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Full Length Research Paper

Municipal Solid Wastes Management Technologies – A Case Study

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Abstract
The Central Pollution Control Board (CPCB) has reported that 1,33,760 metric tonnes of waste is generated daily in urban areas in the country (SPCB response 2012-13). Uncontrolled dumping of wastes on precious land resource in and around towns and cities has created huge piles of waste, some running into millions of tonnes and are a source of contamination of ground water and air pollution posing a risk to public health. In comparison to the levels of the developed world, of 1-2.5 kg capita/day, our per capita average generation of 450 gm/day of MSW is of course, lower. The total quantity of waste currently handled each day in the urban areas in the country is estimated to be 1, 70,000 metric tonnes i.e. about 62 million tonne per year. As per 2011 census, 31.16 % population of India i.e. 377 million people live in 7,935 urban areas with 4041 municipal authorities. Rapid urbanization and changing lifestyles is resulting in generation of huge amounts of municipal solid waste in urban areas and Saharanpur in the western part of Uttar Pradesh is no exception. Total waste generation is more than 350 ton/day including domestic, industrial and biomedical waste .With nearly 1.25 lakhs households in the city, the domestic waste generation in the city is close to 65 tons in a day. Considering the severity of the problem of safe and low cost disposal of household waste, Muskan Jyoti Samiti, a NGO under its social development initiative has developed this model .which reduces the burden of land filling ,helps in recycling & reusing of the waste, provide income opportunity to a large number of urban poor's in the city, Involved the Community and Government bodies & production of a superior quality organic compost from the biodegradable waste collected from households in Saharanpur .

Keywords: *Municipal Solid Waste (MSW), Composting , Organic Compost, Recyclable waste, Muskan Jyoti Samiti (MJS),*

Introduction

Muskan Jyoti Samiti has started MSW management project in Saharanpur in October, 2006; the project now covers nearly 10500 households in the city for door-to-door collection on 6 days a week & has become self-sustainable in itself. The waste from the households are collected between 7:30 am & 1:30 pm by waste collectors who moves around in a rickshaw trolley carrying plastic bags for recyclable waste biodegradable waste & non-recyclable waste. This is primary segregation done at the household level & secondary segregation is done at the waste management site. The biodegradable waste is further processed to make organic compost; the recyclable waste is sold to the private vendor & non-recyclable waste is transported to the landfills. Each waste collector covers 225-250 households in a day. Process flow diagram of this project is given in Figure -1.Following is the major sources of generation of waste in Saharanpur

- Solid Waste from Residential Areas , Institutional/ Community areas
- Solid Waste from vegetables markets (retail & wholesale)
- Solid Waste from Hotels and Restaurants
- Waste from street cleansing
- Waste from Domestic / Stray Animals /Dairies
- Solid Waste from Commercial Establishments
- ETP Sludge from Industry
- Miscellaneous

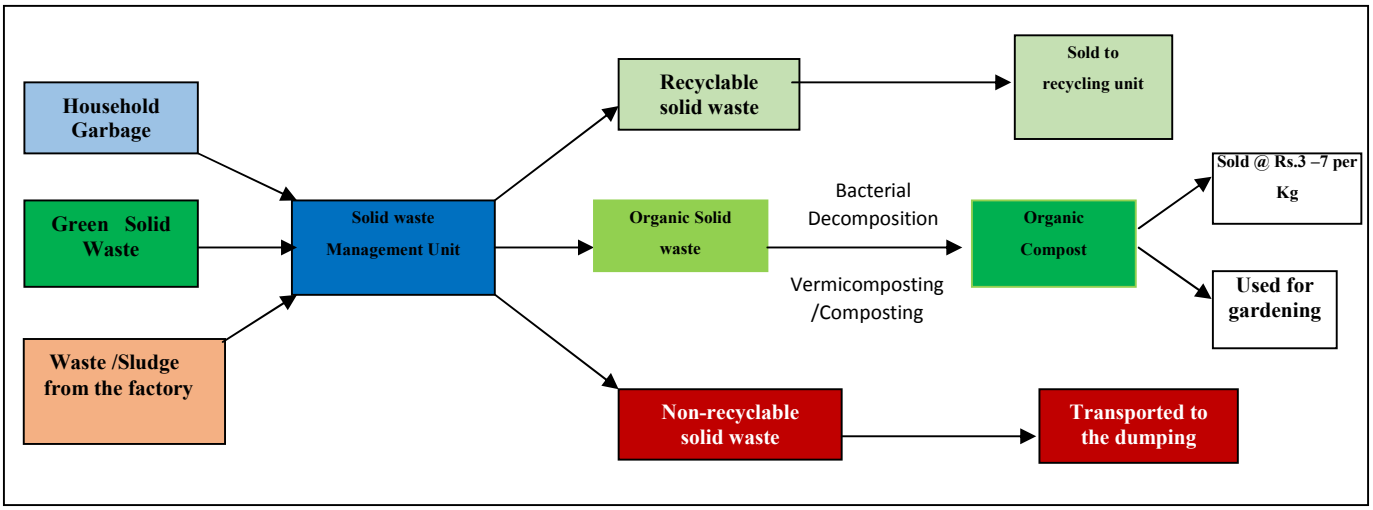


Figure -1. Schematic Diagram of Waste Disposal Process of Project run by Muskan Jyoti Samiti

Materials & Methods

With the aim to safely manage MSW, its effective processing and disposal in terms of the specified measures to prevent contamination of ground-water, surface water and ambient air quality, The following scientifically managed methods can be used for disposal of municipal solid waste (refuse):The following scientifically managed methods can be used for disposal of municipal solid waste (refuse):

A. Sanitary land-filling, also called Controlled tipping
B. Shredding and Pulverization
C. Composting including Vermicomposting
D. Incineration and Thermal pyrolysis
E. Adoption to Innovative Technologies

The organic content of Municipal Solid Waste (MSW) tends to decompose leading to various smell and odour problems. It also leads to pollution of the environment. To ensure a safe disposal of the MSW it is desirable to reduce its pollution potential and several processing methods are proposed above for this purpose. Out of above mentioned methods Muskan Jyoti Samiti is focusing on disposal of MSW through Composting process**.** This is quite commonly used and results in production of a stable product - compost which depending upon its quality can be used as a low grade manure and soil conditioner. The process results in conservation of natural resources and is an important processing method, especially in agricultural and horticultural areas. Composting of refuse is a biological method of decomposing solid wastes. This decomposition can be affected either under aerobic conditions, or under anaerobic conditions, or both. The final end product is manure, called the compost or humus.

The Municipal Solid Wastes (Management and Handling) Rules, 2000 has laid down the following specifications for compost quality, to ensure its safe application.

Composition/Quality Standards for Compost : In order to ensure safe application of compost, the following specifications of compost quality shall be met as mentioned in Table -1& 2

Table -1. Compost Quality Standards

Parameters	Concentration not to exceed * (mg/kg dry basis , except pH value and C/N ratio)
Arsenic	10.00
Cadmium	5.00
Chromium	50.00
Copper	300.00
Lead	100.00
Mercury	0.15
Nickel	50.00
Zinc	1000.00

C/N ratio	20-40
PH	5.5-8.5

* Compost (final product) exceeding the above stated concentration limits shall not be used for food crops. However, it may be utilized for purposes other than growing food crops. Ministry of Agriculture, Department of Agriculture and Cooperation, Government of India, New Delhi, included biofertilizers and organic fertilizers under section 3 of the Essential Commodities Act, 1955 (10 of 1955), in Fertilizer (Control) Order, 1985 as amended . These rules were further amended in respect of applicability, specifications and testing protocols , Following specifications of Organic Fertilizers have been prescribed in the above said order

Table -2 City Compost Specifications

Parameters	Limits
Moisture, per cent by weight	15.0-25.0
Colour	Dark brown to black
Odour	Absence of foul odour
Particle size	Minimum 90% material should pass through 4.0 mm IS sieve
Bulk density (g/cm3)	<1.0
Total organic carbon, per cent by weight,	minimum 12.0
Total Nitrogen (as N), per cent by weight,	minimum 0.8
Total Phosphates (as P2O5), per cent by weight,	minimum 0.4
Total Potash (as K2O), per cent by weight,	minimum 0.4
C:N ratio	<20
pH	6.5 - 7.5
Conductivity (as dsm-1),	not more than 4.0
Pathogens	Nil
Heavy metal content, (as mg/Kg), maximum	
Arsenic as (As2O3)	10
Cadmium (as Cd)	5
Chromium (as Cr)	50
Copper (as Cu)	300
Mercury (as Hg)	0.15
Nickel (as Ni)	50
Lead (as Pb)	100
Zinc (as Zn)	1000

Tolerance limit of organic fertilizer

A sum total of nitrogen, phosphorus and potassium nutrients shall not be less than 1.5% in City Compost and shall be not less than 2.5% in case of vermicompost .

Principles of composting – Manual and Mechanised methods

Decomposition and stabilization of organic waste matter is a natural phenomenon. Composting is an organized method of producing compost manure by adopting this natural phenomenon. Compost is particularly useful as an organic manure which contains plant nutrients (Nitrogen, Phosphorous and Potassium) as well as micro nutrients which can be utilized for the growth of plants (Gotaas 1956). When used in conjunction with chemical fertilizers optimum results are obtained. Composting can be carried out in two ways i.e., aerobically and anaerobically. During aerobic composting aerobic micro-organisms oxidize organic compounds to Carbon dioxide, Nitrite and Nitrate. Carbon from organic compounds is used as a source of energy while nitrogen is recycled. Due to exothermic reaction, temperature of the mass rises. During anaerobic process, the anaerobic micro organisms, while metabolizing the nutrients, break down the organic compounds through a process of reduction. A very small amount of energy is released during the process and the temperature of composting mass does not rise much. The gases evolved are mainly Methane and Carbon dioxide. An anaerobic process is a reduction process and the final product is subjected to some minor oxidation when applied to land.

Indore & Bangalore methods of composting

Manual composting was systematized by Howard & his associates. It was further developed by Acharya & Subrahmanyam and the methods are conventionally referred as Indore and Bangalore methods of composting.

Bangalore Method

This is an anaerobic method conventionally carried out in pits. Formerly the waste was anaerobically stabilized in pits where alternate layers of MSW and night soil were laid. The pit is completely filled and a final soil layer is laid to prevent fly breeding, entry of rain water into the pit and for conservation of the released energy. The material is allowed to decompose for 4 to 6 months after which the stabilized material is taken out and used as compost.

Indore Method

This method of composting in pits involves filling of alternate layers of similar thickness as in Bangalore method. However, to ensure aerobic condition the material is turned at specific intervals for which a 60 cm strip on the longitudinal side of the pit is kept vacant. For starting the turning operation, the first turn is manually given using long handled rakes 4 to 7 days after filling. The second turn is given after 5 to 10 more days. Further turning is normally not required and the compost is ready in 2 to 4 weeks. In the urban areas, due to extensive provision of water carriage system of sanitation, night soil is not available. Composting of MSW alone is hence often carried out. Aerobic composting of MSW is commonly carried out in windrows.

Comparison of the Methods

The Bangalore method requires longer time for stabilization of the material & hence needs larger land space, which is in short supply in urban areas. The gases generated in this anaerobic process also pose smell & odor problems. The Indore method on the other hand stabilizes the material in shorter time & needs lesser land space. As no odorous gases are generated in this process, it is environment friendly & hence commonly preferred. While the organic matter is stabilized during the composting process, the moisture content also changes. The nondecomposable are also rejected. Hence the quantity of compost is much lesser than the input & is normally around 50%, and the exact value depends upon the characteristics of the input material.

Windrow Composting

The organic material present in Municipal Waste can be converted into a stable mass by aerobic decomposition. Aerobic micro organisms oxidize organic compounds to Carbon di oxide and oxides of Nitrogen and Carbon from organic compounds is used as a source of energy, while Nitrogen is recycled. Due to exothermic reactions, temperature of mass rises. In areas/regions were higher ambient temperatures are available, composting in open windrows is to be preferred. In this method, refuse is delivered on a paved/unpaved open space but leveled and well drained land in about 20 windrows with each windrow 3m long x 2m wide x 1.5m high, with a total volume not exceeding 9.0 cum. Each windrow would be turned on 6th & 11th days outside to the centre to destroy insect's larvae and to provide aeration. On 16th day, windrow would be broken down and passed through manually operated rotary screens of about 25mm square mesh to remove the oversize contrary material. The screened compost is stored for about 30 days in heaps about 2m wide x 1.5m high and up to 20m long to ensure stabilization before sale.

Factors affecting the composting process

Organisms

Aerobic composting is a dynamic system wherein bacteria, actinomycetes, fungi and other biological forms are actively involved. The relative preponderance of one species over another depends upon the constantly changing food supply, temperature and substrate conditions. Facultative and obligate forms of bacteria, actinomycetes and fungi are most active in this process. In the initial stages mesophilic forms predominate and thermophilic bacteria and fungi soon take over except in the final stage of composting. Except when the temperature drops, actinomycetes and fungi are confined to 5 to 15 cm outer surface layer. If the turning is not carried out frequently the actinomycetes and fungi in these layers register increased growth imparting it typical grayish white color. Thermophilic actinomycetes and fungi are known to grow well in the range of 45 to 60^0C. Different organisms are known to play predominant role in breaking down different constituents of municipal solid waste.

Use of Cultures

During the development of composting process various innovators came forward with inoculum, enzymes etc., claimed to hasten the composting process. Investigations carried out by various workers have shown that they are not necessary**.** The required forms of bacteria, actinomycetes and fungi are indigenous to MSW. Under proper environmental conditions the indigenous bacteria adapted to MSW rapidly multiply, as compared to the added cultures which are more attuned to controlled laboratory conditions and carry out decomposition. The process is dynamic and as any specific organism can survive over a specific range of environmental conditions, as one group starts diminishing, another group of organisms starts flourishing. Thus, in such a mixed system appropriate life forms develop and multiply to keep pace with the available nutrients and environmental conditions. Hence, addition of similar and extraneous organisms in the form of inoculum is unnecessary. However, such inoculum will be required during composting of industrial and agricultural solid waste which do not have the large mix of indigenous bacterial population.

Moisture

The moisture tends to occupy the free air space between the particles. Hence, when the moisture content is very high, anaerobic conditions set in. However, the composting mass should have a certain minimum moisture content in it for the organisms to survive. The optimum moisture content is known to be between 50 to 60 % . Higher moisture content may be required while composting straw and strong fibrous material which soften the fiber and fills the large pore spaces. Higher moisture content can also be used in mechanically aerated digesters. In anaerobic composting the moisture content used will depend upon the method of handling and whether it is carried out in the open or in closed container.

Temperature

The aerobic decomposition of a gram mole of glucose releases 484 to 674 kilo calories (kcal) energy under controlled conditions, while only 26 kcal are released when it is decomposed anaerobically. Municipal solid waste is known to have good insulation properties and hence the released heat results in increase in temperature of the decomposing mass. As some of the heat loss occurs from the exposed surface, the actual rise in temperature will be slightly less. When the decomposing mass is disturbed, as during turning of windrows, the resultant heat loss results in drop in temperatures. Under properly controlled conditions temperatures are known to rise beyond 70^0C in aerobic composting. Under properly controlled conditions temperatures are known to rise beyond 70^0C in aerobic composting. During anaerobic composting as the released heat is quite small and as part of it is lost from the surface only a marginal rise in temperature occurs. This increased temperature results in increased rate of biological activity and hence results in faster stabilization of the material.

Carbon/Nitrogen (C/N) Ratio

The organisms involved in stabilization of organic matter utilize about 30 parts of carbon for each part of nitrogen and hence an initial C/N ratio of 30 is most favorable for composting. The initial C-N ratio and moisture content of the compost heap are the important controlling factors in the success of anaerobic digestion**,** which finally produces a compost free from pathogens and contains 1%N, 1.1% P (as P_20_5) and 1.5% K(as K_2O) on dry basis, thus proving to be a valuable nutrient for the soils, along with producing biogas as a by-product.


Household Waste Collection & Primary Segregation


Unloading at site & Secondary Segregation

Mixing of MSW

Bed Formation

Sieving of Compost

Final Product ready for sale

Figure -2: Muskan Jyoti Samiti Project - Process Flow Diagram of Compositing

Operating Procedures of Solid Waste Management at Muskan Jyoti Site

Primary Collection:

All waste workers are assembled and marked their present in the attendance register at segregation centre by designated time.Every rickshaw trolleys having its own significant code or serial numbers that have been allotted to respective waste collector.Every waste collector will manage 200-220 house hold waste in the span of 4 hours per day except Sunday.All waste collected from house hold is segregated in two gunny bags/waste bins carried by the waste worker.Following are the details of waste:

- **Recyclable Waste**: Paper, Polythene, Plastic, Bottle, Carton,
- **Kitchen Waste:** Entire Kitchen waste
- **Land fill Waste :** Soil, Cloth, Wood, Ash, Sandstone
- **De-Composting Waste:** Layers of Vegetables and Fruits, Perishable food items

Required Personal Protective Equipment (hand gloves ,face mask ,gumboot ,goggles)are issued to them regular internal & their inspection is happening accordingly .

Segregation of waste materials is being done as per categories mentioned above

Recyclable Waste

All waste collectors are reaching to the segregation centre by 12:00-1:00 PM with their trolleys and report to centre in charge. Recyclable waste of each collector is weighed through digital weighing machine and entered in separate register. Moisture reduction to be established. Separate register of recyclable waste is maintained on daily basis. Recyclable waste is being sold to different vendors through seeking their quotation on weekly basis .Vendor finalization process is based upon the competitive rate received from & purchase order is issued accordingly.There is a TOR with each of the vendors referring to terms and condition that both parties must be abide with. Recyclable sold is verified by weighing on weighbridge against the quantity mentioned in the purchase order.

Kitchen Waste

Kitchen waste is brought into one platform where segregation of landfills waste and decomposing waste is done by workers. Workers must be equipped with personal protective equipments like hand gloves, face-mask, gumboot and goggles.Segregated decomposing material is sent to the processing center on the same day.A Material Issue Note is issued against every decomposing material to be sent to processing center.

Decomposition Bed Formation

Composting material comprises of green waste, kitchen waste and sludge is arranged at the site of bed formation & The entire component is weighed as per the established weight unit or device.The ratio of composting material is maintained as per norms i.e 9:6:3 for Green Waste: Kitchen Waste: & ETP Sludge.Material should be mixed properly and drenched after pouring water on it.Bacterial culture in proportion of 1 liter with 1000 kg of composing material is sprayed.Formation of bed in the standard size of 4'x 4' x 9' after ensuring that the mixing is completed in proper manner.Each bed formation is done in its designated time schedule includes congregation of compost material, weighing of compost material,spreading of compost material and single out ,spraying of water and mixing of bacterial culture& finally formation of bed.

1st Turning of Decomposed Bed

After 10 to 15 days of bed formation, 1st turning of decomposed bed is taken place. However it also depends upon the height of the decomposed bed that should in between 2 to 2.5 feet.During 1st turning, de compost bed must be stretched in the floor.Segregation of recyclable and non recyclable waste Pouring of adequate water and mixing of bacterial culture in the correct proportion .Date of the 1st turning should be mentioned in the tag of all respective bed.

2nd Turning of Decomposed Bed

2nd turning must be after 10 to 15 days of 1st turning of decomposed bed and procedure as 1st turning must be followed.During 2nd turning, two beds that already had gone through of 1st turning be combined together into one bed.Filling should be on as per process requirement after 45 days, material from decomposed bed must be got into the pit ,every 7 days turning and segregation is taken place& ,spraying of water on daily basis to maintain 40% moisture.

Harvesting

Ready composting material must be got to the platform for proper exposure to air and sunlight to reduce the moisture.Material should be put up in the sieving machine after ensuring that the same have been dried out properly.Bacterial culture mixed with water to be poured on the manure to ascertain and maintained 20 to 25% moisture.

Results & Discussion

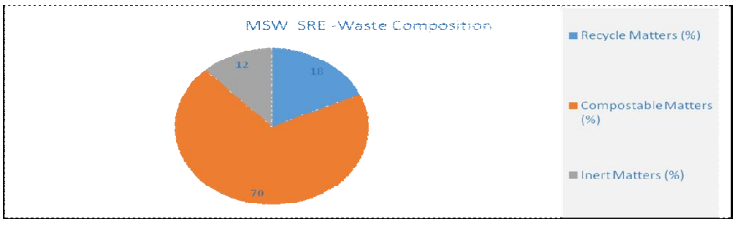
MSW Management project run by M/s Muskan Jyoti Samiti is successfully operating in Saharanpur City & out of total MSW collected through this model is managed properly ,nearly 85% of the total waste is recycled or reused and only 15% (non-recyclable) goes to landfills.MSW collected during (13-14)in Saharanpur showed following composition

Table- 3 Composition of MSW Fiscal (2013-2014)

Quantity of Total Waste Generated Approx (Tons)	Recycle Matters	Compostable Matters	Inert Matters
2078.6	376.3	1454.8	248.5
Total Waste Generated (%)	18	70	12

***Data**: M/s Muskan Jyoti Samiti*

If we compare compostable waste percentage from other cities studied by CPCB/NEERI, In Sahranpur MSW ,recyclable waste is more because in Other cities data sampled by agencies having MWS contains Street sweeping ,construction debris etc but in case of M/s Muskan Jyoti Samiti, Waste is collected directly from individual households so compostable waste percentage is comparatively higher in side as mentioned in Table -3 & Figure 3



Analysis of Physico-Chemical Parameters of Organic Compost:

Organic compost samples were collected at final stage of composting process and sent to National Botanical Research Institute (A Council of Scientific and Industrial Research) Lucknow –NABL Accredited Laboratory, for physico – chemical parameters analysis. The analysis reports of various samples are presented in below mentioned in Table-4 & graphically represented in Figure 4.

Table -4 Analysis Report of Compost Samples

Sample	Total Phosphorous(%)	Total Potassium (%)	Total Nitrogen (%)	Organic Carbon (%)	C/N Ratio	pH
Sample No 1	0.021	0.85	0.71	4.05	5.7	8.63
Sample No 2	0.027	1.05	0.77	3.91	5	9.1
Sample No 3	0.035	1.35	0.83	10.21	12.3	8.63
Sample No 4	0.027	1.53	0.7	9.88	14.1	8.61
Sample No 5	0.03	1.41	0.65	10.08	15.5	8.48
Average	0.028	1.14	0.73	7.62	10.5	8.69

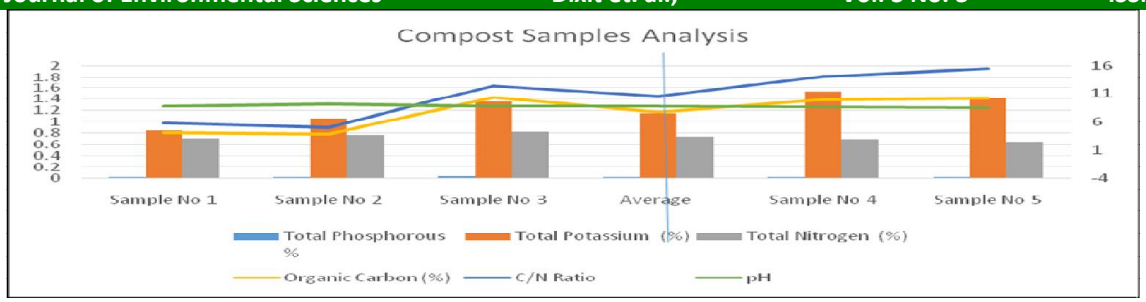


Figure -4 Graphical Representation of Compost Analysis Report

Improvements in Compost Quality

PH value (average 8.69) was observed higher in range from 8.5 mentioned in MSW Rules for Compost and 7.5 mentioned in Fertilizer Control Order for organic compost .This shows basic character of compost .C/N ratio (average 10.5) was well below the limit (20) mentioned in Fertilizer Control order for organic compost & not meeting compost quality standard given in MSW Rules i.e 20-40. As per Fertilizer (Control) Order, 1985 as amended , a sum total of nitrogen, phosphorus and potassium nutrients shall not be less than 1.5% in City Compost .Out of 5 compost sample analyses average nitrogen ,phosphorous and potassium nutrient content was found 1.89 %,which indicates availability of required nutrients in compost fertilizer. The Nitrogen should be in the form of Nitrates for proper utilization by the plants.

Other Scope of Improvements

It is recommended to take extra care while storage of waste at the site. To the extent possible, the waste storage area should be covered. As storage is done in an partially open area and facility for collection of leachate and surface water run-off into lined drains leading to a leachate treatment and disposal facility to prevent run-off from landfill area entering in to nearby river.It is also recommended to take necessary precautions to minimize nuisance of odor, flies, rodents, bird menace and fire hazard with proper provision of fire dousing facility.Project authorities may think to convert manual processes in to mechanized mode for ease of operation & enhanced productivity.It is recommended to take care of biomedical waste as per the Bio-medical Wastes (Management and Handling) Rules, 1998 and hazardous wastes shall be managed in accordance with the Hazardous Wastes (Management and Handling) Rules, 1989, as amended from time to time.Primary segregation is done at the household level need to segregate for recyclable, biodegradable & non-recyclable waste category by providing different waste bins to minimize efforts on secondary segregation. There is requirement to create more awareness of households about importance of segregation at source.Waste collectors, who move around in a rickshaw trolley carrying two plastic bags; one for recyclable waste and another for biodegradable waste & non-recyclable waste. It is recommended to provide three waste bins in each rickshaw trolley for ease of segregation at primary stage.It is recommended to monitor ground Water Quality ,Air Quality on regular basis as recommended in statues.

Conclusion

Produced compost can be used as a low grade manure and soil conditioner. This composting process results in conservation of natural resources and is an important processing method, especially in agricultural and horticultural areas. The organisms involved in stabilization of organic matter utilize about 30 parts of carbon for each part of nitrogen and hence an initial C/N ratio of 30 is most favorable for composting. Research workers have reported the optimum value to range between 26-31 depending upon other environmental conditions. As we found low C/N ratio of this compost indicates more addition of carbon sources such as, horticulture waste straw, sawdust, papers etc to get optimum C/N ratio as mentioned in Fertilizer Control Order . Presently organic compost is being sold to nurseries located in Dehradun, Haridwar, Saharanpur, Chandigarh, Meerut etc. In future project authorities are planning to supply this manure for agriculture purpose also so It is recommended to analyses heavy metals as mentioned in fertilizer control odder to see that toxicants are well within the prescribed limits. Muskan Jyoti Samiti may carry out physico-chemical analysis of MWS samples to get establish desired C/N ratio in organic compost. Although basic facilities at the processing site have been provided, still safety provisions including health inspections of workers shall be periodically conducted. Adequate personal protective equipments to be provided to handle hazardous waste if received and there should be display of safety, hygiene and health awareness posters to raise awareness of person involved in these operations. It is emphasised to take adequate precautions during monsoon season to prevent run off going to nearby river stream & no odor and hygiene nuisance to nearby community.

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