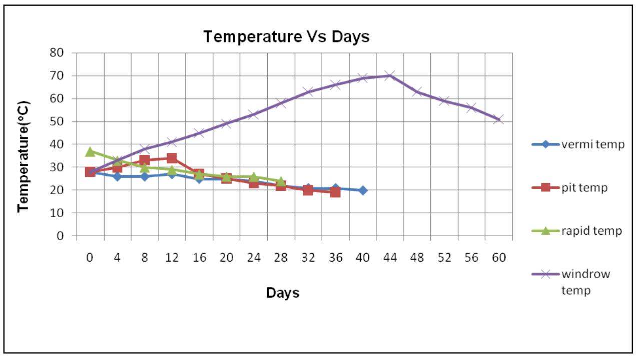

Fig. 4: Variation of temperature on composts.

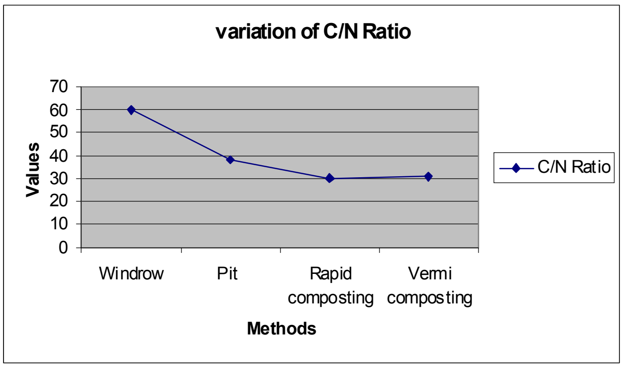

Fig. 5: Effect of C/N ratio for all the compost.

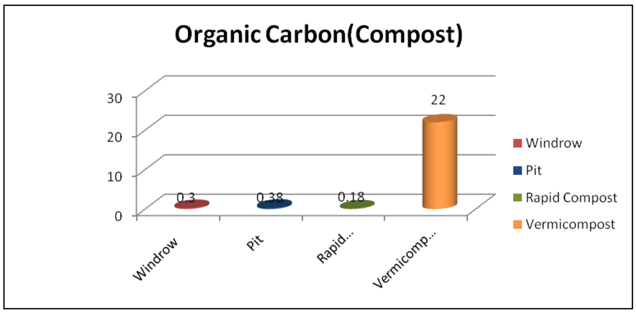

Fig. 6: Organic carbon content.

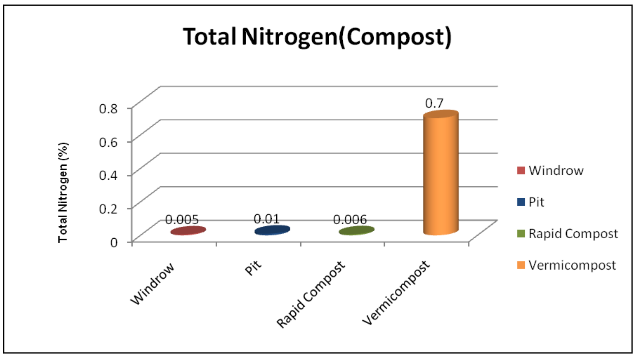

Fig. 7: Total Nitrogen content.

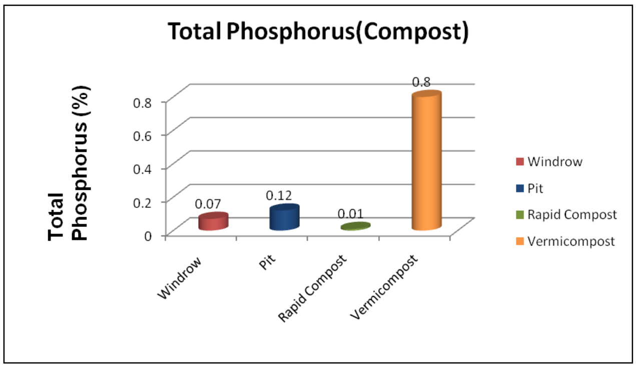

Fig. 8: Total phosphorus.

ratio (e.g. 16:1). Increasing the C/N ratio will correct this symptom and reduce the amount of nitrogen loss as ammonia. A high pH (pH 9-12) may also cause ammonia release since ammonium ions start to become unstable in the compost and are released as ammonia. Composting process optimization is also important in preventing the loss of nitrogen to the atmosphere as ammonia. Under anaerobic conditions, there are large amounts of ammonia that are produced from ammonification of organic compounds which cannot be oxidized by nitrification processes to form nitrates. Therefore, to conserve nitrogen in composts it is crucial to maintain aerobic conditions. Apart from ammonia, nitrogen in compost is also lost as nitrogen gas and nitrous oxides. Nitrogen gas does not pose an environmental concern, however nitrous oxides are considered greenhouse gases. Nitrous oxides are also a result of anaerobic processes and under optimal conditions these compounds should be converted to nitrogen gas by microorganisms. When compost piles are not

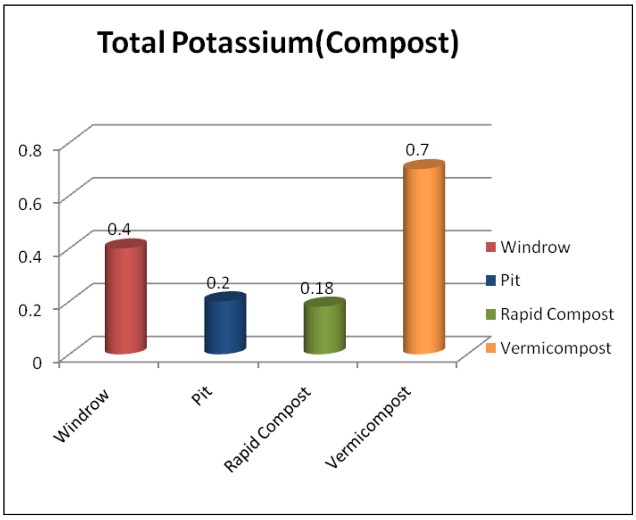

Fig. 9: Total potassium content.

managed effectively much of the nitrogen can be loss in the leachate. Nitrates in the leachate can pose environmental, and health and safety issues with ground water.

Total phosphorus and potassium: Figs. 8 and 9 indicate the total phosphorus (P) and potassium (K) content of the compost prepared. Phosphorus (P) and potassium (K) are plant macronutrients. These results provide an indication of the nutrient value of the compost sample. However, plant availability of total phosphorus and potassium in compost has not yet been established. In this study, vermicompost proves dominant in nutrient content when compared to other types of compost. Pit method of compost proves next to vermicompost in nutrient content. Windrow compost has got good potassium content but takes more time for degradation. Carbon and nitrogen are lesser in other compost when compared to vermicompost.

From the investigations given in Table 1 it is clear that total organic carbon, total nitrogen, total phosphorus and potassium seems to be higher in vermicompost when compared to other types of aerobic compost.

CONCLUSION

Comparative study clearly proves that pH, temperature and electrical conductivity varies significantly with respect to the retention time for decomposition. Wind row composting method takes more time for degradation and nutrient content are less, hence it can be used for polluted land reclamation purpose. Rapid compost and pit method of compost have nutrient content in the desirable amount but is comparatively less when compared to vermicomposting. C/N ratio also varies for all the compost and it is very less in vermicompost and it is more suitable for using in the agricultural field. NPK values seems to be higher in vermicompost when compared to other types of compost obtained.

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