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# DIVERSIFICATION IN PHYSICO-CHEMICAL ASPECTS OF MUNICIPAL SOLID WASTE COMPOST AT DIFFERENT PHASES IN VELLALORE LANDFILL SITE

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## Abstract

The existing evaluation was commenced to estimate the variations prevailing throughout the decomposition of municipal solid waste at vellalore landfill site, through the evaluation of some distinctive physico-chemical aspects and heavy metal concentrations. Alteration in the values of constituent elements of the compost over a period of time, included rise in chlorides, carbonate and bicarbonates, calcium and magnesium, sulphate, phosphorus, sodium, potassium, nitrogen, depletion in moisture, bulk density and particle density, ash content, organic carbon and C:N ratio. In the consecutive stages of composting technique, the physico-chemical testing of compost from the perspective marginal heavy metals concentrations were identified at all the decomposition phases of composting. The values were found to be within the tolerable limits of Ohai- EPA standards. From the outcome, it can be finalized that, windrow composting could generate reasonable quality of compost, which can be utilized as fertilizer or soil amendment.

**Keywords:** Vellalore, Solid waste, Physico – Chemical parameters, Heavy metals, Compost, Ohai- EPA standards

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## Introduction

The menace of environmental pollution has been haunting the human world since early times and it continues to grow due to excessive population growth in developing countries. Municipal solid waste (MSW) normally termed as “garbage” or “trash” is an inevitable byproduct of human activity. Population growth and economic development lead to enormous amounts of solid waste generation by the dwellers of the urban areas. Improper MSW disposal and management causes all types of pollution: air, soil, and water. Indiscriminate dumping of wastes contaminates Surface And Ground Water Supplies Like Untreated Leachate Pollutes Surrounding Soil And Water Bodies (Pervez Alam & Kafeel Ahmade, 2013).

The public at risk from the unscientific disposal of solid waste include – the population in areas where there is no proper waste disposal method, especially the pre-school children; waste workers; and workers in facilities producing toxic and infectious material. Other high-risk group include population living close to a waste dump and those, whose water supply has become contaminated either due to waste dumping or leakage from landfill sites. Uncollected solid waste also increases risk of injury, and infection.

Waste treatment and disposal sites can also create health hazards for the neighborhood. Improperly operated incineration plants cause air pollution and improperly managed and designed landfills attract all types of insects and rodents that spread disease. Ideally these sites should be located at a safe distance from all human settlement. Landfill sites should be well lined and walled to ensure that there is no leakage into the nearby ground water sources (N.Raman and D.Sathiya Narayanan, 2008).

Skin and blood infections resulting from direct contact with waste and from infected wounds, eye and respiratory infections resulting from exposure to infected dust, especially during landfill operations. Different diseases that results from the bites of animals feeding on the waste and intestinal infections that are transmitted by flies. Incineration operators are at risk of chronic respiratory diseases, including cancers resulting from exposure to dust and hazardous compounds.

Proper methods of waste disposal have to be undertaken to ensure that it does not affect the environment around the area or cause health hazards to the people living there. At the household-level proper segregation of waste has to be done and it should be ensured that all organic matter is kept aside for composting, which is undoubtedly the best method for the correct disposal of this segment of the waste. In fact, the organic part of the waste that is generated decomposes more easily, attracts insects and causes disease. Organic waste can be composted and then used as a fertilizer (Swati Srivastava and Ritu Singhvi, 2015).

This study involves physio - chemical analysis and Heavy metal analysis of the different stages of solid waste dumped in the Vellalore landfill site. The aim of the study is to understand how the changes in physio – chemical parameters and heavy metal concentration take place in different stages.

## MATERIAL AND METHODS

### Study Area

Vellalore (10°58′02″N, 77°01′40″E) is a panchayat town in Coimbatore district in the Indian state of Tamil Nadu. It is at 13 km east of the heart of the city Coimbatore, situated on the southern bank of the River Noyyal.

Since years, the entire solid as well as sewage waste of Coimbatore city is being dumped in the Vellalore Yard. It was reported that thousands of tons of garbage is getting disposed every day within the Corporation limits of Coimbatore and all these reaches straight to Vellalore.

### Collection of compost samples

Individual degraded compost samples were collected from solid waste treatment plant at Vellalore, Coimbatore during the month of December 2015. At each heap, six compost samples (Fresh, 15 days, 30 days, 45 days, 60 days and 90 days) were taken randomly within a 0.5 meter quadrate and mixed into a composite sample of the particular heap. These samples were then transported in sealed aluminium foil to the laboratory, where stones, plastic and metals were removed, oven dried at 70 ℃ and the compost is homogenized through a 2 mm sieve. The compost samples were stored in the dark bottles till further analysis.

### Analysis of compost samples

### Physico-chemical analysis

All experiments were carried out in triplicates. The collected degraded compost samples were analysed for various physico-chemical characteristics such as Colour, Moisture content (drying at 105 0C to constant weight by gravimetric method); Particle and Bulk densities (Pycnometric method); pH (1:5 water extract by pH meter); Ash Content, Calcium and Magnesium (1N ammonium acetate, EDTA method); Chlorides (1:5 water extract $AgNO_3$ method); Carbonate and Bicarbonate; Total organic carbon (cold oxidation with potassium dichromate Walkey and Black method ); Total organic nitrogen (Kjeldhal method); Sulphate (1:5 water extract for $BaCl_2$ method); Phosphorus (tri acid mixture with a aqua digestion); Potassium and Sodium (1N ammonium acetate extract using flame photometer method), Total nitrogen values used in C/N were calculated by adding the three forms determined (organic nitrate and ammonium) using standard procedures for analysis (Jackson, 1973; Saha Arun Kumar, 2008 and Mani et al 2007).

### Heavy metal analysis

The 1g of oven dried sample was transferred to 100 ml beaker. A tri acid mixture (10 ml) consisting of $HNO_3$, $H_2SO_4$ and $HClO_4$ in the ratio 9:2:1 was added to each of the flasks with 100 ml of distilled water and digested on hot plate until the dense fumes of $HClO_4$ cease, to get a clear extract. The beakers were then allowed to cool and the extracts were filtered with Whatman No.42 filter paper. The filtrates were diluted to 100 ml in standard flasks to have an adequate volume of solution for analysis. The dilution factor was noted. The water soluble and acid digested extracts were analyzed for quantitative estimation of heavy metals (copper, cadmium, lead, mercury and arsenic) using atomic absorption spectrophotometer (Mani et al, 2007).

## RESULTS AND DISCUSSION

### Estimation of Physico – Chemical Characteristics at Different Maturity Stages of Compost

The physico-chemical characteristics at different maturity stages of compost are presented given in Table.1

### Colour

The colour of the samples changed from brownish green (Fresh) to brownish black (90 days) which resulted in proper degradation of waste during composting process. This indicates the maturity of compost. The change in colour is due to the presence of humus content produced during degradation process. Humus has a characteristic black or dark brown colour and is organic due to an accumulation of organic carbon.

### Moisture Content

Moisture content is a measure of the amount of moisture present in a compost sample and is expressed as a percentage of fresh weight. Moisture content of the composting blend is an important environmental variable as it provides a medium for the transport of dissolved nutrients required for the metabolic and physiological activities of micro-organisms (Elango *et al*, 2009). The moisture content of fresh waste was found to be 74.2% as the days increased the moisture content were found to be decreasing till 23.42% because water is needed in the right amounts to maintain activity without causing anaerobic conditions. Decline in the moisture content percentage during the thermophilic phase of composting due to high evaporating rates has been recorded by Larney and Blackshow (2003). The moisture content of the composting material must be between 45 and 65% moisture content. The bacteria and fungi that do the composting live in a water layer around the organic particles. If the moisture content is below 45%, there is not enough water around the particles for the microorganisms to live.

**Table 1: Physico Chemical Characteristics at Different Maturity Stages of Composting Process**

| S.No | Parameters | Units | Fresh | 15 Days | 30 Days | 45 Days | 60 Days | 90 Days |
|---|---|---|---|---|---|---|---|---|
| 1 | Colour | -- | Brown/Green | Brown/Green | Brown/Green | Brown | Brown | Brown/Black |
| 2 | Moisture Content | % | 74.21 | 71.36 | 63.15 | 53.27 | 36.18 | 23.42 |
| 3 | Bulk Density | $mg/m^3$ | 0.61 | 0.59 | 0.53 | 0.42 | 0.39 | 0.33 |
| 4 | Particle Density | $mg/m^3$ | 2.5 | 2.5 | 2 | 1.9 | 0.75 | 0.65 |
| 5 | Ash Content | % | 33.51 | 28.68 | 25.53 | 22.87 | 18.55 | 14.39 |
| 6 | pH @ 25°C | -- | 8.21 | 8.08 | 7.93 | 7.61 | 7.37 | 7.21 |
| 7 | Chloride as $Cl^-$ | % | 1.2 | 3.98 | 4.13 | 4.66 | 11.09 | 11.94 |
| 8 | Carbonates as $CO_3$ | % | 0.02 | 0.03 | 0.07 | 0.13 | 0.15 | 0.17 |
| 9 | Bicarbonates as $HCO_3$ | % | 0.8 | 0.91 | 1.08 | 1.44 | 1.48 | 1.51 |
| 10 | Calcium as Ca | % | 8.71 | 10.43 | 12.58 | 13.63 | 14.44 | 21.75 |
| 11 | Magnesium as Mg | % | 0.83 | 1.21 | 2.85 | 3.15 | 6.23 | 8.53 |
| 12 | Sulphate as $SO_4$ | % | 9.51 | 11.38 | 21.58 | 24.63 | 29.77 | 31.45 |
| 13 | Total Phosphorous as $PO_4$ | % | 1.21 | 4.02 | 5.01 | 6.13 | 5.92 | 12.76 |
| 14 | Sodium as Na | % | 0.77 | 2.56 | 2.66 | 3.08 | 7.13 | 7.68 |
| 15 | Potassium as K | % | 0.02 | 0.07 | 0.07 | 0.08 | 0.18 | 0.19 |
| 16 | Total Nitrogen | % | 0.81 | 0.97 | 1.05 | 1.03 | 1.11 | 1.27 |
| 17 | Total Organic Carbon | % | 15.92 | 14.96 | 12.96 | 11.86 | 10.42 | 9.69 |
| 18 | C:N Ratio | -- | 23.66 | 18.58 | 14.78 | 13.76 | 9.45 | 9.18 |

## Bulk Density

Bulk density is the weight of compost in a given volume. The bulk density was found to be decreasing from 0.61 $mg/m^3$ to 0.33 $mg/m^3$ with increase in days in comparison with recommended standard (Brinton, 2003) in all the maturity stages. The composting material should have a bulk density of between 600 and 700 kg per cubic meter. Material having a bulk density lower than this is likely too dry, or the particles are too large to compost properly.

## Particle Density

The weight of an individual compost particle per unit volume is called particle density. Similar to bulk density the particle density also decreases with increase in days from 2.5 $mg/m^3$ to 0.65$mg/m^3$ in comparison with recommended standards (Bord na Mona, 2003).

## Ash Content

Loss of Ignition (LOI) is a simple method for determining ash content, by reciprocation of organic matter content of compost and manure. Organic matter is an important component of manure and compost, which influences many soil properties (Nelson and Sommers, 1996). Organic matter is the measure of carbon based materials in the compost. Organic matter is an important ingredient in all soils and has an important role to play in maintaining soil structure, nutrient availability and water holding capacity. High quality compost will usually have a minimum of 50 % organic content based on dry weight. The ash content obtained was in decreasing order from 33.51% to 14.39%. For compost, the minimum ash content was 66.2% at 650 ℃ for16 hrs and maximum value was75.7% at 400 ℃ for 1 hr. This transcribes to organic matter contents of 33.8% and 24.3% respectively (Matthiessen *et al*, 2005).

## pH

pH is a measure of acidic or alkaline nature of the compost as composting progresses. pH was estimated for the samples every 15 days. The pH of the fresh sample and 90 days sample was found to be 8.21and 7.21 respectively in comparison with recommended standards (Bord na Mona, 2003). pH of compost depends very much on the materials added. If manure is added the compost will be more alkaline. As the compost is being made it goes through pH swings. In the beginning, organic acids are produced which makes the compost pH drop (acidic). In these conditions fungi grow better than bacteria and start the decomposition. The pH of the finished compost varies based on the time taken. Earlier the time the pH would be acidic, if later the time the pH would be alkaline. In general the pH of compost lies between 6 and 8 with compost made from home (municipal/residential solid waste) showing a mean pH of 7.0 to 7.5 (neutral).

## Chloride

During the study period, the chloride concentration of compost samples varied from 1.2 to 11.94 %. The concentrations of chloride for the samples are attributed to the dissolution of chlorinated soluble salts present in the solid wastes. The chloride concentration increased for each of the composting process.

## Carbonates and Bicarbonates

The concentrations of carbonates and bicarbonates of compost samples were found in the range of 0.02 to 0.17 % and 0.8 to 1.51 %, respectively. The results shown that, minimum concentrations of carbonate and bicarbonate were recorded from fresh compost samples and maximum carbonate bicarbonate at 90 days samples.

## Calcium

Calcium and magnesium act as bases when they exist as oxides, hydroxides and carbonates. During the present investigation, calcium concentrations of compost samples varied from 8.71 to 21.75%, in comparison with recommended standards (Barker, 1997). Calcium has no hazardous effect on human health. In fact, it is one of the most important nutrient required by the organisms and can also aid in maintaining the structure of plant cells and soil condition. The main sources of calcium in the solid wastes are food and vegetable wastes, animal wastes, fine earth, organic wastes etc.

## Magnesium

Magnesium concentrations varied from 0.83 to8.53%, in comparison with recommended standards (Barker, 1997). The concentration of magnesium was found to be lesser than calcium, which is regarded as, non-toxic to human health. The principal sources of magnesium in the solid wastes are domestic, food and vegetable wastes, fine earth and small scale industrial wastes etc. (Shivakumar et al., 2004).

## Sulphate

The present investigation on sulphate varied from 9.51 to 31.45 %. The minimum percentage of soluble sulphate was recorded in fresh compost sample with 9.51 % and maximum for 90 days old compost sample with 31.45 %. The variation of sulphate concentrations mainly depends on the decomposition of organic matter present in the solid wastes. In anaerobic decomposition of solid wastes, sulphate is reduced to hydrogen sulphide, causing obnoxious odours and promotes corrosion (Shivakumar et al., 2004).

## Phosphorus

Phosphorous is also an important nutrient for plant growth. Total phosphorous (TP) is usually expressed in terms of percentage concentration per dry weight. During the present investigation, the total phosphorous concentration varied from 1.21 to 12.76%, in comparison with recommended standards (Bord na Mona, 2003). Total phosphorous content gradually increased during composting process and water solubility of phosphorous decreases with humification, so that, phosphorous solubility during the decomposition was subjected to further immobilization factor (Elango et al., 2009).

## Sodium

The sodium concentration varied from 0.77 to 7.68 %. Minimum concentration of sodium was found to be in fresh compost sample and maximum for 90 days compost sample. Sodium content in the waste was highly soluble and readily gets leached. Part of the sodium salt gets solubilised during decomposition. Up to moderate concentration, there was no adverse effect but the higher concentration of sodium may affect the soil structure as well as permeability resulting in alkaline salts and become toxic to plants (also corrosive).

## Potassium

In the present study, potassium concentration varies from 0.02 to 0.19 %. Potassium is highly soluble in the wastes. Therefore, potassium is leached easily. The insoluble potassium salts can be solubilised by the decomposition of the wastes. Potassium increases during the period of composting and effective use of some fibrous materials like, straw or wood chips which can absorb relatively large quantities of water and still maintain structural integrity and porosity could prevent the loss of potassium from the compost formed (Gallardo-Lara et al., 1987). Potassium is not known to have harmful or toxic effects on human beings and it helps in plant growth as an essential nutritional element.

## Total Nitrogen

Total nitrogen (N) includes all forms of nitrogen, organic nitrogen, ammonium nitrogen ($NH_4$-N) and nitrate nitrogen ($NO_3$-N). The measure of total nitrogen content includes both organic and inorganic forms of nitrogen in compost. In mature composts, most of the nitrogen is in organic form. The total nitrogen of all the compost samples varied from 0.81 to 1.27 %. The increase in total nitrogen concentration during composting was caused by the decrease of substrate carbon resulting from the loss of $CO_2$ (because of the decomposition of the organic matter, which is chemically bound to nitrogen).

## Total Organic Carbon

During the present investigation, the total organic carbon varied from 9.69 to 15.62 %. The total organic carbon content was found to be reduced in all the degradation stages of compost samples. The losses of organic carbon were significantly affected by composting. It was found that, the percentage of organic carbon decreased, which shows the decomposition of waste by microbial population (Mondini et al., 2003). Part of the carbon in the decomposing residues evolved as $CO_2$ and a part was assimilated by the microbial biomass (Cabrera et al., 2005; Fang et al., 2001; Nakasaki et al., 1985). Fares et al. (2005) reported that carbon loss accounted for initial total carbon during the composting process.

## C/N Ratio

C/N ratio is one of the most important parameters that determine the extent of composting and degree of compost maturity, irrespective of the materials used for composting. The C/N ratio of all the compost samples varied from 9.18 to 23.66, in comparison with recommended standards (EPA waste management act 1996). It was reported that the C/N ratio falls down as nitrogen remain in the system, while some of the carbon is released as $CO_2$ (Sadasivam and Manickam, 1993). Further nitrogen fixing microbes indirectly help in decreasing C/N ratio by making more nitrogen available from added Organic Matter (Rasal et al., 1988; Shinde et al., 1992). A ratio of >25 likely indicated stable compost.

### Estimation of Heavy Metal Concentrations of Different Maturity Stages of Compost

The corresponding heavy metals concentrations of different maturity stages of compost are tabulated in Table 2.

**Table 2: Heavy Metal Concentration of Different Maturity Stages of Composting Process**

| S.No | Parameters | Units | Fresh | 15 Days | 30 Days | 45 Days | 60 Days | 90 Days |
|---|---|---|---|---|---|---|---|---|
| 1 | Total Iron as Fe | mg/Kg | 22.81 | 14.59 | 16.78 | 19.21 | 17.53 | 16.97 |
| 2 | Copper as Cu | mg/Kg | 51.57 | 47.83 | 44.29 | 48.57 | 49.89 | 53.84 |
| 3 | Cadmium as Cd | mg/Kg | 1.23 | 1.05 | 0.94 | 0.98 | 0.76 | 0.81 |
| 4 | Lead as Pb | mg/Kg | 7.21 | 5.23 | 8.27 | 6.75 | 3.22 | 2.18 |
| 5 | Mercury as Hg | mg/Kg | 1.27 | 2.81 | 0.88 | >0.001 | >0.001 | >0.001 |
| 6 | Arsenic as As | mg/Kg | 0.51 | 0.27 | >0.001 | >0.001 | >0.001 | >0.001 |
| 7 | Zinc as Zn | mg/Kg | 76.25 | 74.51 | 70.88 | 67.49 | 62.24 | 68.43 |

### Iron

Iron is important for crops that prefer acid soils such as blueberries, strawberries, grain, soybeans, and cole crops such as cabbage and broccoli. It's an important part of nitrogen-fixing in legume crops. 8 mg/kg is the average level of available iron found in the compost. The concentration of iron was found to be within the range 14.59 mg/kg to 22.31 mg/kg with minimum concentration at 15 days compost sample and maximum at fresh compost sample. Excessive iron availability at lower soil pH may limit phosphorus availability (James W. Travis *et al*, 2003).

### Copper

In the present study, the concentration of copper varied from 44.29 to 53.84 mg/kg with minimum at 30 days compost sample and maximum at 90 days compost sample and was found to be, below the permissible limits of Ohai EPA Standards (1500 mg/kg). Copper is essential for the activity of enzymes in human beings. Copper toxicity in humans results in abnormalities of kidney functions (Sharma and Gupta, 2006).

### Cadmium

The cadmium concentration in all compost samples varied from 0.76 to 1.23 mg/kg. The cadmium concentration for all the 6 set of compost samples had lower than the permissible limits prescribed by Ohai EPA Standards (35 mg/kg). Cadmium is of particular concern in plants, since its accumulation in soil is due to application of soil amendment such as compost of refuse and fertilizers. Cadmium is of particular concern in plants, since it accumulates in leaves at very high levels. It may affect the animal feeding on crops grown on solid waste treated soil. In order to apply the solid waste compost, the highest permissible concentration of cadmium was 5 mg/kg.

### Lead

The lead concentration in all compost samples varied from 2.18 to 8.27 mg/kg, with minimum obtained at 90 days compost sample and maximum at 30 days compost sample. During the study period, lead concentration in all the 6 sets of compost samples was below the detection limits, of Ohai EPA standards (300 mg/kg). Lead is toxic metal and its concentration in sewage is mainly through pesticide and paints runoff. The lead content may enter the food chain through fishes, grazing cattles or vegetables grown using sewage treated water. Depending upon the level of exposure, lead has the potential, to cause a variety of biological and environmental effects. Soils get contaminated with heavy metals after addition of solid waste.

### Mercury

In the present study, the mercury concentration was found to be from zero (> 0.001) to 3 mg/kg for all the 6 set of compost samples which is less than the permissible limits, of Ohai EPA standards (7.8 mg/kg).

### Arsenic

The arsenic concentration in all compost samples varied from zero (> 0.001) to 1 mg/kg and was found to be lower than permissible limits of Ohai EPA Standards (41 mg/kg). Arsenic contamination in soils results from various human activities including milling, combustion, wood preservation, pesticide application and adding arsenic contaminated manure. There are tens of thousands of arsenic contaminated sites worldwide, with arsenic concentrations as high as 26.5 mg/kg (Hingston, 2001).

### Zinc

From all the compost samples, zinc was estimated within the range of 68.43 to 76.25 mg/kg with minimum and maximum concentration at 60 days compost sample and fresh compost sample respectively.

### Conclusions:-

The results of the study clearly indicate that, the biodegradation and recycling of solid urban wastes can transform garbage to enriched composts. Physico-chemical analysis of compost from the point of view moisture content, pH, chloride, organic matter, calcium, magnesium, total phosphorus, total nitrogen, C/N ratio, sodium, potassium agreed with recommended standards (Biotrate, 2003, Bord na Mona 2003, EPA Waste Management Act 1996 and Barker, 1997), and heavy metals are like, copper, cadmium, lead, mercury and arsenic were found to be within the permissible limits of Ohai EPA Standards at all the maturations stages. The data presented in tables 1 and 2 showed that, the windrows system was more effective for nutrients marinating. Considering the high volume of garbage or MSW in Coimbatore, aerobic composting may be implemented and could be concluded as the best method of MSW management. In this regard, windrow composting system may be recommended for better method for recycling of MSW, which can be used as fertilizer or soil amendment. Although applications of sewage sludge have caused toxicity to plants due to zinc, MSW composts contain much lower concentrations of zinc than does sludge. Zinc in MSW compost is unlikely to injure crops and may, in fact, be beneficial in regions deficient in zinc.

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