Studies on variations in physico-chemical, biochemical and biological characteristics at different maturity stages of segregated and unsegregated urban solid waste of drum compost

Comment [A1]: The title is reformulated according to the content

Abstract: The present study was under-taken to assess the changes of occurring during the decomposition of segregated and unsegregated urban solid waste of drum compost some typical physico-chemical, biochemical and biological characteristics. The physic-chemical analysis of compost from the point of view moisture content, pH, EC, organic carbon, calcium, magnesium, total NPK, C/N ratio, and micro nutrients agreed with recommended standards and higher heavy metals concentrations was detected at all the decomposition stages of composting. From the results, it can be concluded that, drum composting could produce acceptable quality of compost, which can be used as fertilizer or soil amendment.

Comment [A2]: Please note the guidelines for authors on how to write abstracts

Comment [A3]: The research method has not been described

Keywords: Physico-chemical, Biochemical, Biological characteristic, Heavy metals, Urban solid waste drum compost.

Introduction

Municipal solid waste comprises all the wastes arising from human and animal activities. According to WHO (World Health Organization), solid waste can be defined as useless, unwanted or discarded materials arising from domestic, trade, commercial, industrial and agricultural as well as from public services. At present municipal solid waste (MSW) management has become a serious environmental problem and one of the major growing concerns for urban areas all over the world. In the typical countries, the major portion of the total solid waste is biodegradable organic matter. The high content of these biodegradable organic matter and other inert material, results in high waste density and high moisture content. Theses physical characteristics significantly influence the feasibility of certain treatment options.

Comment [A4]: Citations are required to confirm this opinion

Current global waste generation levels are approximately 1.3 billion tonnes per year and are expected to increase approximately 2.6 billion tonnes annually by 2025. This represents a significant increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day. The total municipal solid waste (MSW) generated in urban India is 68.8 million tonnes per year or 1, 88,500tonnes per day. Per capita waste generation in major Indian cities ranges from 0.2 kg to 0.6 kg. This is estimated to increase at 1.33 percent annually (Shekdar, 1999). If the trend continues, urban India will generate 160.5 million tonnes per year (4,40,000 tonnes per day) by 2041.

Municipal solid waste composting, however, has proved to be a safe and effective way to accelerate the decomposition and stabilization of biodegradable components of bio-waste from MSW, leading to production of compost for soil amendment or as an organic nutrient source (Hargreaves *et al.,* 2008; Herrera *et al.,*2008). Composting is gaining interest as suitable option for chemical fertilizers with environmental profit, since this process eliminatesor reduces toxicity of MSW (Kaushik and Garg (2003); Araujo and Monteiro (2005) and leads to a final product which can be used in improving and maintaining soil quality. Many studies have shown that the compost improves physical and chemical properties of soils by increasing nutrient content, organic matter, water holding capacity and cation exchange capacity. Thus contributing to improvement of crop yield and quality (Mylavarapu and Zinati, 2009; Iovieno*et al.,* 2009).

Generally, successful composting depends on a number of factors that have both direct and indirect influence on the activities of the microorganism. They include the type of raw materials being composted, its nutrient composition, moisture content, temperature, alkalinity and aeration. To obtain a final product that is stable, free of pathogens, plant seeds can be beneficially applied to land (Lee and Han, 2005). Due to industrialization and urbanization in the Bengaluru city, population and municipal solid waste has increased simultaneously So, the study was undertaken to evaluate physico-chemical, biochemical and biological characteristics and heavy metal concentrations during different maturity stages of composting process of municipal solid waste. This study would help to understand the degradation of solid wastes at various stages.

Comment [A5]: Need support from previous research

Materialsandmethods

Collection of compost samples: City solid waste is obtained from in and around GKVK Bengaluru for the preparation of segregated and unsegregated composts, during the month of July 2015. Segregated urban solid waste such as vegetables, fruits, flower, dry leaves and saw dust are dumped into the drum composters and composting is done with microbial consortia (*Trichodermaviridae, Trichodermaharzianum, Pseudomonas fluorescence, phaenerochatechryosporium, Bacillus subtiles*) without contact with other urban dry waste. Whereas unsegregated urban waste as such available as waste without segregation and vegetables, fruits, flower, leaf litter along with solid dry waste like metals, papers, medicines, cosmetics etc. are dumped into the drum composters and composting is done with the use of microbial consortia. The segregated and unsegregated samples were collected during drum composting at different intervals of 20^{th}, 40^{th}, 60^{th} and 80^{th} days of compost.

Fig 1: A simple technology of composting urban waste and its use in agriculture

UAS (B) Drum Composter

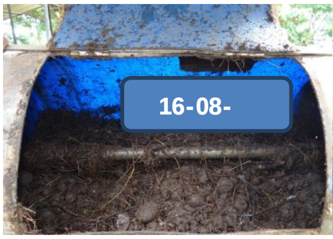
Fig 2: Changes during composting of segregated and unsegregated urban solid waste at different days of intervals

Segregated drum compost

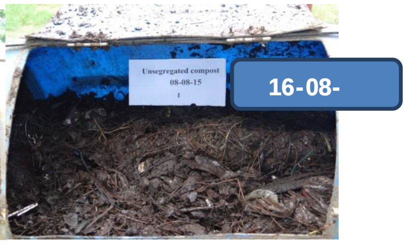
Unsegregated drum compost

20th dayof Segregated drum compost

20th dayof Unsegregated drum compost

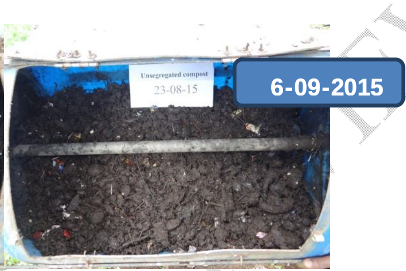


40th dayof Segregated drum compost

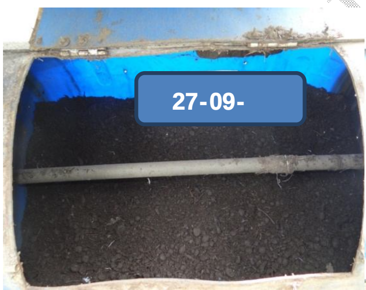


40th dayof Unsegregated drum compost

60th dayof Segregated drum compost



60th dayof Unsegregated drum compost



80th dayof Segregated drum compost

80th dayof Unsegregated drum compost

Analysis of compost samples

1. Physico-chemical analysis

The collected segregated and unsegregated samples were analyzed for various physico-chemical characteristics such as Moisture content (Pressure plate apparatus method); Bulk densities (Keen's cup method); pH (1:5 water extract by pH meter); Electrical conductivity (1:5 water extract, conductivity meter); Calcium and Magnesium

Comment [A6]: How do you assess and compare the quality of the compost against the results of the analysis of physical, chemical and biochemical data.

(1N ammonium acetate, EDTA method); organic carbon (Dry combustion); Total nitrogen (Microkjeldahl Digestion and Distillation); Total phosphorus (Vanadomolybdic yellow colour spectrophotometry)Total potassium (Flame photometry), Sulphur (Turbidimetry), Micronutrients(Atomic absorption spectrophotometry). The C/N ratio was calculated by using standard procedures for analysis (Jackson, 1973; SahaArun Kumar, 2008 and Mani *et al* 2007).

2.Biochemical analysis

Lignin and cellulose Determination of lignin and cellulose was carried out by adopting the methodology given by Van Soest and Wine (1968).

2.1Acid Detergent Fibre (ADF): One gram of sample was taken in a 250 ml round bottom flask and 100 ml acid detergent solution (Cetyl trimethyl ammonium bromide) was added. The contents of the flask were boiled for 10 minutes and refluxed for one hour after the onset of boiling. Later the contents were cooled and filtered through preweighed Gooch crucible by suction and washed with hot water twice, again washed with acetone to break the lumps. It was then dried to 100 °Cin a hot air oven for 12 hours and weight was recorded after cooling.

2.2Acid Detergent Lignin (ADL): The residue from ADF was transferred to 100 ml beaker containing 50 ml of 72 percent H_2SO_4 and allowed to stand for three hours and boiled for 4 hours after diluting. The contents were cooled and filtered through preweighed Whatman No. 1 filter paper. The residue was washed several times with distilled water to get rid of acid. Filter paper along with residue was dried at 100 °C and weight was recorded after cooling the desiccator. The filter paper along with residue was transferred to pre-weighed silica crucible and contents were ashed in muffle furnace kept at 550 °C for 3 hours. Weight of the crucible was recorded after cooling in desiccators and the ash content was calculated.

The lignin and cellulose were calculated using formulae

Lignin= Residue after extraction with 72 percent H_2SO_4- Ash

Cellulose= ADF - Residue after extraction with 72 percent H_2SO_4

2.3 Extraction, fractionation and quantification of humic substances

2.3.1Extraction of humic substances: Ten gram of air dried compost sample was taken in 250 ml conical flask to which 100 ml of 0.1 M NaOH in 0.1 M sodium pyrophosphate was added, stoppered and shaken for 24 hours. The dark colored supernatant was separated by centrifugation and collected. The extraction was repeated thrice with 50 ml of extractant for complete extraction of the humic substances.

2.3.2 Fractionation of humic substances: The pooled alkali extracts were acidified to pH 2.0 with 2 N HCl, stirred well and allowed to stand at room temperature for 24 hours. Then the soluble fulvic acid was separated from the coagulated humic acid fraction by centrifugation. The process of precipitation and centrifugation were repeated to attain partial purification of humic acid fraction as described by Schnitzer (1982).

2.4 Purification and quantification of organic matter fractions

2.4.1 Purification of humic acid: Humic acid was further purified by treating the extracted humic acid fraction with HCl-HF mixture (5 mL. each of HCl and HF acids were dissolved in 990 mL of double distilled water) for 24 hours. The acid mixture was separated by centrifugation. This treatment was repeated thrice in succession. Finally, the residue was thoroughly washed with distilled water and freeze dried. The sample weights were recorded before using it for the further analysis.

2.4.2 Purification of fulvic acid: The purification of fulvic acid was done as outlined by Wander and Traina (1996). The fulvic acid fraction was transferred to 100 mwco dialysis bags and dialysed against double distilled water for 24 hours. The dialyzed fraction was evaporated under low temperature and finally freeze dried. The dried sample were weighed and stored for further analysis.

2.5 Characterization of humic acid and fulvic acid

Purified samples of humic and fulvic acids extracted from matured composts were subjected to E_4/E_6 ratio using the procedure outlined by Schnitzer (1982). E_4/E_6 ratio: The degree of humification and aromaticity of humic acid was measured using E_4/E_6 ratios. A known quantity of the sample was taken and dissolved in 10 mL of 1x10-2 M $NaHCO_3$ solution. The absorbance's at 465 and 665 nm was measured using UV-VIS scanning spectrophotometer and the absorbance ratio was recorded.

3. Bacteriological analysis

N fixer and P solubilize

The microbial load of compost was analysed for N fixer and P solubilizer by following the standard dilution plate count technique. Combined carbon media for N fixers and Sperber's medium for PO_4-solubilizers were used for enumeration of microbial population. The petri plates containing media for N-fixers and P solubilizer were incubated at 300°C for three to six days and population was counted and expressed per unit dry weight of substrate.

4. 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 (cadmium, lead, chromium and nickel) using atomic absorption spectrophotometer (Mani *et al*, 2007).

Resultsand discussion

Comment [A7]: It is necessary to use the latest reference citations to support the results and discussion

Physical characteristics

Moisture content

The moisture content decreased in both methods with increasing days of interval (Table 1). The moisture ranged from 47.50 percent (S_1) to 45.33 percent (S_2) on 20^{th} day and on 80^{th} day from 23.65 percent (S_1) to 22.03 percent (S_2) (table 1). Among the methods segregated (S_1) recorded higher moisture content over unsegregated (S_2) method at all interval of days.

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, 2009).

In comparison with recommended standards (Biotreat, 2003) except 60 and 50 days compost sample, in all the maturity stages, moisture content percentage was found to be high and during different degradation stages decrease in moisture content has been observed from 10 days to 60 days which can heat generated by biological metabolism and air flow increases the water evaporation in the bioreactor, consequently decreasing the moisture content. 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).

Table 1. Changes in moisture, temperature and bulk density during composting of segregated and unsegregated urban solid waste in drum composting at different intervals of days

Days	Moisture (%)				Temperature (°C)				Bulk density (g/cm^3)			
	20	40	60	80	20	40	60	80	20	40	60	80
Segregated drum compost (S_1)	47.5	38.52	26.64	23.65	44	61	52	31	1.14	1.07	1.02	1.01
Unsegregated drum compost (S_2)	45.33	32.91	25.60	22.03	47	65	56	35	1.34	1.28	1.12	1.04

Table 2. Changes in the pH, EC, organic carbon and C/N ratio during composting of segregated and unsegregated urban solid waste

Methods	pH				Electrical Conductivity (dSm-1)				Organic carbon (%)				C/N ratio			
	20	40	60	80	20	40	60	80	20	40	60	80	20	40	60	80
	Days				Days				Days				Days			
S_1	7.4	8.11	7.71	7.35	4.1	2.36	1.24	1.12	38.1	34.12	31.25	29.16	38.48	25.8	21.85	17.78
S_2	7.74	8.26	8.04	7.84	4.41	3.27	2.42	1.51	37.52	31.84	27.4	24.17	41.68	31.2	23.82	19.81

***** Note: S_1= Segregated drum compost S_2= Unsegregated drum compost

Temperature

The temperature which was initially 35 °C in both of compost was increased to 61°C and 65 °C on the 40^{th} day of composting and later the temperature gradually stabilizing at ambient temperature of 31°C and 35 °C in segregated and unsegregated drum compost, respectively at 80^{th} of composting (Table 1).

As the decomposition is microbial mediated the microbial respiration accompanied by release of energy during decomposition and due to the compaction of overlying decomposable materials the temperature increases (Verdonack, 1988**).**As the decomposition was microbially mediated, the microbial respiration accompanied by the release of carbon dioxide and energy during decomposition and due to the compaction of overlying decomposable materials the temperature increases then stabilized. Similar results were reported by Narkhede *et al.* (2010).

Bulk density

The bulk density of the segregated and unsegregated urban solid waste ranged from 1.14 (S_1) to 1.34 g/cm^3 (S_2) on 20^{th} day and 1.01 (S_1) to 1.04 g/cm^3 (S_2) on 80^{th} days of composting (Table 1).The bulk density of segregated and unsegregated urban compost is defined as its weight per unit volume. During the present investigation the bulk density ranged from 1.34 to 1.04 g/cm^3. The results were in conformity with findings of Brinton (2003) who reported that during the composting process, microbial activity break down the loosely combined raw materials into smaller pieces after degradation resulting in decreased bulk density.

Chemical characteristics

pH

The pH of the segregated and unsegregated urban solid waste ranged from 7.40 (S_1) to 7.74 (S_2) on 20^{th} day and 7.35 segregated (S_1) to 7.84 unsegregated drum compost (S_2) on 80^{th} day of composting (Table 2).The increase in the pH is attributed the dissociation of organic acids to carbon dioxide. The slow increase may be due to disappearance of organic acids to form less acidic intermediates or due to buffering action of humic substances.

Comment [A8]: Please explain what range of good PH is supported by the opinion of previous researchers

The findings of this study concurred with the result of Verdonck (1988) who indicated that during biological conversion of waste to humus the acid forming bacteria brought the drop in pH and this was followed by an increase in pH to alkaline condition due to ammonia formation which finally stabilizes at near neutral condition. In comparison with recommended standards (Bordna Mona, 2003), except 40, 50 and 60 days old compost samples, pH values were found to be higher than the normal range which implies that, during different degradation stages decrease in pH has been observed from 10 days to 60 days which can attributed to the produce CO_2 from organic acids and loss of nitrogen (Lugtenberg, 2009).

Electrical conductivity (EC)

The electrical conductivity (dS m^{-1}) of the two methods ranged from 4.10 (S_1) to 4.41(S_2) on 20th day and decreased to 1.12 segregated (S_1) to 1.51 unsegregated (S_2) on 80th day of composting (Table 2). The findings of this study concurred with the result of Seema (2007) and Reddy *et al.*(2000) assessed the feasibility of composting separated organic matter of municipal solid waste (MSW) generated in low, middle and high income areas of Karachi city with a population over 14 million. The soluble salts 3.90-5.10 mS cm^{-1}. The electrical conductivity decreases might be due to theconcentrationofionsand soluble saltsreduceddduringthecompostingprocess.

Organic carbon and C/N ratio

The data recorded on the changes in organic carbon and C:N ratio of the decomposing materials at different intervals of composting are given in (Table 2).

The organic carbon content decreased during composting irrespective of the treatments. The organic carbon values of segregated and unsegregated urban solid waste ranged from 38.10 (S_1) to 37.52 (S_2) percent on 20th days and decreased from segregated 29.16 (S_1) to 24.17 percent unsegregated (S_2) on 80th day. Among the methods (S_2) segregated recorded least organic carbon 24.17 compared to unsegregated drum compost.

The C: N ratio decreased over the time in both the methods. The C:N ratio ranged from 38.48 (S_1) to 41.68 (S_2) on 20th day and decreased with time interval and recorded 17.78 (S_1) to 19.81 (S_2) on 80th day. Among the methods (S_2) unsegregated recorded higher C: N ratio as compared to segregated compost.

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). The percentage of organic carbon decreased, which shows the decomposition of waste by microbial population. Part of the carbon in the decomposing residues evolved as CO_2 and a part was assimilated by the microbial biomass (Shabani *et al.*, 2011).

C/N ratio is one of the most important parameters that determine the extent of composting and degree of compost maturity. These results are in line with reports of Ayesha(2010). JadiaandFulekar, (2008) reported that the decrease in C:N ratio could be due to respiratory activity of microorganisms and increase in total nitrogen by mineralization of organic matter.

Nitrogen

The nitrogen content of the decomposing material increased during composting period. The nitrogen content ranged from 0.99 segregated (S_1) to 0.86 percent unsegregated on 20th day and the values increased with time intervals as recorded 1.64 segregated(S_1) to 1.22 percent unsegregated (S_2) on 80th day (Table 3). Among the methods, segregated (S_1) recorded higher percentage of nitrogen.

In mature composts, most of the nitrogen is in organic form. The increase in nitrogen concentration during composting will be 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.Dimambro *et al*. (2007)describedthattheincrease innitrogencontentduringcomposting wasduetonitrogenreleasebymicro-organism's metabolic products and dead tissue. Loss of organic carbon might beresponsiblefornitrogenadditionintheformofmucusnitrogenousexcretorysubstances, growth stimulatory hormones and enzymes.

Table 3. Changes in nitrogen, phosphorus and potassium contents during drum composting of segregated and unsegregated urban solid waste

Methods	Nitrogen (%)				Phosphorus (%)				Potassium (%)			
	20	40	60	80	20	40	60	80	20	40	60	80
	Days of composting											
S_1	0.99	1.32	1.43	1.64	0.28	0.35	0.41	0.45	0.72	0.87	0.93	1.11
S_2	0.86	1.02	1.15	1.22	0.19	0.24	0.29	0.32	0.62	0.72	0.85	0.91

Phosphorus

The phosphorus increased in both the methods with time. The phosphorus content ranged from 0.28 (S_1) to 0.19 (S_2) percent on 20th day and higher values of 0.45 (S_1) to 0.32 percent segregated (S_2) on 80th day (Table 3). Among the methods (S_1) recorded higher percentage of phosphorus.In comparison with recommended standards (Bordna Mona, 2003) the phosphorous were found higher in all the samples. The 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).

Potassium

The potassium increased in the all both methods of composting. During the composting period, the potassium content ranged from 0.72 (S_1) to 0.62 (S_2) percent on

20th day and higher values of 1.11 segregated (S_1) 0.91 to percent unsegregated (S_2) on 80th day (Table 3). Among the methods (S_2) recorded lower percentage of potassium. In the present study, compostsmightbeduetoquickmicrobialactivity leading to decrease in volumeofthe material and alsoobservedhigheramountofKcontentincompost.Shabani *et al.* (2011) stated that the increaseinpotassiuminthe compostmight be attributed to increased mineralization of these elements due to enhancedmicrobial and enzyme activity. The results are in conformity with findings ofReddy *et al.* (2000).

Calcium and Magnesium

The calcium content of both the methods increased with time which ranged from 1.23 (S_1) to 0.73 (S_2) percent on 20th day and increased to 1.47 segregated (S_1) to 0.95 percent unsegregated (S_2) on 80th day (Table 4). The magnesium content ranged from 0.49 (S_1) to 0.34 (S_2) percent on 20th day and from 0.74 segregated (S_1) to 0.56 percent unsegregated (S_2) on 80th day.

In both methods of compost calcium and magnesium content increases with increasing days of interval. Increasedcalcium and magnesiumcontentof compostsduring composting might be due to production of calcium and magnesium oxides and hydroxides during decomposition of the organic matter there by increase in the calcium and magnesium content in compost (Garcia*et al.*, 2000).

Table 4. Changes in calcium, magnesium and sulphur contents during drum composting of segregated and unsegregated urban solid waste

Methods	Calcium (%)				Magnesium (%)				Sulphur (%)			
	20	40	60	80	20	40	60	80	20	40	60	80
	Days of composting											
S_1	1.20	1.40	1.40	1.50	0.50	0.60	0.70	0.70	0.50	0.60	0.60	0.76
S_2	0.70	0.80	0.90	10	0.30	0.40	0.50	0.60	0.30	0.50	0.60	0.64

Sulphur

The sulphur content increased in both the methods during the composting. The sulphur content ranged from 0.45 (S_1) to 0.31 (S_2) percent on 20th day and increased to 0.76 segregated (S_1) to 0.64 percent unsegregated (S_2) on 80th day (Table 4). Among the methods (S_1) recorded higher percentage of calcium, magnesium and sulphur as compared to unsegregated compost.

The present investigation on soluble sulphate varied from 16.36 to 61.95 per cent the minimum percentage of soluble sulphate was recorded in 10 days old compost sample with 16.36 percent and maximum for 60 days old compost sample with 61.95 percent.

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 odors and promotes corrosion (Shivakumar*et al.*, 2004).

Micronutrients

The micronutrient content increased in both composting methods during drum composting. The zinc content in both the methods varied from 67.13(S_1) to 129.93 ppm (S_2) on 20th day and on 80th day it ranged from 118.07 segregated (S_1) to 143.17 ppm unsegregated (S_2) (Table 5). The iron content in both the methods varied from 3242.60 (S_1) to 3445.52 ppm (S_2) on 20th day and on 80th day it ranged from 13529.11 segregated (S_1) to 3752.2 ppm unsegregated (S_2).

The copper content in both the methods varied from 22.80 (S_1) to 28.21ppm (S_2) on 20th day and on 80th day it ranged from segregated 44.23 (S_1) to 42.11 ppm unsegregated (S_2). The manganese content in both methods varied from 267.21 (S_1) to 313.33 ppm (S_2) on 20th day and on 80th day it ranged from segregated 350.67 (S_1) to 366.33 ppm unsegregated (S_2). The unsegregated compost was having higher concentration of micronutrients compared to segregated compost. Source segregated composts should contain low level of micronutrients, while higher level can be excepted in mixed MSW compost. Increasedmicronutrients contentinboth methods of compostsmight bedueto organo-metallicchelationofmicronutrients(Dakshinamurthy andUpendra,2008). The concentration of the micronutrients in the raw materials used for the composting also one of the cause increased micronutrients in the composts (Das *et al.*, 2010).

Heavy metals

The lead content increased in during the composting lead content increase in both the segregated and unsegregated composting method (Table 6). The lead content in both treatments ranged from10.20 (S_1) to 34.27 ppm (S_2) on 20th day and on 80th day it ranged from 23.87 segregated (S_1) to 43.62 ppm unsegregated (S_2).

The chromium content in both segregated and unsegregated composting varied from 6.21 (S_1) to 18.32 ppm (S_2) on 20th day and on 80th day it ranged from 12.53 segregated (S_1) to 23.21 unsegregated (S_2). The nickel content in both methods varied from 5.26 (S_1) to 15.54 ppm (S_2) on 20th day and on 80th day it ranged from 10.71 segregated (S_1) to 23.42 ppm unsegregated (S_2). The cadmium was not detected in both methods.

Table 5. Changes in micronutrients content during composting of segregated and unsegregated urban solid waste

Methods	Zinc (ppm)				Iron (ppm)				Copper (ppm)				Manganese (ppm)			
	20	40	60	80	20	40	60	80	20	40	60	80	20	40	60	80
	Days of composting															
S_1	67.13	92.73	108.07	118.07	3242.6	3362.21	3437.71	3529.11	22.8	28.42	36.87	44.23	267.2	275.4	341.6	350.67
S_2	129.93	133.47	135.2	143.07	3445.5	3561.3	3604	3752.2	28.21	32.67	38.24	42.11	313.33	330.67	357.33	366.33

Table 6. Changes in heavy metals contents during composting of segregated and unsegregated urban solid waste

Methods	Pb (ppm)				Cr (ppm)				Cd (ppm)				Ni (ppm)			
	20	40	60	80	20	40	60	80	20	40	60	80	20	40	60	80
	Days of composting															
S_1	10.2	16.4	20	23.9	6.2	8.3	11	12.5	ND	ND	ND	ND	5.3	7	9.3	13
S_2	34.3	39.2	41	43.6	18	20	21	23.2	ND	ND	ND	ND	16	18	20	23

***Note**: S_1-Segregated drum compost S_2-Unsegregated drum compost

The unsegregated compost was having higher concentration of heavy metals compared to segregated compost. Source segregated composts should contain low level of toxic element, while higher level can be accepted in mixed MSW compost. Heavy metals are sourced from batteries, solder, wine bottle cap; circuit stabilizers in plastics may contain potentially toxic elements (Richard and woodbury 1992). Stillwell and David (1993) who reported that the compost prepared frommunicipalsolidwastehadhigherconcentrationofheavymetalelements.Manju*etal*. (2013) also reported thatmunicipal solid waste compost contains theconcentration of heavy metalsas pertheIndian standards.

Biochemical characteristics

Cellulose and lignin

The cellulose content of segregated and unsegregated urban solid waste compost subjected to different methods of composting was decreased with time (Table 7). The cellulose content ranged from 48.38 (S_1) to 44.43 (S_2) percent on 20th day and from 28.12 segregated (S_1) to 25.26 percent unsegregated drum compost (S_2) on 80th day.

The lignin content of the decomposing of segregated and unsegregated urban solid waste subjected to different methods of composting decreased with time. The lignin content ranged from 32.65 (S_1) to 30.10 (S_2) percent on 20th day and from 21.87 segregated (S_1) to 19.32 percent unsegregated drum compost (S_2) on 80th day.

Table 7. Changes in cellulose and lignin properties of during drum composting of segregated and unsegregated urban solid waste

Methods	Cellulose (%)				Lignin (%)			
	20	40	60	80	20	40	60	80
	Days							
S_1	48.38	38.67	32.18	28.12	32.65	27.32	23.05	21.87
S_2	44.43	35.41	29.32	25.26	30.10	23.52	21.12	19.32

Note: S_1-Segregated drum compost S_2-Unsegregated drum compost

The segregated and unsegregated compost changes in the content of cellulose and lignin over the period of time and due to the different methods of composting. The Solid urban wastes are known to be made up of different organic compounds which vary in their degree of being decomposed. Some compounds such as simple sugars and proteins are degraded at a faster rate followed by hemi cellulose, cellulose and lignin.

Since composting is a microbial mediated process these organisms act upon the easily degradable materials first, followed by hard to degrade materials because of their complex chemical structure as in the case of cellulose and lignin. Microbial succession ensures the breaking down of such compounds over a period of time. The results clearly showed that microbial inoculation has enhanced the degradation of cellulose and lignin over a period of time. The results clearly indicate that the segregated compost was having higher cellulose and lignin content than unsegregated compost.

Biochemical properties showed that the degradation of cellulose was marginally higher than lignin (Cortez et al. 1996). However, lignin to cellulose ratio was more in FYM and compared to segregated and unsegregated urban compost and might be due to the presence of fairly good amount of lignin and cellulose which is highly resistant to decomposition.

Summerella and Burges (1989) attributed the decrease in lignin content to weakening of lignin structures to be the cause for reduction in the lignin content over a period of time. Cellulose hydrolysis-fermentation process involving the breakdown of cellulose in to component glucose molecules is as a result of microbial inoculation (Dimambro *et al*., 2007).

Humic acid

The humic acid content of the composting of segregated and unsegregated urban solid waste subjected to different methods of composting increased with time. The humic acid content ranged from 1.13 (S_1) to 0.94 (S_2) percent on 20th day and from 8.02 segregated (S_1) to 6.45 percent unsegregated drum compost (S_2) on 80th day (Table 8). The humic fractions were more in segregated and unsegregated compost compared to FYM which indicates better decomposition and maturity of compost as reported by Chefetz *et al*. (1996).

Fulvic acid

The fulvic acid content of the composting of segregated and unsegregated urban solid waste subjected to different methods of composting increased with time. The fulvic acid content ranged from 0.53 (S_1) to 0.23 (S_2) percent on 20th day and from 2.42 segregated (S_1) to 1.96 percent unsegregated drum compost (S_2) on 80th day (Table 8). A survey of MSW compost reported that the majority of the humic substances found in MSW compost were identified as humic acid, with a humic acid to fulvic acid ratio of 3.55 (He *et al*., 1995).

Table 8. Changes in biochemical properties of during drum composting of segregated and unsegregated solid waste

Methods	Humic acid (%)				Fulvic acid (%)				Humus index				E_4/E_6 ratio			
	20	40	60	80	20	40	60	80	20	40	60	80	20	40	60	80
	Days of composting															
S_1	1.13	3.32	5.67	8.02	0.53	1.32	1.97	2.42	2.13	1.68	2.87	3.31	0.58	2.01	3.54	4.12
S_2	0.94	2.54	4.75	6.45	0.23	0.75	1.21	1.96	4.08	3.38	3.92	3.33	0.49	1.03	2.13	3.43

Humus index

The humus index of the composting of segregated and unsegregated urban solid waste subjected to different methods of composting increased with time. The humus index ranged from 2.13 (S_1) to 4.08 (S_2) on 20th day and from 3.31 segregated (S_1) to 3.29 unsegregated (S_2) on 80th day (Table 8). A survey of MSW compost reported that the majority of the humic substances found in MSW compost were identified as humic acid, with a humic acid to fulvic acid ratio of 3.55 (He *et al.,* 1995).

E_4/E_6 ratio

The E_4/E_6 ratio of the composting of segregated and unsegregated urban solid waste subjected to different methods of composting increased with time. The E_4/E_6 ratio ranged from 0.58 (S_1) to 0.49 (S_2) on 20th day and from 4.12 (S_1) to 3.34 (S_2) on 80th day (Table 8).E_4/E_6 ratio is an indicator of degree of aromatic city of composts and it ranged from 2.12, 4.12 and 3.43 FYM, segregated and unsegregated urban compost, respectively.whichindicates better decomposition and maturity of compost as reported by Chefetz *etal*. (1996).

Biological properties

The biological studies recorded the N fixers population ranges from 21.72 segregated (S_1) to 19.85 cfu x 105 g^{-1} in unsegregated drum compost (S_2) on 80th day of maturity of compost (Table 9). The biological studies recorded the P solubilizer population ranges from 234.56 segregated (S_1) to 225.23 cfu x 105 g^{-1} in unsegregated drum compost (S_2) on 80th day of maturity of compost.

These observations are in conformity with those obtained by other authors (Fang and Wong, 2000; Gestel *et al.*, 2003; Pedro *et al*., 2003). The decrease of microbial diversity in the composting mass could be due to the high temperature (Fang and Wong, 2000) and the bacterial viable counts are more for 10, 20, 30, 40 days compost samples compared to 50 and 60 days old compost samples.

Table 9. N fixers and P solubilizer population in drum compost of segregated and unsegregated urban solid waste at different days of interval

Methods	N fixers (cfu × 10^5 g^{-1} compost)				P solubilizers (cfu × 10^5 g^{-1} compost)			
	20	40	60	80	20	40	60	80
	Days							
S_1	6.27	12.42	28.42	21.72	75.2	150.33	311.92	234.56
S_2	5.25	11.34	25.3	19.85	62.73	120.53	297.3	225.23

Conclusion

The results of the study clearly indicate that, the composting of segregated and unsegregated urban solid waste drum compost. Physico-chemical analysis of compost from the point of view moisture content, temperature, bulk density, pH, EC, organic carbon, C:N ratio, NPK, calcium, magnesium, and sulphuragreed with recommended standards, biochemical properties viz., cellulose, lignin, humic acid, fulvic acid, humus index and E_4/E_6 ratio were increased at 80^{th} days of segregated urban compost.

Biological study, concern the N fixer and P solubilizer population were increased up to 60 days and later reduce the population in last stages (80 days compost sample) and micro nutrients and heavy metals are like lead, nickel and chromium were found to be within the permissible limits of standards at all the maturations stages whereas cadmium was not detected.In this regard, drum composting system may be recommended for better method for recycling of municipal solid waste, which can be used as fertilizer or soil amendment.

Comment [A9]: In this regard, drum composting system may be recommended for a better method for recycling of municipal solid waste, which can be used as fertilizer or soil amendment

The author sees the quality standard from which factor? are all physico-chemical, biochemical and biological characteristics

Comment [A10]: References generally use the oldest, you need to use the latest references for at least the last 10 years

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