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UTILIZATION OF ORGANIC MATTER FROM MUNICIPAL SOLID WASTES IN COMPOST INDUSTRIES

(Pemanfaatan Bahan Organik dari Sampah Padat Perkotaan dalam Industri Kompos)

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Abstract

Recently a huge amount of municipal solid wastes produced in big cities causes serious environmental and health problems. Since nearly three fourth of the wastes is biomass, there is a potential to process the organic matter into agricultural compost. In this way, the weight and volume of wastes which are finally disposed in sanitary landfills can be drastically reduced. The fermentation process of biomass occurs in compost plants. However, a thorough mechanical separation of the organic matter from municipal solid wastes must be carried out first by using pairs of a thrower and a fan. Some important equipments and machineries in a typical compost plant are delineated based on a case of 50 tons per day capacity. Their appropriate types and dimensions are discussed as well.

Abstrak

Dewasa ini sampah padat yang dihasilkan oleh kota besar sudah sangat banyak dan berpotensial untuk menimbulkan dampak negatif terhadap lingkungan dan kesehatan masyarakat. Oleh karena sekitar tiga perempat dari sampah adalah biomassa maka terdapat kemungkinan untuk memproses sampah tersebut menjadi pupuk kompos. Dengan demikian berat dan volume sampah sisa yang terpaksa harus dibuang ke TPA dapat berkurang secara drastis. Proses fermentasi bahan organik ini dilakukan di pabrik kompos. Sebelum itu, harus terlebih dahulu dilakukan proses pemisahan secara mekanis dan seksama untuk memperoleh bahan organik murni dari sampah padat. Pemisahan dilakukan oleh beberapa pasang thrower *(pelempar) dan* fan *(penghembus). Melalui contoh kasus sebuah pabrik kompos berkapasitas 50 ton per hari beberapa peralatan dan mesin penting yang lazim dijumpai pada pabrik kompos dijelaskan pada makalah ini, demikian juga tipe dan ukurannya.*

I. INTRODUCTION

Garbage is one of crucial problems faced especially by large cities. The recent waste problems in Surabaya and Jakarta clearly indicate this. It is even predicted that other cities such as Bandung and Medan will soon experience the similar difficulty if people do not change their old paradigm in managing waste (Anonym, 2001). So far the concept of sanitary landfills has not been implemented properly in Indonesia, the instead, uncontrolled open dumping in TPAs (Final Disposal Sites). It is also observed in many European countries (Anonym, 1997) that household wastes produced yearly by each person from less developed countries, such as Poland and Czech, are much fewer than those from developed countries (e.g. Italy, Sweden, Denmark, Netherland). It seems that „modern" people tend to consume more goods and consequently dispose more garbage.

Waste managements have been developed to cope with the problem. The most popular concept is the recovery of useful and valuable materials from wastes. So far, such concept is implemented satisfactorily in Indonesia with the help of scavengers. Instead of utilizing modern machineries for selecting and separating certain materials from the rest, they do their job manually with relatively low cost. However, they are not really dependable because the huge amount of municipal solid wastes is already too much for them. In the future everyone will have to separate his household waste in two groups i.e. organics and inorganics (e.g. plastics, cans, glass etc.).

Therefore, in order to minimize negative environmental and health impacts from wastes the establishment of many compost plants whose main raw material is organic components of the municipal solid wastes is strongly recommended. Some advantages of such compost plants are obvious. Since nearly three fourth of the waste is organic constituent, the composting industry can help considerably in reducing the mass and volume of the dumped waste. Service life of sanitary landfills can be lengthened significantly. Not necessarily highly educated and qualified personnels are required to run the plants. Another advantage of the plants is to cover the shortage in the supply of fertilizers.

It is even expected that the use of more popular inorganic (chemical) fertilizers in agriculture can be gradually replaced by organic composts, because it is healthier and saver to consume fruits and vegetables which grow naturally without any chemicals. Furthermore, excessive usages of chemical fertilizers can even lead to negative effects for agricultural fields. While people from developed countries realize these facts since years ago, several institutions in Indonesia have just begun to campaign the issue.

A financial analysis has been done for several plant sizes i.e. 200, 100 and 1 tons per day. It was found to be viable (Anonimous, 1999a). However, a more detailed technical design of a typical compost plant is still required. Therefore, the West Java - Jakarta Environmental Management Project asked the author to carry out a literature research, to visit some existing plants and sanitary landfills around Jakarta and then to design an organic fertilizer plant.

II. RAW MATERIALS

A. Required Amounts

The main raw material needed is organic components contained in disposed municipal solid wastes. The first step in designing every compost plant is therefore, calculating the required input rate of the wastes.

The typical composition of household wastes, especially its organic content, has been observed in several field surveys. At least three different surveys can be mentioned and tabulated here (Anonymous, 1999b).

Table 1. Mass Fraction of Organic Matters in Municipal Solid Wastes

No.	% weight of organics	Remarks
1	75.03	carried out by BPPT in 1996 in Surabaya
2	79.37	sampled by BPPT in 1998 for 200 households in Jakarta
3	73.92	Source : Dinas Kebersihan DKI Jakarta 1997 / 1998
4	67.48	composition of Municipal Solid Waste in Jabotabek, 1997

According to the above table, it is assumed that the average weight percentage of organic components in the waste entering a compost plant is 74%.

The designed plant should be able to produce at least 125% of the nominal plant capacity to anticipate a significant increase of compost demand in the future.

The 125% production capacity could come from three similar production lines (units), so that instead of 33% each unit is designed to handle about 42% of the total output. If any serious trouble happens to one of the three available units which forces it to be out of service, the other two can be temporarily overloaded until 50% of the total nominal capacity, so that the plant is still able to produce 100% while the damaged unit is repaired as soon as possible. Mechanical problems during the operation of such (dirty) plants can happen very often (Saptoadi *et al.*, 1999).

In order to determine the amount of the (mixed) municipal solid waste supplied to a plant, it is simply assumed that the waste consists of four main components, i.e organic, paper, plastics and others, whose fractions are also averaged from the same tables. Furthermore,the mean density of these components has been found out from the study of solid waste conducted by the BPPT in Surabaya in the year 1996. They can be listed in the following table.

However, compost plants do not produce pure compost but supplemented compost according to the demand of users. Normally, supplemented composts are composed of 70% organics and 30% additional ingredients (e.g. livestock manure, rice straw and / or urea, CaO and other trace elements) which depend on the purpose of the fertilizer usage.

Thus, in order to produce a certain amount of supplemented compost, for instance 50 tons per day (please keep in mind that the amount already represents 125% of the nominal capacity which is 40 tons per day), approximately 35 tons per day organics or equivalently 47.5 tons per day of municipal solid waste are required and consequently each composting unit should handle about 16 tons solid waste per day. The additional ingredients (about 15 tons per day) from a hopper are fed directly into a mixer where it is mixed with the medium-sized organics from chippers (see Figure 1 Process Flow Diagram).

In the next discussion the plant capacity of 50 tons per day will always be used as a reference for calculations.

B. Waste Trucks

Normally, the raw material of compost plants is transported from temporary transfer stations by trucks. There are different types and also different volumetric capacities of the trucks. For example, in Jabotabek area big

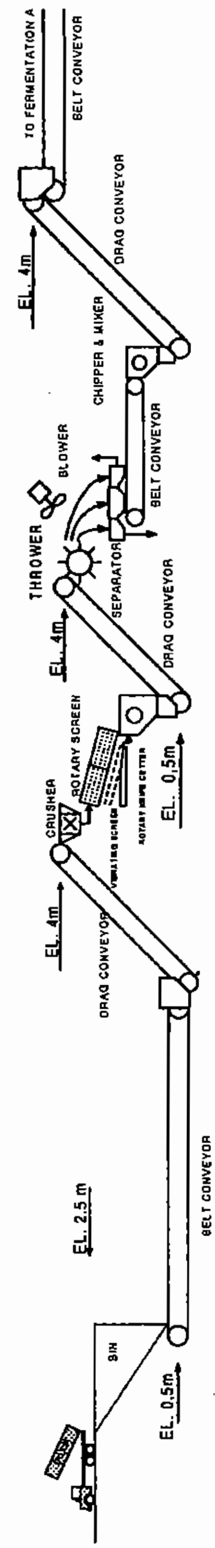

Figure 1. Process Flow Diagram

trucks are capable of transporting 10 cubic meter waste, while small trucks can transfer only 6 cubic meter. For calculation purposes it can be assumed that these trucks have an average capacity of 8 m^3.

To estimate the number of trucks required to supply 47.5 tons per day municipal solid wastes, the total volume of the waste must be first determined with the help of the mean densities presented in Table 2. The total waste volume is the sum of the volumes of its components as seen in the following table.

Table 2. Mean Densities of Waste Components

Component	Fraction % (by weight)	Mean density (kg/m^3)
Organics	74.0	378.7
Paper	9.0	259.6
Plastics	8.25	115.7
Others	8.75	236.5

Therefore, these 160.6 m^3 per day of solid waste must be transported by about 20 trucks daily. Assuming that these trucks deliver waste to the plant only 4 hours a day (for example from 10.00 am until 2.00 pm), the average amount of trucks going in and out is five trucks per hour. Since the plant consists of three processing units, there are also three dumping sites (storage bins) available. These three bins are located separately from each other (the distance between two dumping sites is roughly 20 m) so that enough space is still available for trucks to maneuver before and after unloading without being interfered by others. Actually the space availability enables six waste trucks (for three units) to dump simultaneously (see Figure 2 : Plant Layout) thus every truck can stay even longer than 60 minutes in the dumping site. Therefore an unexpected queue of trucks is avoided.

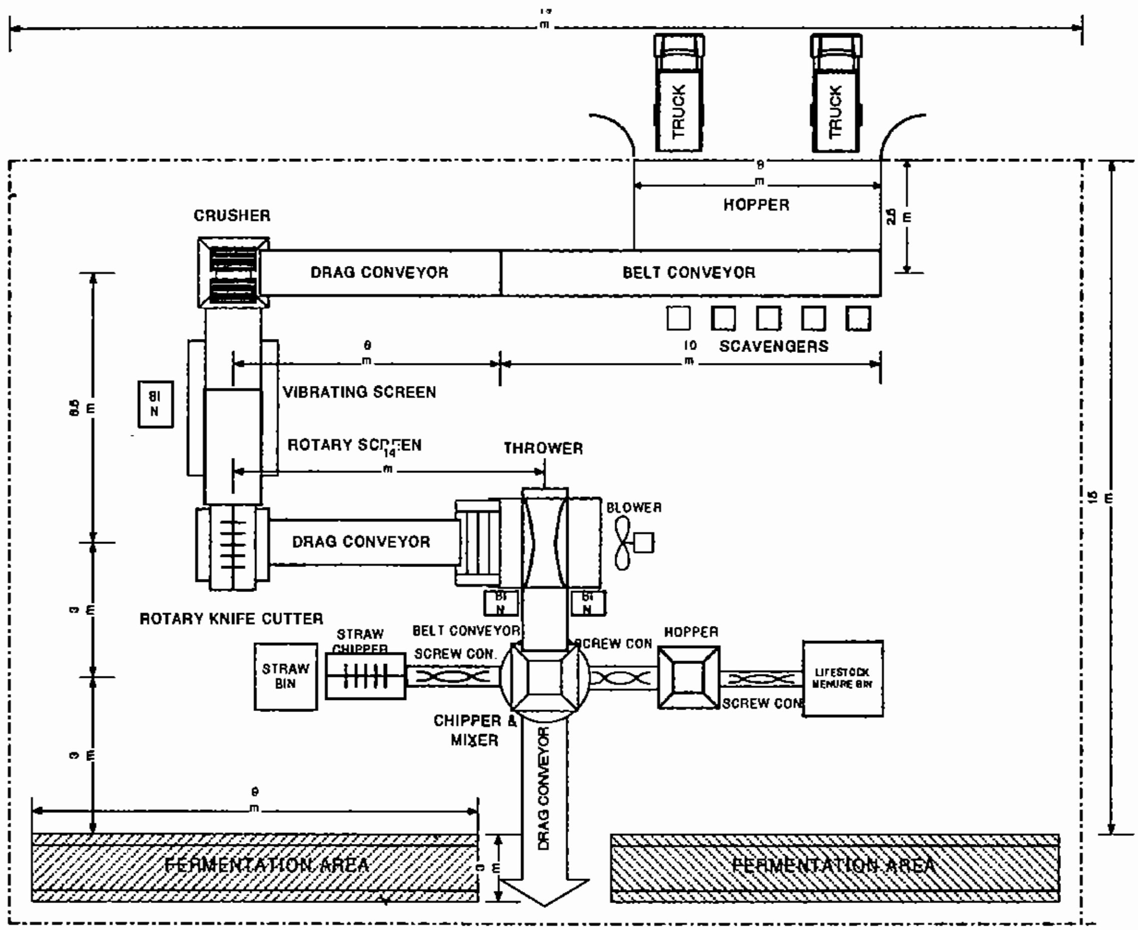

Figure 2. Plant Layout

In order to let sorters / scavengers, who collect valuable materials from the belt conveyor, work at the ground level, the waste trucks must first climb about 2.5 meters high before unload the waste. It is still possible for the trucks to climb because the inclination is only a few degree before they reach a flat platform. Meanwhile trucks which supply approximately 7.5 tons per day livestock manure and 7.5 tons per day rice straw approach the plant from other sides, so they do not create any problem either. These trucks must also climb about 2.5 meters high before unload their contents into hoppers.

C. Storage Bins (Hoppers)

Bins have a function of bridging the difference between the batchwise relatively high incoming rate and the continuously low outcoming rate of the waste transported by belt conveyors. Bins act as a storage as well. Three bins are available in the dumping sites. It happens very often that although plant workers already come at 7.00 am but the first waste truck arrives at 10.00 am (because it takes time for the truck to collect wastes and then bring it to a distant compost plant), however the workers can begin to process the available materials dumped and stored in the bins on the foregoing day.

never be more than 20 cm by using an adjustable gate. Moreover, to ease the selection the conveyor's moving speed must be low enough. The moving speed can be calculated by considering the waste's mass flow rate, the average waste density (see Table 3) and the flow area (0.2 m x 0.6 m).

In calculating the mass flow rate of the waste it must be considered that the 16 tons per day (for each production line) is the amount of waste processed in about 10 hours (from 7.00 am until 5.00 pm), so the actual mass flow rate is 1.6 tons per hour.

Although it is expected that all non-organics can be sorted out by 12 persons, it is hardly possible, due to some reasons such as poor working atmosphere, too much wastes to be handled, tiredness, lack of motivation, etc. Therefore, it is assumed that only half of every recycables can be recovered. In the calculation, the average fractions of glass and metal are taken 1.35% and 1.5% respectively, based on the same data listed in Table 2. The following Table 4 shows details of the picked and left materials for each belt conveyor (each production line).

There is a magnetic separator at the end of the horizontal conveyors to catch ferrous metals that probably still exist on the belt. This far, the flow rate of the waste decreases to 14.39 tons per day. Then the waste climbs up the next inclined drag conveyor so that its elevation changes from 0.5 m to 4 m above the ground. The drag conveyor is 7 m long, 0.6 m wide and makes about 30 degrees to the horizontal.

In addition to these conveyors there are still other two drag conveyors and three belt conveyors for each processing unit. Their specifications will be discussed later.

B. Jaw Crushers

About 14.39 tons per day of waste then proceed into a jaw crusher. The crusher is intended to tear, break and reduce the size of some relatively big pieces such as tree branches, furnitures, plastic bags with wastes inside, etc. Medium and small size wastes remain unchanged. Then all wastes are sent to rotary and vibrating screens for further separation.

C. Rotary and Vibrating Screens

The rotary screen is made from woven stainless steel wires wrapped in a cylindrical shaped frame. Only about 20% of the trommel volume should be occupied by the moving waste. Therefore, the rotary trommel is designed to have a diameter of about 0.85 m and length of 2.75 meters. The waste flows with a relatively low velocity along the revolving screen and pieces

Table 4. Recovered and Left Materials from the Belt Conveyor

Materials	Weight fraction (%)	Flow rate (tons per day)	50% recovered (tons per day)	50% left (tons per day)
Papers	9.0	1.44	0.72	0.72
Plastics	8.25	1.32	0.66	0.66
Glass	1.35	0.22	0.11	0.11
Metals	1.5	0.24	0.12	0.12
Organics	74.0	11.84	0	11.84
Others	5.9	0.94	0	0.94
TOTAL	100.0	16.0	1.61	14.39

which are still larger than 20 cm (and thus cannot pass through the screen) leave the screen after about 3 minutes and proceed into a rotary knife cutter located next to the rotary screen. The screen is slightly inclined, normally about 10 degrees, and it is so installed that the angle of inclination is adjustable. The rotational speed of the cylindrical screen can be regulated as well.

Meanwhile, smaller pieces (less than 20 cm) can immediately escape through the wire mesh and fall down on a flat vibrating screen whose dimension is 1 m x 2.9 m. The screen is mechanically vibrated and made from a perforated stainless steel plate. Some of these pieces that are finer than 1 cm (e.g. sand, soil, gravel etc.) escape through the vibrating screen and fall down into a special box, while the rest (between 1 cm and 20 cm) flows into another box and mixed with the waste already cut by the rotary knife cutter.

Before the waste is processed further, it must be elevated by a drag conveyor from about 0.5 m up to 4 m. The second drag conveyor is about 7 m long, 0.6 m wide and makes an angle of 30 degrees to the horizontal. Its construction and dimension are very similar to the first mentioned drag conveyor, so that they are interchangeable.

D. Throwers and Fans

These are obviously the most crucial equipments in the separation process. In order to completely separate various components of waste once more, the solid waste is sent to a density based separator. It consists of a thrower and a fan which are located oppositely. First the waste is kicked up by the thrower. The higher the density of the waste, the farther it is thrown. Additionally, the fan will improve the resolution of the separation process because slightly pressurized air flows against the movement of the thrown waste, hence lighter materials (e.g. plastics) suffer more resistant to fly than dense materials such as batteries, non ferrous metals, rubber, stones, ceramics etc. Consequently, these waste's components land separately on three different areas, whose borders are adjustable, on a short belt conveyor. The lighter and denser materials are forced to leave the third horizontal belt conveyor and flow into two special boxes for further utilization. The rest of them, about 11.84 tons per day for each production unit (see Table 4), is expected to be organic matter only and finally flows into a chipper for further processing.

In order to ensure a broad and flexible separation capability, it is highly recommended to install a thrower whose kicking power is adjustable and also a fan whose discharge pressure can be regulated.

E. Chippers and Mixers

Before the waste is sent to fermentation areas, it must be cut to medium sized pieces because a material pile which consists of mediocre sized pieces can be easily penetrated by air and thus good fermentation process can be ensured. A chipper cut the waste to a size between 1.5 and 5 cm. Then the waste is sent to a mixer to obtain a homogeneous mixture of organics, manure, straw, urea, CaO and others (according to the purpose of the product). All of these additional supplements are transferred by screw conveyors into a mixer. Approximately 16.9 tons per day of the raw mixture for each production unit can be obtained from 11.84 tons per day of organics. Finally, the mixture is elevated from about 0.5 m above the ground up to 4.5 m high by a drag conveyor in order to be distributed by a belt conveyor's arrangement to the available composting area. The third drag conveyor used for this is 7 m long and 0.6 m wide. It makes an angle of about 30 degrees to the horizontal. Again, the construction and dimension are very similar to the first and second drag conveyor, so that they are not only interchangeable but also the spare parts are easier to stock.

IV. COMPOSTING AREA

Composting technology keeps developing toward shorter fermentation period with the help of more effective inoculants (starters) which are useful for accelerating the decomposition of organic matter. Therefore, it is expected that compost plants will be more space efficient, because fermentation area and buildings can be smaller. Accordingly, other supporting equipments, such as distributing belt conveyors, can be smaller and cheaper. Consequently, a compost plant of certain product capacity that is erected today will be certainly too large in the future.

The fermentation area consists of six blocks where every two blocks belong to one production unit. The calculated 16.9 tons per day mixture of organic matters must be equally distributed and piled up in the availabe two blocks. Assuming that the density of organics is about 380 kg/m^3 (see Table 2) it can be estimated that the 16.9 tons per day occupy 45 m^3 in two blocks (or about 22.5 m^3 for each block). Raw materials obtained in the same day must only be piled up in the same place.

The mixture is piled up in layers of about 25 cm thick, while inoculants of about 2.5 cm thick are spread between the layers to initiate the fermentation. Up to five layers of organics can be stacked because in order to obtain good fermentation process the total maximum thickness of waste piles should be less than 1.5 m. The distance between each pile to its neighbors (the pile from the foregoing day) should be 1 meter to allow plant workers carry out necessary treatments such as regular watering, flipping over the speciment, etc. The mixing process through flipping over is intended to enable the inoculants to grow uniformly. A special equipment called „Bucket loader with gathering paddle screw" can be used for it. The total length of every fermentation unit depends on the number of piles. Meanwhile, the number of piles is dictated by the fermentation period. Each pile requires about 3 m (including 1 m free area between piles). Assuming a composting period is 30 days, then the number of piles is 33 (including three additional rows for spare space) and the overall length of the fermentation area is 99 m. Meanwhile, the width of each block should be 9 meter (which makes a total width of each unit to be 19 meter including a 1 meter free lane between the blocks)

The longest belt conveyor is installed in the area. Although it is 99 m long but most of the time its entire length is not fully utilized to transfer organics, because the flow of organics on the conveyor is purposedly blocked by a movable plate in a certain location. The movable plate is placed and secured at the position (depends on which day) so that the blocked flow of materials is forced to fall down to the right side or to the left side (depends on the direction of the plate and on which block organics should be poured) onto another belt conveyor which is perpendicular to the longest one. The mentioned belt conveyor is only 9.5 m long and 0.5 m wide. With the help of another movable plate the belt conveyor can evenly pour the organics on the fermentation ground to form a pile layer by layer.

The piles require regular daily watering to maintain the optimum humidity for the fermentation process. It should be considered as well, that the bins and the bulk of waste can discharge some leachate. The leachate can be collected through the existing sanitary system and mixed with water and then used for daily watering.

V. AUXILIARY EQUIPMENTS

A. Fine Cutting, Weighing and Packaging

After the fermentation process is completed, the product is transported into a storage house where it is chopped to a smaller size (about 5 mm) and stored in the form of bulk. Then some of the compost is loaded

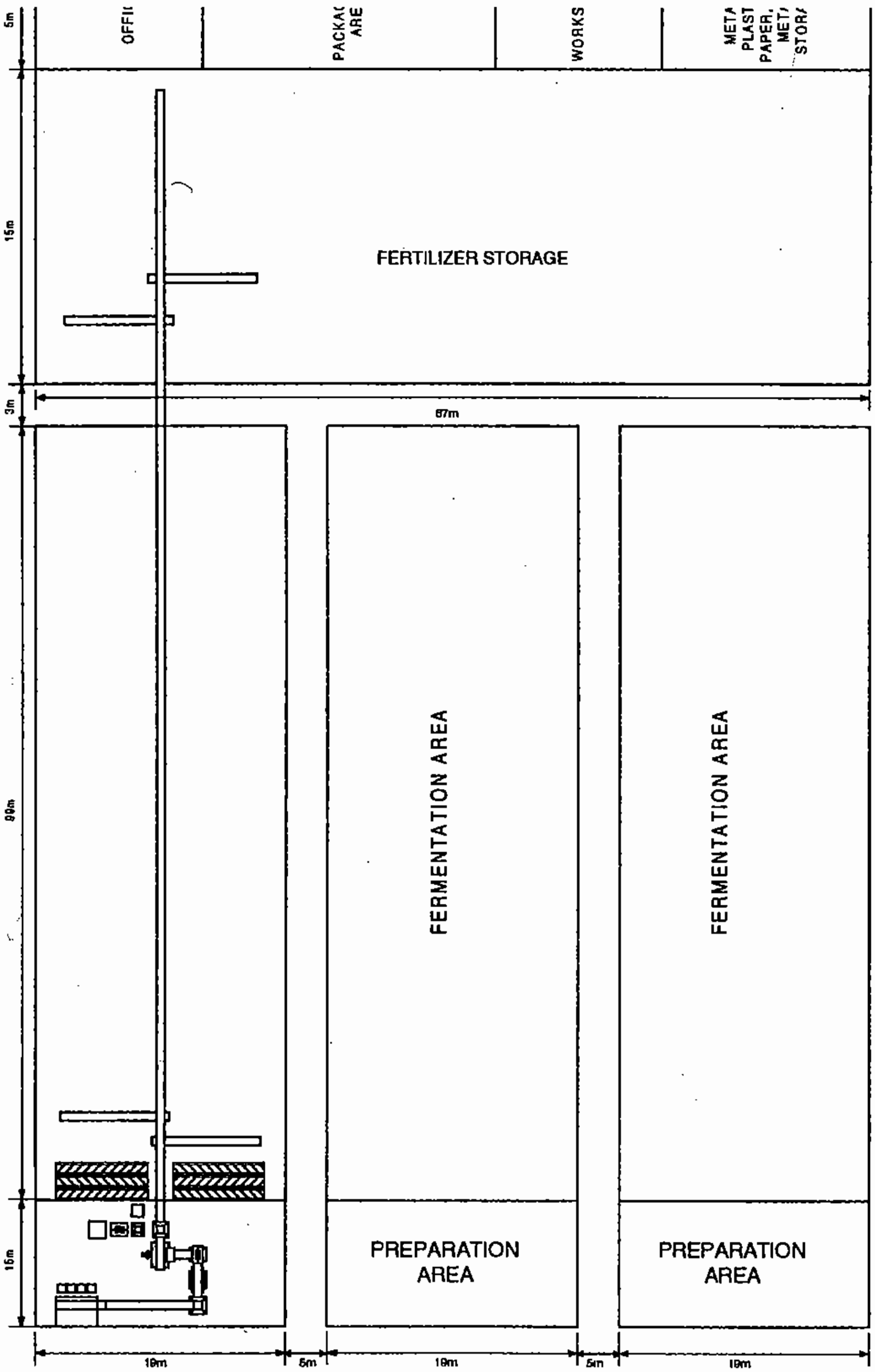

Figure 3. Composting Plant Area