Environment Conservation Journal 3 (2) 37-42, 2002
(ISSN 0972 - 3099)

Studies on Changes in Characterization of Municipal Solid Waste due to Composting

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Abstract

Municipal Solid Waste (MSW) is a rich source of organic matter, nitrogen, phosphorous, potassium (NPK) and many trace metals liked Cd, Cr, Cu, Pb, Ni, Mn, Co, Fe etc. MSW was composted aerobically for seven weeks. Physical parameters like water holding capacity (WHC), Particle size, Bulk density, Porosity and Chemical parameters like pH, Electrical conductivity (EC), Total organic carbon, NPK and eight heavy metals (Cd,Cr,Cu, Zn, Pb, Ni, Mn, Fe) were analyzed in compost during the process of composting. Water extractable and available forms of metals were also estimated. It was observed that there was significant improvement in some physical and chemical properties during composting (WHC, particle size, pH, EC etc.). There was reduction in availability and solubility of some potentially toxic metals like Cd, Cr, Pb, Ni and Zn. Composting of MSW can thus provide an environmentally safe product which can be used for soil amendment.

Key Words: *MSW, Compost, Heavy Metals, Availability, Solubility*

Introduction

Aerobic composting is the degradation of organic matter in presence of oxygen under controlled conditions. The term 'controlled' distinguishes composting from natural degradation or putrefaction. Currently solid wastes sre disposed off in India mainly by dumping I the outskirts of city/town/village. Municipal solid waste however should be disposed of in such a way that it should be non polluting and economically less expensive. Out of the four proper ways of disposal of MSW (Sanitary land filling, Incineration, pyrolysis and composting) composting is better suited for most Indian MSW since Indian MSW usually contains high amount of organic matter (40-60%). There were only a few composting plants ion India. Compost plants were operated by municipal corporations of Delhi, Bangalore, Vijaywada, Calucutta, Mumbai etc. but due to many reasons most of them are not in working condition. These plants utilize only a small portion of the waste. Large scale composting is yet to gain popularity in India. Developed countries compost significant portion of their MSW (Hornick *et al.* 1984).

In many places in India like Hyderabad, Calcutta, Delhi raw MSW is used as a soil amendment. Rao and Shantaram 1984 have reported contamination of agricultural soil due to application of MSW. Olaniya *et al.* 1998 have reported high levels of heavy metals in soil and vegetables grown on agricultural land amended with MSW. The logic behind such practice is to enrich the soil with organic matter and NPK. But MSW can have harmful effects on soil and vegetation as it contains large population of pathogens and high concentration of some potentially toxic heavy metals like Cd, Cr, Pb, Ni,Cu, and Zn (Nogawa *et al.* 1978, Saito *et al.* 1977, Olaniya *et al.* 1998). Composting of MSW could lead to solution of the above mentioned problems as composting stabilizes biosolids (Wilson *et al.* 1978), reduces malodours (Hornick *et al.* 1984) and destroys pathogens (Burge *et al.* 1988). This study aims to determine the changes in some physical and chemical properties of MSW during composting including availability and solubility of heavy metals.

Materials and Methods

Fresh municipal solid waste (MSW) was collected from Nagpur Municipal Corporation from cotton market area which is rich in organic fraction. The material was screened through a 2 inch wire mesh in order to separate fines, inert as well as bioresistant materials etc. smaller pieces of paper, plastic bags were manually separated. The particle size of the MSW was reduced to 2-4" by shredding. A compost pile of dimension 1 m. in height and 1.6m diameter was constructed by loosely stacking the waste (Gotaas 1956). Moisture was maintained between 50-60%. Temperature was monitored daily. Representative samples of compost were collected in triplicates on 0, 7, 14, 21,28,35,42, and 49 days (7 weeks). The samples collected were first air dried and then oven dried at 450C for 24 hours. Samples were reduced to particle size1mm by grinding. Particle size analysis was carried out by "hydrometer Methods" as suggested by Piper (1950). The particles were grouped into sizes 0.2 mm, 0.02 mm and 0.002 mm. Water holding capacity (WHC) was determined by Raczkowski's Methods (Piper 1950). Bulk density was determined by Method suggested in Black 1965. Porosity was calculated from bulk and particle densities (McIntyre 1974).

pH and Electrical conductivity (EC) were determined in sample to water ratio of 1 : 10 (Jackson 1967). Organic carbon was determined by Walkey-Black Method (Black 1995), N, P and K were determined by Standard Methods (USEPA 68-03-2552 1981, Black 1965). For total heavy metals samples were digested in acid mixture of HNO_3 and $HCLO_4$ (Jackson, 1967). Soluble metals were determined by standard leaching tests (USEPA-600162 1971). Available forms of metals were extracted with DTPA (diethylene triamine penta acetic acid) in presence of Triethylamine and $CaCl_2$ at pH 7. Total, plant available and soluble metals were estimated by Atomic Spectrophotometer (model GBC 904 AA).

Results and Discussion

Temperature during the "Thermophillic phase" went as high as 66 °C. The "Thermophillic phase" lasted for 18 days out of which temperature was higher than 55 °C continuously for 11 days. High temperature for such long periods can eliminate most pathogens. According to Golueke 1972, temperature above 60 °C for one hour can eliminate most pathogenic organisms. Bulk density increased as composting progressed (Table 1). This might have happened due to compassion of the residue left as the compost pile ingredients got more homogenized. The pile acquired a dark brown colour and had soil like appearance after 28 days (4 weeks). Water holding capacity also increased. Particle size analysis indicated that particles of size 0.002 mm increased. This can be attributed to the breakdown of biodegradable fraction such as fruits, vegetables and other food waste into soil like substance.

Table 1. Changes in Physical Characteristics During Composting

Days	WHC %	Particle Size % 0.2mm	0.02mm	0.002mm	Bulk Density g/cm^3	Porosity %
0	58.46	72	10	18	0.8739	57.00
7	60.31	72	10	18	0.8994	54.00
14	60.62	70	12	18	0.9800	49.00
21	63.08	64	16	20	0.9641	49.60
28	66.73	62	16	22	0.9512	49.19
35	66.33	58	18	24	0.9256	47.50
42	66.41	58	18	24	1.0041	40.00
49	66.68	56	18	26	1.1864	41.00

When a waste is subjected to composting two main phenomena occur (I) Decomposition or break down of organic substances into CO_2 and H_2O with evolution of heat (Aerobic composting is an exothermic process) and (ii) Synthesis of more stabilized complex polymeric substances by microorganisms. This stabilized organic substance, which is dark brown in colour, amorphous in nature and has a very high molecular weight, is called 'humus'. Humus is analysis excellent soil conditioner and can also serve as a fertilizer by providing nitrogen phosphorous and metals (Dixon *et al.* 1995).

pH of compost increased as organic matter got stabilized and also due to formation of carbonates & hydroxides. The pH of mature compost was 8.6; at this pH solubility of metals is expected to decrease. Electrical conductivity (EC) decreased with stabilization. EC arises due to soluble salts of ions like Ca^{2+} , Mg^{2+} , K^+ and Na^+. Decrease in EC indicates that the amount of soluble salts get fixed by precipitate formation or complexing during composing. High concentration of soluble salts may cause damage to plant roots. Total organic carbon decreased as composting progressed. Most of the organic carbon is lost as CO_2 due to volatilization leading to decrease in total carbon content. Some nitrogen was also lost due to formation of ammonia and nitrates from degradation of proteins. But due to presence of 78% of nitrogen in the atmosphere, organic nitrogen cycles and fixing of nitrogen by some micro organisms there was comparatively less depletion in nitrogen as compared to carbon. Thus the carbon to nitrogen ratio (C/N ratio) decreases as composting progressed. There was some change in concentration of concentration of phosphorous and potassium. Cation exchange capacity (CEC) also increased as composting progressed, the total humic substances were estimated in 0 and 49 day compost and it was found that the percentage of humic substances in the composted matter increased from 71% on 0 day to 89% in the 49th day of composting. Humic substances or 'humus' is made of miscelles, composed of carbon, hydrogen and oxygen. It carries a large number of adsorbed cations like Ca^{2+}, Mg^{2+} Na^+ & K^+. There are negatively charged hydroxyl (-OH), carboxylic (-COOH) and phenolic groups (-C_6H_5OH). At high pH CEC of humus is around 300-500 meq/100g and negative sites are more abundant (Brady 1996). These negative sites bind heavy metals and cations more strongly which leads to their lower mobility. Humus also has a high WHC which is why WHC increased as composting progressed. Increase in CEC and total humic substances endorsed this fact that there is high amount of stabilized organic matter i.e. humus in compost. Results of chemical analysis are presented in Table 2.

Table 2. Changes in chemical characteristics during composting

Days	pH	EC mS/cm	Carbon %	N %	Pas P_2O_5 %	Kas K_2O %	CEC Meq/100mg
0	5.8	1.23	18.87	0.42	0.44	0.34	28.65
7	6.2	0.90	17.98	0.49	0.41	0.36	29.44
14	7.4	0.95	14.62	0.41	0.44	0.50	30.89
21	7.7	0.98	11.52	0.55	0.42	0.42	32.68
28	8.1	0.84	12.44	0.50	0.46	0.49	34.64
35	8.4	0.61	11.47	0.73	0.46	0.57	34.48
42	8.6	0.61	11.47	0.63	0.46	0.42	35.62
49	8.6	0.53	11.00	0.63	0.45	0.54	35.98

All values are in mg/kg on dry weight basis

Total heavy metal content increased as composting progressed. This happened as organic matter degraded and released the heavy metals. These metals got added to the stabilized mass left after composting. There was about 40% reduction in the mass during composting. But proportional increase in metal levels was not observed for all 8 metals. Some metals being more mobile (Cd, Ni, Zn) might have leached to the soil below the pile while other like Pb and Cr which are comparatively less mobile showed almost proportional increase. Table 3 depicts the total metals at various stages of composting.

"Plant available" or "available" metals were determined by DTPA extraction procedure. It was observed that "available" forms of Cd, Cr, Zn, Pb and Ni decreased due to composting. There was increase in availability of Cu, Mn and Fe (Table 4). Cu, Mn, Zn and Fe are required by plants in trace amounts. Reduction in availability of metals like Cd, Cr, Pb and Ni is a good indication of compost being safer as these metals are potentially toxic. These metals are not required by plants for any of their metabolic activities (Ni is required by a few plants). However plants do absorb these metals if they are 'available', particularly in absence of Zn plants may adsorb Cd as these metals show similar behaviour.

Solubility of all metals decreased as composting progressed. Cd and Pb were absent in soluble form in 49 days compost. Solubility of Cr, Mn, Ni and Zn was drastically reduced. Cu and Fe showed Slight reduction in solubility (Results are presented in Table 5). This indicates that metals were being fixed by stabilized organic matter by complexing. Particularly 28-49 days compost was found to be very effective in reducing the 'availability' and solubility of potentially toxic metals in MSW. The availability and solubility of metals decreased despite increase in the total metal content in compost. Solubility of metals is also affected by pH. According to Woodbery 1992, the increase in pH can bring about strong adsorption of metals like Cr and precipitation of others like Cd, Mn, Pb and Zn.

Table 3. Changes in availability of heavy metals content during composting

Days	Cd	Cr	Cu	Zn	Pb	Ni	Mn	Fe
0	0.65	20.38	191.14	262.66	53.07	31.84	626.77	26607
7	0.63	24.59	175.63	264.77	62.03	33.32	847.63	26484
14	0.58	24.30	141.70	273.20	80.92	36.05	1042.11	31112
21	0.64	28.98	186.85	254.24	95.69	40.92	1001.13	32239
28	0.73	26.10	209.86	271.79	103.97	36.67	939.57	35230
35	0.68	25.41	222.41	286.49	97.41	37.75	923.02	31687
42	0.72	25.64	265.95	284.66	99.86	39.96	1041.46	33633
49	0.71	27.10	260.90	292.79	101.18	40.82	1143.60	34864

All values are in mg/kg on dry weight basis

Table 4. Changes in availability of heavy metals during composting

Days	Cd	Cr	Cu	Zn	Pb	Ni	Mn	Fe
0	0.17	0.20	22.56	41.20	20.25	2.56	79.60	19.49
7	0.14	0.18	26.69	38.46	19.86	2.49	80.96	20.89
14	0.16	0.20	29.86	37.41	20.46	2.36	82.15	22.41
21	0.13	0.14	34.65	38.41	18.48	1.98	84.66	21.46
28	0.14	0.08	39.84	35.46	18.56	2.01	79.81	25.93
35	0.12	0.00	47.68	34.31	19.11	1.86	86.41	24.86
42	0.13	0.00	51.66	32.91	18.04	1.79	87.69	26.47
49	0.13	0.00	59.48	33.39	18.24	1.77	97.48	30.88

All values are in mg/kg on dry weight basis

Table-3. Changes in solubility of Heavy Metals Content during Composting

Days	Cd	Cr	Cu	Zn	Pb	Ni	Mn	Fe
0	0.50	1.02	3.64	9.71	0.28	3.78	8.92	26.29
7	0.46	1.08	3.58	6.44	0.22	2.86	7.69	26.22
14	0.44	0.94	3.58	2.86	0.16	2.11	6.41	26.71
21	0.40	0.73	3.27	0.91	0.11	1.54	5.11	25.69
28	0.26	0.71	3.14	0.86	0.09	0.98	3.98	22.41
35	0.13	0.68	3.09	0.75	0.06	0.76	0.68	20.98
42	0.04	0.67	3.04	0.41	0.00	0.68	0.54	18.86
49	0.00	0.57	3.07	0.26	0.00	0.63	0.40	15.63

All values are in mg/kg on dry weight basis

Conclusions

From the studies carried out it can be concluded that compost can reduce some hazards associated with application of raw MSW to agricultural land. It can be helpful in improving soil physical properties like WHC, soil texture and porosity and chemical properties like available nutrients, humic substances, dissolved salts and pH. Compost was found to be reducing solubility and 'available' of same toxic metals. MSW can be treated in this way and turned into a useful resource. Similarly organic wastes generated from sugar industries, pesticide industries etc. can be treated by composting. These wastes can be mixed with MSW and co-composted. Effluents generated from industries, sewage sludge etc. can be used for providing moisture and other nutrients. The possibilities are endless. More research needs to be done in this field, as in a resource constraint country like India, resource conservation is very essential.

Acknowledgements

The authors wish to thank Director, NEERI, Nagpur for providing facilities for carrying this research. Acknowledgements are due to CSIR for funding this research through award no. 9/121/(13)/97-EMR-I.

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