GRADING OF MUNICIPAL SOLID WASTE COMPOST FOR SAFE AND MAXIMUM RECYCLING IN AGRICULTURE

Indian Institute of Soil Science

(Indian Council of Agricultural Research)

Nabibagh, Berasia Road,

Bhopal-462038 (M.P.)

GRADING OF MUNICIPAL SOLID WASTE COMPOST FOR SAFE AND MAXIMUM RECYCLING IN AGRICULTURE

Unscientific disposal of municipal solid wastes causes severe environment pollution

India generates about 70 million tonnes of municipal solid wastes (MSW) from cities every year. Majority (more than 90 %) of these wastes are used for unscientific land filling or uncontrolled dumping on outskirts of towns and cities, which have serious environmental implications including global warming through green house gases emission. Composting MSW is seen as a low cost method of diverting organic waste materials from landfills while creating a product for agricultural purposes. India has the potential of producing about 5 - 14 million tonnes of compost annually from municipal solid wastes depending on the method of composting, which can provide about 1.2 to 2.5 lakhs tonnes of N, P_2O_5 and K_2O for raising agricultural production and improving soil fertility.

Quality of MSW composts prepared in India

A study was conducted by Indian Institute of Soil Science to investigate physico-chemical properties, fertilizing potential and heavy metal polluting potentials of municipal solid waste composts produced by 34 manufacturers in 29 cities of the country. Different preprocessing methods are followed for preparing compost from MSW. In majority of cities, pre-processing of wastes is not followed at all and non-segregated wastes are piled in heaps and left for several months with or without turning for decomposition of biodegradable wastes (termed as 'mixed waste compost'). In several composting plants, big size non-biodegradable wastes, like plastics, rubber, metals etc. are manually removed at composting yard prior to composting (termed as 'partially segregated waste compost'). In rest of the cities, biodegradable wastes are segregated at generator level and this is done in two ways. In few cities (Namakkal, Suryapet and Vijaywada), individual households deliver segregated biodegradable wastes separately during 'door-to-door' collection by municipal organization, which are composted in pits or heaps using earthworms. In several other cities, sources generating mainly biodegradable wastes, like hotels & restaurant, vegetable market, slaughterhouse etc. are selected for feedstock collection for composting plants. Compost prepared from biodegradable wastes collected through these two methods is termed as 'biowaste compost'.

Results indicated that organic matter as well as major nutrients N and P contents in MSW composts are generally low and heavy metal contents are quite high (Table 1). Quality of 'biowaste compost' prepared from source separated biodegradable wastes is always better than 'mixed waste compost' and 'partially segregated waste compost' as indicated by higher organic matter and plant nutrient contents, but lower concentrations of heavy metals (Fig. 1 & 2).

Table 1. Physical and chemical properties of the municipal solid waste composts produced in different cities in India.

	Range	Median	Within limit (%)
Fertility parameters			
Moisture (% wm*)	3.6 - 45.4	17.1	44
Bulk density (g cm^{-3} dm*)	0.52 - 1.15	0.86	56
pH	6.64 - 9.63	7.50	62
EC (dS m^{-1} dm)	0.52 - 8.41	3.07	88
Total organic C (% dm)	5.2 - 22.6	11.3	15
Total N (% dm)	0.26 - 1.71	0.63	68
Total P (% dm)	0.08 - 0.73	0.16	21
Total K (% dm)	0.12 - 1.31	0.46	9
C:N	7.2 – 36.5	16.4	65
Heavy metal parameters			
Zn (mg kg^{-1} dm)	82 - 946	252	100
Cu (mg kg^{-1} dm)	25 - 865	198	70
Cd (mg kg^{-1} dm)	Trace - 8.4	0.94	98
Pb (mg kg^{-1} dm)	11 - 647	133	38
Ni (mg kg^{-1} dm)	9 - 190	25	86
Cr (mg kg^{-1} dm)	14 – 401	69	23

***wm = wet matter, dm = dry matter**

In order to safeguard the land resources from pollution and ensure minimum manurial value, Government of India enforced quality control limits for MSW compost through Fertilizer Control Order (1985). In order to be eligible for marketing, MSW compost sample has to comply with all parameters specified in the FCO. However, none of the compost samples from 29 cities complied fully with the FCO limits, despite sincere efforts by several municipalities.

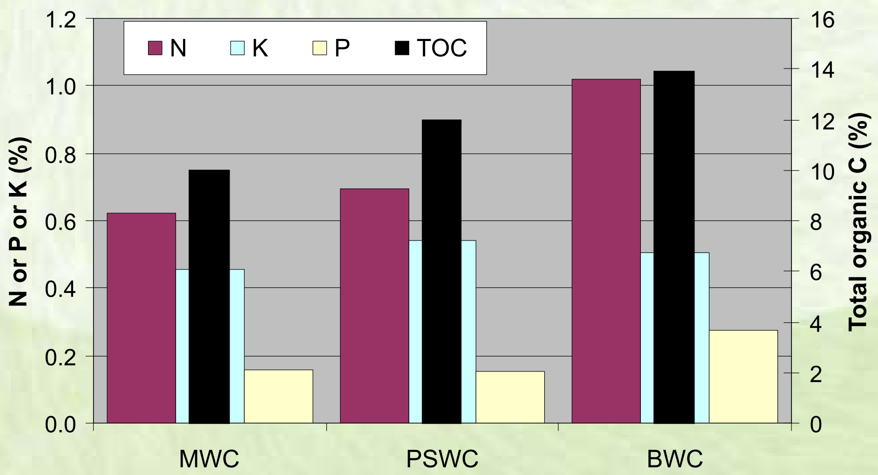

Fig. 1. Effect of segregation of feedstock on fertilizing parameters of MSW composts (MWC = mixed waste compost, PSWC = partially segregated waste compost, BWS = biodegradable waste compost)

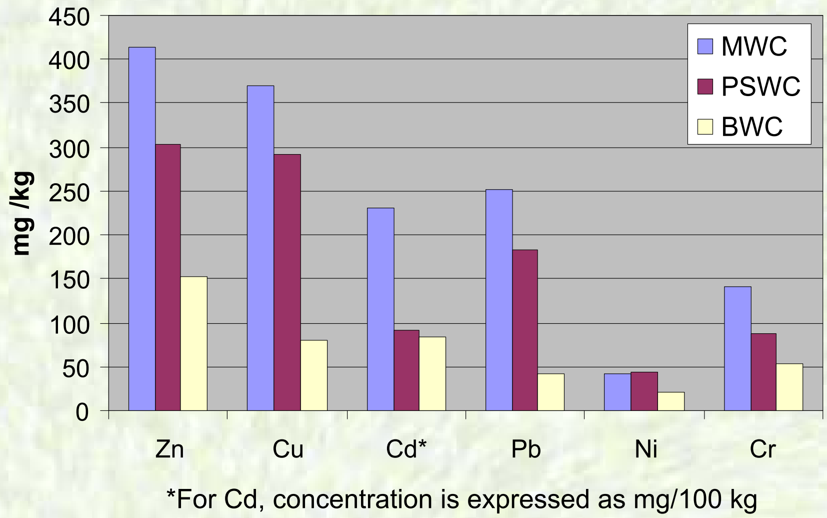

Fig. 2. Effect of segregation of feedstock on heavy metal concentrations in MSW composts (MWC = mixed waste compost, PSWC = partially segregated waste compost, BWS = biodegradable waste compost)

Drawbacks in the existing quality control guidelines (FCO, 1985)

1. Composts not complying with all the fertilizing parameters but complying specifications related to heavy metal contents are rejected even though these do no harm to the environment.
2. It fails to indicate their overall quality resulting from the use of certain type input material and following a definite method of composting.
3. Does not appreciate very good quality of MSW composts produced with better techniques of composting.

Addressing the above drawbacks, IISS has put forward a new method of assigning grade for the quality of compost in order to maximize recycling MSW for their beneficial use in agriculture, to protect land from heavy metal pollution and to safeguard interest of manufacturers.

Method of assigning grade for the quality of MSW composts

Assigning grade to the composts is done on the basis of their potential for improving soil productivity, content of plant nutrients and level of maturity (collectively indicated by 'Fertilizing index') as well as on the basis of their potential of contaminating land with heavy metals (indicated by 'Clean index').

Fertilizing index

Each analytical data affecting the fertilizing value (i.e., responsible for improving soil productivity) of compost, like total C, N, P and K contents as well as maturity parameters (C:N ratio and respiration activity), are assigned to a 'score' value as per the category given in Table 2. Higher value of any fertilizing parameters was assigned higher score value. On the basis of scientific knowledge on their role in improving soil productivity, each of these fertility parameters was assigned a 'weighing factor'. Organic C controls several soil productivity parameters like water holding capacity, nature of porosity, soil structure, plant nutrient reserve pool as well as promotes soil biological activity. Also, C entered in soil through compost has higher residence time (due to formation of clay-humus complex) as compared to that in the landfill area. These, in turn, help in sequestering of atmospheric C and mitigating climate change through minimizing production of green-house gases. Hence TOC content in the compost was assigned maximum weighing factor. Compost with high C:N ratio as well as those with high respiration activity is likely to immobilize N and other nutrients and, therefore, these compost maturity parameters were also assigned higher weighing factor. Although all the three major nutrients N, P and K are essential for higher crop productivity, these were assigned different weighing factors on the basis of their functional importance and prevalence of deficiency in soils.

Table 2. Criteria for assigning 'Weighing factor' to fertility parameters and 'Score value' to analytical data

	Score value (S_i)					Weighing factor (W_i)
	5	4	3	2	1	
Total organic C (%)	>20.0	15.1-20.0	12.1-15.0	9.1-12.0	<9.1	**5**
Total N (%)	>1.25	1.01-1.25	0.81-1.00	0.51-0.80	<0.51	**3**
Total P (%)	>0.60	0.41-0.60	0.21-0.40	0.11-0.20	<0.11	**3**
Total K (%)	>1.00	0.76-1.00	0.51-0.75	0.26-0.50	<0.26	**1**
C:N	< 10.1	10.1-15	15.1-20	20.1-25	>25	**3**
Respiration activity (mg CO_2-C / g VS d)	<2.1	2.1-6.0	6.1-10.0	10.1-15	>15	**4**

The '*Fertilizing index*' of the MSW composts is computed using the formula:

$$\text{'Fertilizing index'} = \frac{\sum_{n}^{i=1} S_i W_i}{\sum_{n}^{i=1} W_i}$$

Where, 'S_i' is score value of analytical data and 'W_i' is weighing factor of the 'i"th fertility parameter.

Computed 'Fertilizing index' values of the MSW composts varied from 1.8 to 4.2 with a mean value of 3.0 (in 5.0 point scale). No significant difference in 'Fertilizing index' was observed between composts from smaller cities and bigger cities. Composts prepared from source separate collected wastes recorded, on average, about 26 % more index value compared to those prepared from mixed wastes. Composts prepared from source separated (at household level) wastes in Vijaywada (A.P.) recorded the highest 'Fertilizing index' value of 4.2.

Clean index

Score values were given to each analytical value of the heavy metals as per scheme mentioned in Table 3. While assigning score values, the quality control limit values implemented by different European countries as well as those computed by Indian Institute of Soil Science for Indian soils were taken into consideration. For each heavy metal a 'Weighing factor' was allocated. This was done on the basis of available information on known biological functions (if any) in organisms as well as phytotoxicity and mammalian toxicity potential of the concerned metal. Cadmium was assigned maximum 'weighing factor' due to its high mammalian toxicity, medium to high phytotoxicity potential and having no known biological function. On the contrary, Ni and Zn have low to medium mammalian toxicity and phytotoxicity potential as well as have some functional role in organism. Therefore these elements had been assigned lowest 'weighing factor'.

Table 3. Criteria for assigning 'Weighing factor' to heavy metal parameters and 'Score value' to analytical data

Heavy metal (mg / kg)	Score value (S_j)						Weighing factor (W_j)
	5	4	3	2	1	0	
Zn	<151	151-300	301-500	501-700	701-900	>900	**1**
Cu	<51	51-100	101-200	201-400	401-600	>600	**2**
Cd	<0.3	0.3-0.6	0.7-1.0	1.1-2.0	2.0-4.0	>4.0	**5**
Pb	<51	51-100	101-150	151-250	251-400	>400	**3**
Ni	<21	21-40	41-80	81-120	121-160	>160	**1**
Cr	<51	51-100	101-150	151-250	251-350	>350	**3**

The '*Clean index*' of the MSW composts is computed using the formula:

$$\text{Clean index'} = \frac{\sum_{n}^{j=1} S_j W_j}{\sum_{n}^{j=1} W_j}$$

Where, 'S_j' is score value of analytical data and 'W_j' is weighing factor of the 'j'th heavy metal.

Computed 'Clean index' values for MSW composts from Indian cities varied from 0.5 to 5.0 with a mean value of 3.1 (in the 5.0 point scale). Composts from smaller cities recorded, on average, 35 % higher 'Clean index' value as compared to those from bigger cities. Like wise, composts prepared from mixed wastes had the lowest 'Clean index' value (2.3) followed by with those prepared from partially segregated wastes (3.1) and source separated biodegradable wastes (4.2).

Classification of composts on the basis of 'Fertilizing index' and 'Clean index'

While 'Fertilizing index' can be taken as a measure of nutrient supplying potential, 'Clean index' value can be used by regulatory authority for restricting the entry of heavy metals into sensitive components of environment (like agricultural land and water bodies). On the basis of 'Fertilizing index', and 'Clean index' values, following scheme of classification of MSW compost has been proposed for their use in different application areas as well as for their suitability as marketable product (Table 4).

Table 4 : Classification of MSW composts for their marketability and use in different area

Class		Fertilizing index	Clean index	Quality control compliance	Overall quality and area of application
Marketable classes	A	> 3.5	> 4.0	Complying for all heavy metal parameters	**Best quality.** High manurial value and low heavy metal content. Can be used for high value crops and in organic farming
	B	3.1 to 3.5	> 4.0		**Very good quality.** Medium fertilizing potential and low heavy metal content
	C	> 3.5	3.1 – 4.0		**Good quality.** High fertilizing potential and medium heavy metal content.
	D	3.1 to 3.5	3.1 – 4.0		**Medium quality.** Medium fertilizing potential and medium heavy metal content.
Restricted use classes	RU-1	< 3.1	--		Low fertilizing potential but safe for environment. Can be used as soil conditioner.
	RU-2	≥ 3.1	> 4.0	Not complying for all heavy metal parameters	Can be used for growing non-food crops. Requires periodic monitoring of soil quality if used repeatedly.
	RU-3	≥ 3.1	≤ 4.0		Can be used only for developing lawns/gardens, tree plantation in forestry (with one time application).
The samples not falling under above marketable and restricted use classes are not suitable for agricultural land application and can be used for rehabilitation of degraded land.					

Maximum safe concentrations of heavy metals in the MSW composts

Through experiments on sensitive soil (where metal toxicity is likely to appear early) using sensitive plant (having high metal uptake capacity), Indian Institute of Soil Science has determined maximum safe concentration limits of heavy metals in Indian soil which do not adversely affect soil micro-organisms and crop growth as well as do not contaminate food chain beyond background levels. Assuming cumulative allowable MSW compost application rate in crop land as 1000 Mg ha^{-1} during the 100 years of recycling program, maximum permissible concentrations of heavy metals in the compost were computed as 750 mg Zn kg^{-1}, 340 mg Cu kg^{-1}, 1.0 mg Cd kg^{-1}, 160 mg Pb kg^{-1}, 40 mg Ni kg^{-1} and 60 mg Cr kg^{-1} respectively, on the basis of computed maximum safe concentration limit values.

Suitability of MSW compost produced through different methods

MSW compost samples from 29 cities of India were evaluated for their fertilizing and heavy metal parameters and were classified according to the above scheme.

Compost prepared from mixed MSW: Most of the manufacturers who installed mechanical composting plant for handling large volume of wastes were producing compost in this way. None of the composts produced in this way belonged to marketable classes due to either low manurial value or high heavy metal contents or both. About 79% of the composts produced from mixed wastes were unsuitable for land application, and remaining belonged to restricted use classes RU-3 (21%).

Compost prepared from partially segregated MSW: About 50% of the composts produced in this way were unsuitable for land application, 41% belonged to restricted use classes (8% in RU-1 and 33% in RU-3) and remaining 8% were classified under marketable class D.

Compost prepared from segregated MSW: Seventy percent of the composts produced from segregated bio-wastes were suitable for land application. Half of the samples under this category contained heavy metals within the regulatory limits and were suitable land application for growing any kind of crops. The composts produced only from source separated biodegradable wastes following 'door-to-door' collection had high manurial value and were categorized under either 'A' or 'B' classes. Compared to cattle dung manure, such composts had considerably higher N content, but similar content of P, K and organic matter.

Benefit of grading system in the quality control

There are several stakeholders in the process of composting of municipal solid wastes, like municipal authority, compost manufacturer, farmers, public departments / organizations concerning environment and public health. Farmers view compost mainly as a source of plant nutrients and as a soil conditioner and hence, may concern only for 'Fertilizing index' value of the compost. But, public departments / organizations concerning environment and public health perceive composts originating from municipal solid wastes as probable polluter of land resources and therefore, 'Clean index' value is likely to be their principal concern. Municipal authority desires maximum recycling of wastes through compost production so that burden on landfill area with consequent emissions from landfills is reduced. On the other hand, compost manufacturers view composting as a business and expect a better pricing of their product for profit maximization. Grading of MSW composts will help all of these stakeholders in several following ways:

- Efficient use of plant nutrients in the MSW compost
- Maximizes profits of compost manufacturer with better price for better quality
- Apprises user (i.e. farmers) about the overall quality of composts and expected relative benefit from its application
- Maximizes recycling of municipal solid wastes by suggesting alternate safe use of poor quality composts
- Protects land from accumulation of unsafe level of heavy metals

Segregation of biodegradable waste at source is essential for producing 'A' grade compost

Composts produced from non-segregated mixed wastes are poor quality and unsuitable for marketing

Sorting papers for recycling in paper mills

Sorting plastics for recycling

Vermicomposting biodegradable wastes

Segregation and recycling of biodegradable and non-biodegradable municipal wastes are essential components of ideal solid waste management

Prepared by
Dr. J. K. Saha* and Dr. N. R. Panwar
Division of Environmental Soil Science,
Indian Institute of Soil Science, Bhopal
*e-mail : jk_saha12000@yahoo.com

Published by
Dr. A. Subba Rao
Director,
Indian Institute of Soil Science,
Nabibagh, Berasia Road, Bhopal – 462038 (M.P.)