# Developing a Technique for Organic Waste Composting at Engro


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**(BE in Chemical Engineering)**

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# Certificate

This is to clarify that work in this thesis has been carried out by Ahsun Ali, Waqas Ahmed Siddiqui and Abdullah Butt, and completed under my supervision at School of Chemical and Materials Engineering, National University of Science and technology, H-12, Islamabad, Pakistan.

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# Dedication

Dedicated to our beloved Ma'am Amna Chaudhry (late).

# Acknowledgements

Thanks to Almighty ALLAH who has helped us in our endeavor and gave us the ability to conclude this project successfully.

It is a genuine pleasure to express our deep sense of thanks and gratitude to our mentor and guide Dr. Erum Parvez, Assistant Professor chemical engineering department SCME; NUST. Her dedication and keen interest above all her overwhelming attitude to help her students had been solely and mainly responsible for completing our work. Her timely advice, scrutiny, scholarly advice and scientific approach have helped us to a very great extent to complete this project.

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# Contents

# List of Figures

# List of Tables

# Abstract

Engro is currently incinerating all the waste generated from its residential colony. Due to emission of hazardous and toxic gases, an environment friendly solution is required. Composting is that alternative which not only avoids the deleterious incineration method, but also yields a nutrient rich and marketable product—compost. Composting can be done in multiple ways but an efficient and cost effective solution is required that is suitable for Engro Colony Dharki to adopt.

# 1. Introduction

## 1. Background

Engro colony Daharki is found next to Engro fertilizer plant. Engro colony houses a population of 2,500. The residential colony generates a total of 3,600 pounds of waste every day that is disposed of by waste incineration. Waste incineration causes pollution of the environment. Air pollution is most dominantly a result. Ash residue from burning waste may pollute the land and water. This has overall bad effect on human health and environment. Engro Fertilizers is encouraged to change this waste disposal method by a environmental friendly process, Composting.

The aerial map below (figure 1.1) represents area of our interest. Green boarder marks the Engro colony area. All the waste of this colony is collected and sent to the incinerators as shown in the figure 1.1. Other than environmental concerns a problem Engro Colony

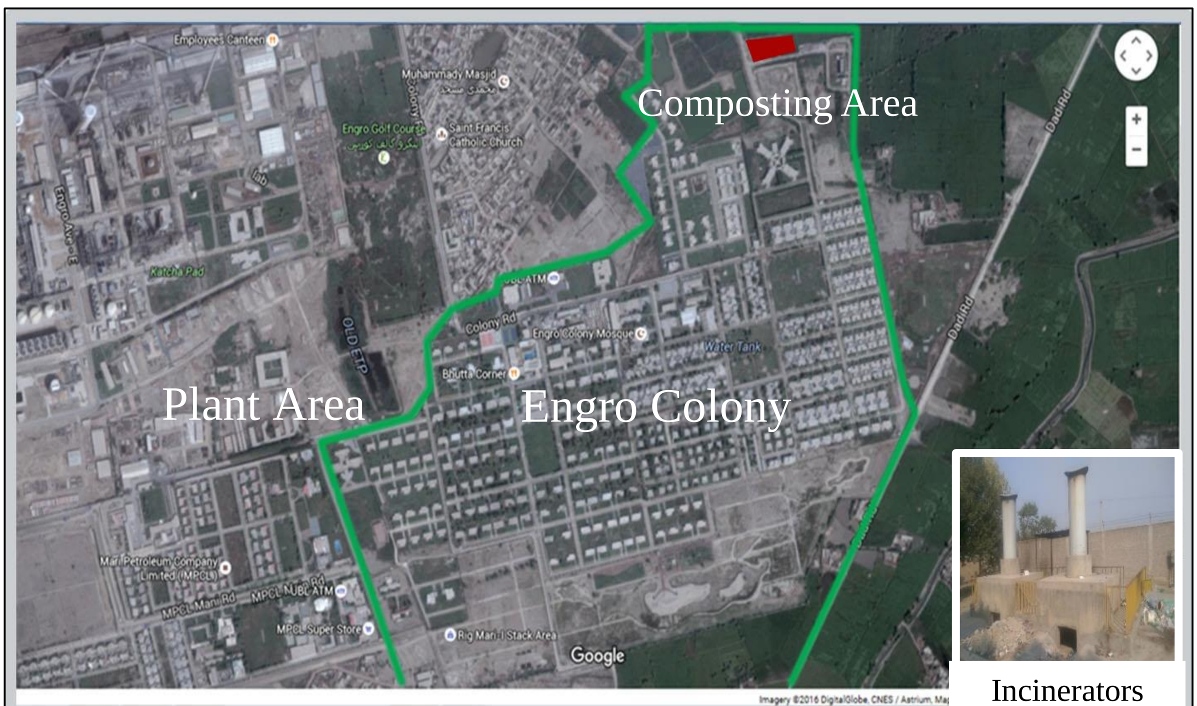



Figure 1.1: Birds eye view of Engro Fertilizers setup at Dharaki, (*google.maps)*

is facing is high moisture content of the waste that is to be incinerated. Due to presence of high percentage of organic food waste.   The red zone in the map marks the land available for composting.

## 1.2 What is Composting?

Composting is a natural and aerobic process of breaking down organic substances e.g. grass clippings, yard waste, food leftover, fruits & vegetables, sawdust etc. by using microorganisms such as protozoa, fungi and bacteria to simple carbon and nitrogen compounds which can be readily absorbed by plant soil if used as in farming.

Composting practices dates back to the Roman and Greek Empire. Over hundreds of years the process has improves. Traditional composting techniques were simple. Many farmers stack plant cuttings in a heap or pile. This is natural composting without any modern aid. The natural process may take more than a year to fully produce mature compost.

Nowadays Industrial composting practices are very common. Composting is being done for a large number of feedstocks: sewage sludge, manure, dead animal, food waste, yard waste, domestic waste (such as paper), industrial wastes, and military wastes. It is an exceptional method of disinfection of wastes. Bacteria, viruses, and parasites that resides within the waste are completely destroyed and becomes disinfected. If waste is properly composted it can be used for production of crops.

## 1.3 Advantages of composting

The advantages of developing compost

- Decomposes organic waste
- Environmentally beneficial process
- Reduces the need of landfills
- Produces a useable product compost that increases the fertility of soil

The numerous advantages of *using* compost are as followed

- Soil bulk density is reduced

- Increases the water holding, hence requires less irrigation of water. Improves water infiltration and drought tolerance.
- It has beneficial synergy when used with Chemical Fertilizer (more efficiency, less chemical fertilizer are required).
- Improves nutrients holding capacity of soil.
- Provides plants both with macronutrients of Nitrogen Phosphorus, and Potash (NPK) along with a number of micronutrients.
- Increases soil fertility and hence ease of cultivation.
- Improves root growth and yields.
- Protects plants from diseases.
- Reduces and kills weed seeds and degrades pesticides.
- Helps in reclamation of saline land.

# 2. Literature Review

Composting is a very broad technique and can span from as little as one month to up to two years. Therefore, it becomes imperative to use the apposite conditions to accelerate this process to commercialize and market compost as an agricultural product.

## 2.1 Basic Concepts of Composting

Following are some of the factors that are crucial to efficient composting process:

### 2.2.1 C/N Ratio:

C/N ratio means the ratio of total carbon present to the total nitrogen present. Normally, a C/N ratio between 20 and 40 is suitable for efficient composting. If it's too high, the microorganisms cannot utilize the carbon and break it down at a fast rate. In contrast to it, if the C/N ratio is too low, the microorganisms literally starve to death due to the lack of carbon diet and consequently anaerobic respiration starts. Due to anaerobic respiration, odor generates attracting parasitic flies and rodents.

### 2.2.2 Temperature:

Temperature is another basic parameter that contributes towards proper composting. There are two temperature zones in which the entire process occurs. The first, **mesophilic**, temperature range is prevalent in the starting and curing stage and spans from 20 to 45 degree Celsius. The second, **thermophilic**, is more short spanned and generally stays for two to three days. In the latter temperature range, all the pathogens and weed seeds are destroyed. In the former, the actual process of degrading complex organic substances occurs. Figure 2.1 shows the two temperature region and carbon dioxide respiration during composting.

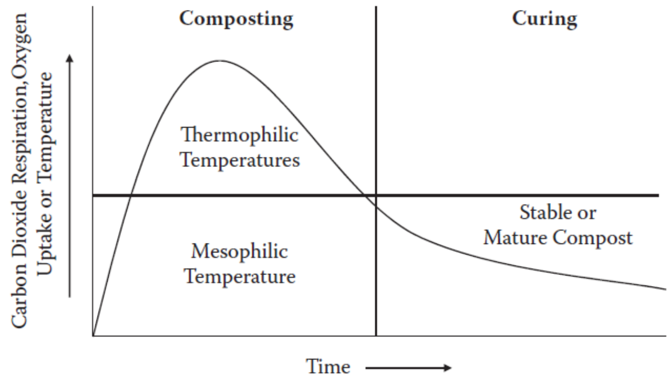



**FIGURE 2.1** Changes in temperature and carbon dioxide respiration during composting.

#### 2.2.3 Moisture Content:

Maintaining proper moisture is a difficult and an important task. If there is too little moisture, the microbes don't efficiently act on the feed and the entire process is delayed. The opposite i.e. too much moisture reduces the porosity of the feed and causes poor aeration. Normally, moisture is maintained between 40-65 % to ensure proper composting.

#### 2.2.4 Aeration:

Proper aeration is maintained to ensure there is surplus amount of oxygen present for the aerobic process to occur. If inadequate amount of air passes through the feed, the aerobic microbes will perish leading to anaerobic process. On the other hand, if too much air is passed, the temperature drops and pathogens may not be thoroughly killed leading to detrimental consequences if the finished product is used on plant soil.

### 2.2 Composing Facility

A composting facility is the site where composting process takes place.y. A proper facility planning is required to establish a well-design composting site. The following are the key factors that are needed to be addressed.

- Facility location and area
- Technology choice
- Environmental management, such as odor control
- Potential Market of final compost

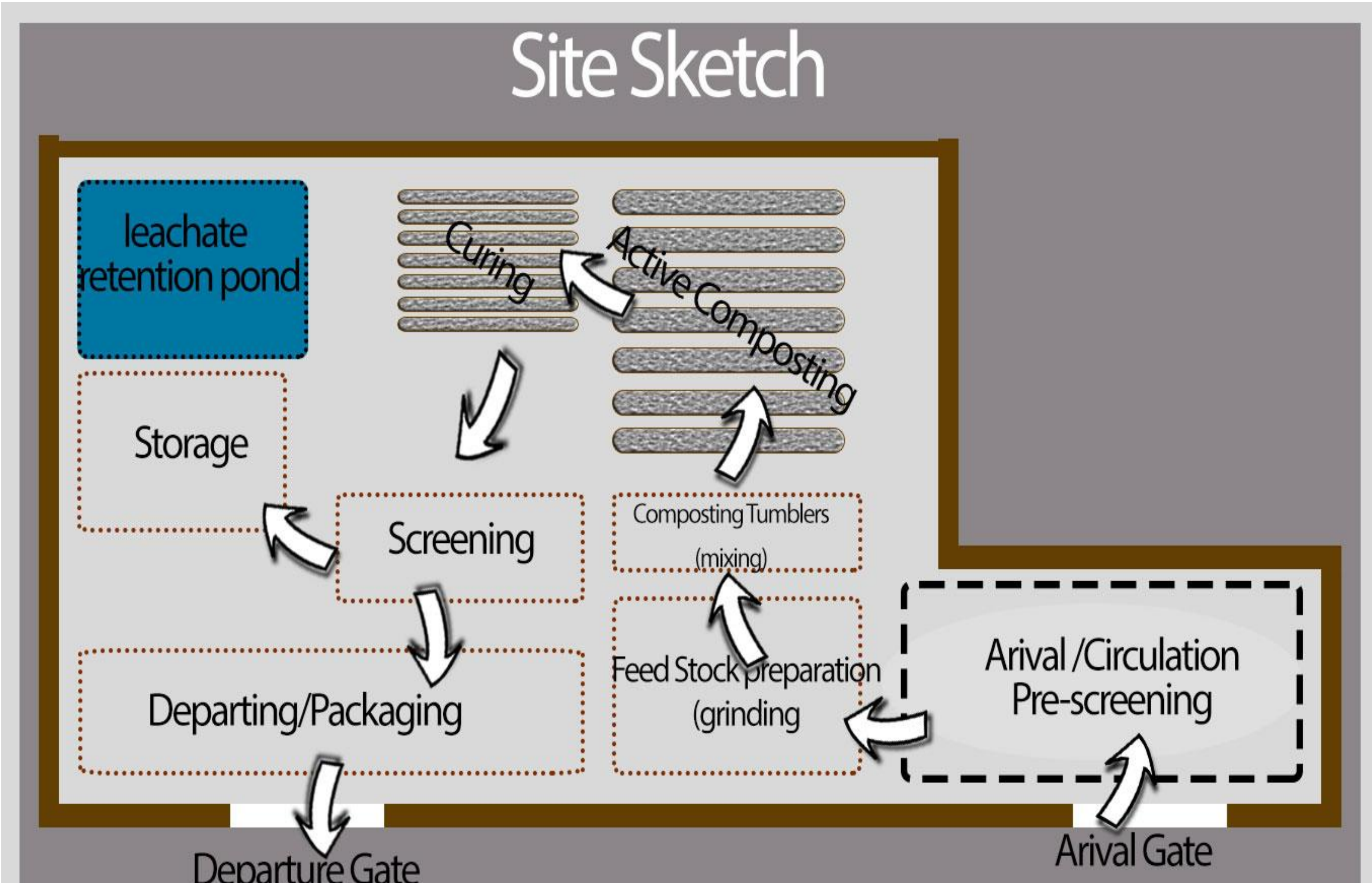



**Figure 2.2:** Composting Site Concept

The site sketch repersents concept of our composting sight. It is composed of several zone as described below.

### 2.2.1 Waste Arrival and Pre-Screening

Feedstock arrives at the site through waste trolleys that collect the waste from the colony. As it arrives it is pre-screened manually by labor. Chunks of plastics, metals, rubber and other non-compostable materials are handpicked and separated. The compostable waste is also sorted in one of the following category

- Food Scraps
- Paper
- Cardboard
- Yard Waste
- others

### 2.2.2 Feed Stock Preparation

Feed stock is prepared by using the right ratio of each category to give the optimum Carbon to Nitrogen ratio.  In this area testing of feedstock is also conducted. Testing include bulk density measurements, moisture content, PH and toxicity testing.

### 2.2.3 Composting Tumblers

After feedstock is prepared it is then send to our composting tumblers. These are rotating composting tumblers. It serves two primary function. First is mixing of the feed. Secondly it offers a more controllable environment to for active composting. The feed is kept here for 10 days ensuring that it is kept at the required temperature, moisture and oxygen.

### 2.2.4 Active composting

This area is composed of aerated piles for composting. Piles are sorted in to rows of specific width and length. Details are covered in the next topic.

### 2.2.5 Curing

After active composting, curing phase is required to achieve a stable product that is properly and thoroughly decomposed. The compost from active composting area is transferred to the curing area. Composted is piled and it is turned once a week.

### 2.2.6 leachate Retention pond

As most of the feed we are handling is very moist. Leachate will be released. The pond is designed to hold runoff from the entire composting area. This water has high pathogens that should not be allowed to seep into ground or mix with other water drainage system. A leachate retention pond is designed to hold any run off of leachate coming from either active composting area or curing area.

### 2.2.7 Screening

During screening, particle size is reduced to from 3 to 9.5 mm (0.125 to 0.375 inch) using rotary screening trommel. Screening is best achieved when the compost has a moisture content of 40 to 45%. At higher moisture contents, it is difficult to properly screen. At moisture contents below 40%, the material is dusty. In screening area, we are also refining our product by typically removes glass, metals, wood, film plastic, hard plastic, and other physical contaminants. Air classifiers can achieve separation along with magnets.

### 2.2.8 Storage Departing and packaging

Screen product is ready for use. It can be sent to storage or any other area for use.

### 2.2.9 Quality and testing

The following the final compost must be test and quality must fall in the following ranges

Final compost is test for presence of metals (property Table) and pathogens E.coil < 1000 MPN/g)

| | |
|---|---|
| C/N Ratio: | < 15 |
| Moisture: | < 75% (normal 5%) |
| Stones % of dry weight | <5% of <5 mm size |
| Plastics, glass, metals | <1% total |
| Odor free | Earthly smell |

# 3. Proposed Solution/Methodology:

## 3.1 Waste generation at Engro Colony

In order to estimate the daily waste we need to know the population of the Engro colony. The details for housing is given in the table "Colony Data Input". This data was given to us by Engro. We estimated that 532 houses of Engro colony will host about 2,500 people as shown by **Table 3.1:** Colony Data Input.

| **Table 3.1:** Colony Data Input | | | |
|---|---|---|---|
| *Colony Data* | *# of Houses* | *Average number of people per house* | *Total No. of people* |
| Employees | 340 | 5.0 | 1700.0 |
| Management | 146 | 4.0 | 584.0 |
| Others | 46 | 5.0 | 230.0 |
| Engro Colony (total) | 532 | 4.7 | 2482.67 |

Waste estimation: Estimated was of a person ranges from 0.5 lb to 2 lb per day (According to Government of Pakistan census average Pakistani produces 0.3 Ib to 1.3 lb per day) . For our better calculation we took the average waste generated by a person to be 1.433 lb per day. Likewise, the total population of Engro generates 3,558 lb waste/day. This include both compostable and non-compostable waste.

| **Table 3.2:** Daily waste produced | |
|---|---|
| Average waste (Ib/person) | Daily Waste produced (Ib/day) |
| 1.433 | 3557.666 |

Not all of the waste that is generated is compostable. However, to properly design our composting facility we need to estimate the compostable waste. The table below shows the composition for waste production of a house hold. Forexample, a house in engro management colony would generate 23.9% food scraps, 16.4% paper waste, 12.40% plastic waste and so on. “Rubber, Leather,Textile” , Plastics, Metals and glass are not well suited for composting. Hence in our calculation we only use those waste components that can be easily biodegraded. This waste was found out to be 1995.8 lb/day. Using bulk density of individual components, we also calculated the volume of waste that is generated daily.

| **Table 3.3: Typical Waste Generation** | | | | |
|---|---|---|---|---|
| **Typical Compostable Waste Production** | | | **Generation per day** | |
| **Feed Material** | **Waste Production* %** | Waste Prod. (lb/day) | Comp- waste (lb/day) | Vol Comp-Waste ($ft^3$/day) |
| **Food Scraps** | 23.90% | 850.3 | 850.3 | 47.2 |
| **Paper** | 16.40% | 583.5 | 583.5 | 32.4 |
| **Cardboard** | 2.00% | 71.2 | 71.2 | 7.9 |
| **Yard Waste*** | 13.40% | 476.7 | 476.7 | 39.7 |
| **Wood** | 0.40% | 14.2 | 14.2 | 0.7 |
| **Rubber,leather Textile** | 8.40% | 298.8 | 0.0 | 0.0 |
| **Plastics** | 12.40% | 441.2 | 0.0 | 0.0 |
| **Metals** | 9.00% | 320.2 | 0.0 | 0.0 |
| **Glass** | 4.60% | 163.7 | 0.0 | 0.0 |
| **Other** | 9.50% | 338.0 | 0.0 | 0.0 |
| Total | 100.00% | 3557.7 | 1995.8 | 128.0 |

## 3.2 Mass Balance

3.3.1. Mass Balance:

The process proposed by our group is inherently a batch process. This is because the feed used is not of constant composition and there are different operating conditions required for different constituents. The mass balance mainly involves determining the volume of all the organic matter present in the feed according to various classifications such as food, grass clippings, sawdust etc. the combined volume of all the mixture is then converted into mass by multiplying the individual volumes of organic matter with their respective bulk densities. The total mass represents the net weight of the entire mixture to be composted. There is a provision for entering the properties i.e. the bulk density, the volume, C/N ratio and the nitrogen percentage on dry basis of a substance that isn't present in the list shown in the figure. The mass balance has been conceived

**Table 3.4:**
**Compost Recipe( Volume & Mass of material coming in daily)**

| Material | Bulk Density($lb/ft^3$) | Volume($ft^3$/day) | Mass(lb/day) |
|---|---|---|---|
| Wood Chips | 20.0 | 0.7 | 14.0 |
| Straw | 8.0 | 0.0 | 0.0 |
| Corn Stalks | 1.0 | 0.0 | 0.0 |
| Food Waste | 18.0 | 47.2 | 849.6 |
| Paper (shredded) | 18.0 | 32.4 | 583.2 |
| Cardboard | 9.0 | 7.9 | 71.1 |
| Yard Waste | 12.0 | 39.7 | 476.4 |
| Grass Clippings | 20.0 | 0.0 | 0.0 |
| Leaves | 11.0 | 0.0 | 0.0 |
| Shrub Trimmings | 16.0 | 0.0 | 0.0 |
| Tree Trimmings | 48.0 | 0.0 | 0.0 |
| Paper Pulp | 52.0 | 0.0 | 0.0 |
| Other | 0.0 | 0.0 | 0.0 |
| Total | | **127.9** | **1994.3** |

to be able to handle any substance that is used for composting. The properties of commonly used substances have already been incorporated by literature review.

In order to achieve an efficient composting process, it is necessary to ensure certain parameters are in a suitable range. These parameters are:

- Bulk Density < 40 $lb/ft^3$
- C/N ratio between 20 & 40
- Moisture content between 40 & 65

The mass balance calculation process takes into account these parameters and the aforementioned parameters can be varied by adding appropriate amounts of bulking agents to bring these properties within the desirable range. The main worksheet also informs about the effects of adding various substances i.e. the change in C/N ratio, bulk density, moisture content. This information proves useful in combining the various organic substances to achieve the suitable compost feed.

**Table 3.5:** Component property Relation

| **Material** | **%Moisture** | **C/N Ratio** | **Bulk Density** |
|---|---|---|---|
| Food Waste | ↑ | ↓ | ↓ |
| Paper (shredded) | ↓ | ↑ | ↓ |
| Cardboard | ↓ | ↑ | ↓ |
| Yard Waste | - | ↑ | ↓ |
| Grass Clippings | ↑ | ↓ | ↓ |
| Leaves | - | ↑ | ↓ |
| Shrub Trimmings | ↓ | ↑ | ↓ |
| Tree Trimmings | ↑ | ↓ | ↑ |
| Paper Pulp | ↑ | ↑ | ↑ |
| **Bulking Agents** | **%Moisture** | **C/N Ratio** | **Bulk Density** |
| Wood Chips | ↓ | ↑ | ↓ |
| Straw | ↓ | ↑ | ↓ |
| Corn Stalks | ↓ | ↑ | ↓ |

**Table 3.6:** Material Properties

| Material | Moisture Content (%) | C/N | Bulk Density(lb/ft$^3$) |
|---|---|---|---|
| Wood Chips | 30 | 600 | 20 |
| Straw | 10 | 80 | 8 |
| Corn Stalks | 10 | 65 | 1 |
| Food Waste | 70 | 15 | 18 |
| Paper (shredded) | 20 | 155 | 18 |
| Cardboard | 10 | 565 | 9 |
| Yard Waste | 45 | 40 | 12 |
| Grass Clippings | 80 | 17 | 20 |
| Leaves | 40 | 54 | 11 |
| Shrub Trimmings | 15 | 53 | 16 |
| Tree Trimmings | 70 | 16 | 48 |
| Paper Pulp | 82 | 90 | 52 |

The C/N ratio, bulk density and the moisture content of the mixture is calculated by first by individually calculating the carbon content of each substance present, the amount of water present and the mass. Then, the cumulative properties (C/N, moisture content, bulk density) are calculated and displayed.

## 3.3 The composting process

Following are the major unit operations involved in the composting process.

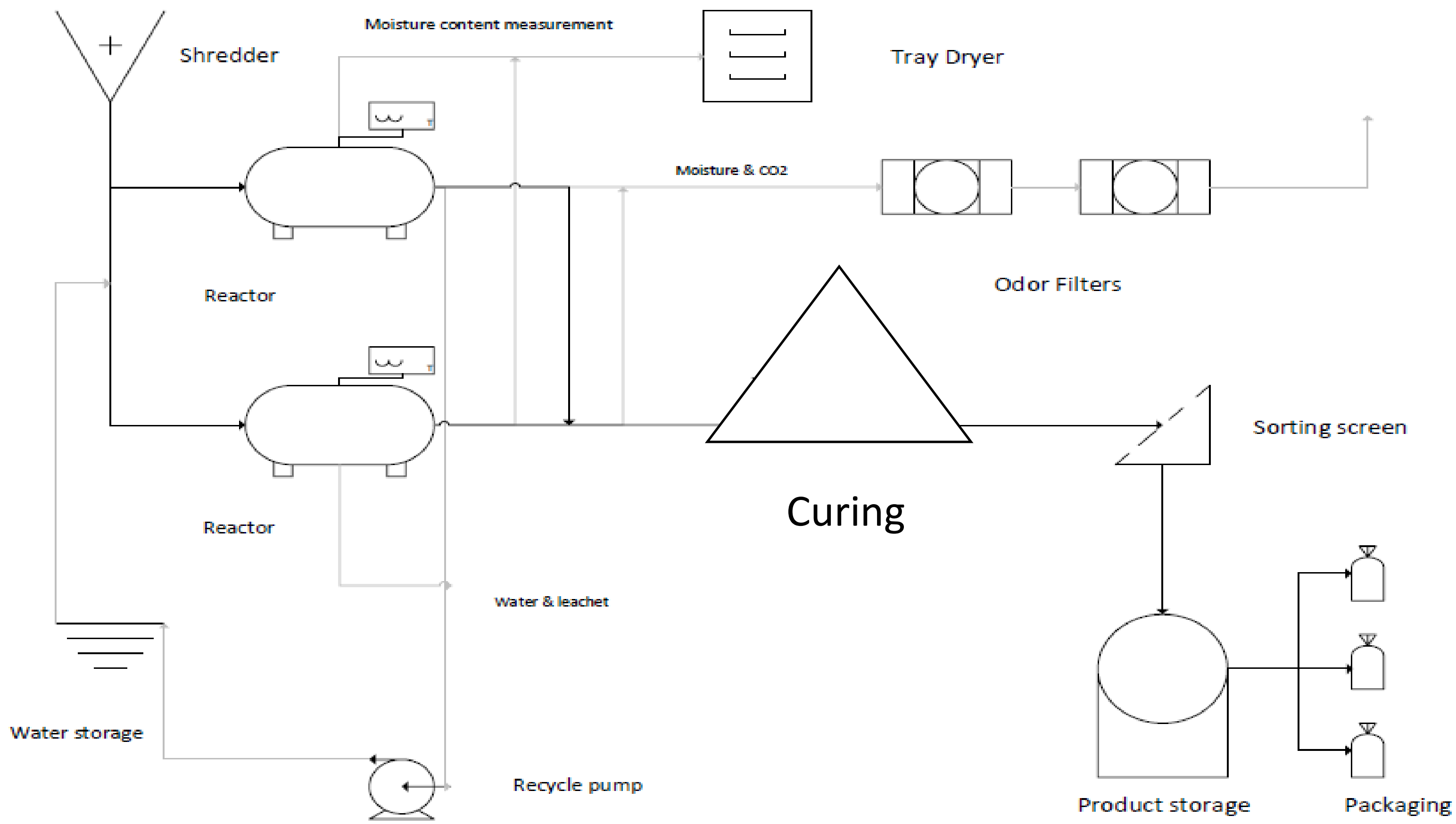



**Figure 3.1:** Process Flow Diagram of composting

### 3.3.1. Shredding:

In order to increase the surface area for the microbes to biologically degrade the organic waste generated, it is important to shred the waste coming to a smaller size. The shredder is the most energy intensive unit operation in this entire process. But, it also plays an instrumental in improving the efficiency of the entire process. The shredder has been sized to handle 150 kg/hr of feed. All the design parameters have been followed according to the usual design practices. The main parameters to be determined are:

- the driver power required to generate the required torque in the shaft on which, the cutting blades are installed.
- Determining the shaft diameter according to the torque generated. This is important to ensure that the shaft doesn't bend or break during service and is able to handle the applied load.

The power required has been calculated using the equation [1]:

$$\mathbf{P_R = P * f_c}$$

$P_R$ = Required power(KW)

P= Power of the motor/turbine(KW)

$f_c$= correction factor

The power of the motor used in this equation has been adopted from the commercial shredders used for shredding MSW. The correction factor has been determined from literature. In order to determine the torque generated by the motor, the following equation is used [1]:

$$\mathbf{T = 9.74 * 10^5 * P_R / n}$$

T = torque generated (Kg.mm)

$P_R$ = required power (KW)

n = RPM

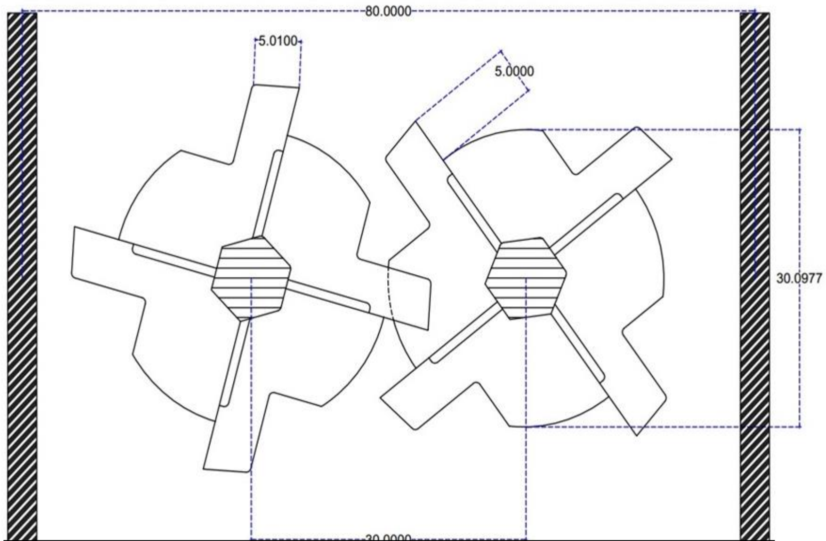



**Figure 3.2:** Shredder design

Again, the rpm used in this equation has been adopted from the conventional shredders used for MSW. From the torque calculated, the shaft diameter is calculated. There will be a set of two shafts one rotating clockwise and the other one rotating anti-clock wise. This shaft set will be connected to the driver. It must be noted here that the power calculated is sufficient to drive both of these cutter fitted shafts. The shaft diameter has been calculated using the following equation:

$$\mathbf{D = [\, 5.1 / \tau \, * f_d * f_T * T \,]^{1/3}}$$

D = Diameter(mm)

$f_d$ = Deflection factor

$f_T$ = Torque factor

T = Torque (kg.mm)

The design details along with the sizing calculations are shown below.

| Table 3.7: Shredder Design | | |
|---|---|---|
| Driver power | 160 | kw |
| RPM | 32 | |
| Torque | 5844000 | kg.mm |
| correction factor | 1.2 | |
| Power required | 192 | kw |
| shaft diameter | 300.96034 | mm |
| shear stress (avg.) | 2.46 | kg/mm^2 |
| cutter outward projection | 5 | cm |
| Total width | 80 | cm |
| cutter width | 5 | cm |
| distance b/w cutter | 8 | cm |
| Total length | 130 | cm |

The shredder will have ten cutters longitudinally with cutters of one shaft filling the gap between the two cutter of the other shaft. The shredder has been sized to handle even the toughest feed.

### 3.3.2. Tumbler/Reactor:

After the feed for composting is to be determined, the mixture is put into the tumbler for accelerating the natural decomposition process. The tumbler is rotated manually in the proposed design mainly to reduce operational expenditures. Air is blown through the cylindrical tumbler to provide ample oxygen for the aerobic process. The tumbler has been sized to minimize surface area for the handled volume. This reduces the material requirements and ultimately the cost. The surface area has been calculated using calculus.

Volume of feed handled daily (approx.): 126 $ft^3$

Residence time of feed in tumbler according to standard practices: 10 days

Total volume to be handled = 126 * 10 = 1260 $ft^3$

Number of tumblers = 5

Volume of each tumbler required = 1260/5 = 252 $ft^3$

Now,

**Volume of cylinder = $\pi r^2 h = 252$**

**Surface area = $2\pi rh + 2\pi r^2$**

**$H = 252/\pi r^2$**

**Surface Area = $2\pi r\,(252/\pi r^2) + 2\pi r^2 = 504/r + 2\pi r^2$**

Differentiating the surface area with respect to the radius, the equation becomes:

$dA/dr = -504/r^2 + 4\pi r$


Figure 3.3: Tumbler model

For extreme points, put the derivative of surface area equal to zero, after simplifying, the radius comes out to be:

**Radius = 3.422 ft**

By putting the value of radius in the expression for height, the height comes out to be:

**Height = 6.85 ft**

Thus, using calculus, the minimum surface area is obtained for a cylinder when the ratio of height to radius **is 2 to 1.**

Using our calculation, we had also designed and prepared a model for the tumbler composter as shown in figure 3.3. It is composed of a tumbler that has lovers inside it that allows proper mixing for the waste. A heated fan system is also provided to control the temperature of the compost inside the tumbler. To achieve the temperature as required in the mesophilic we turn on the heater. If we want to decrease the temperature, we simply turn on the fan without the heater to remove the heat from the tumbler. The heat calculations and the energy inputs were found using HYSIS (figure 3.4 -.6).

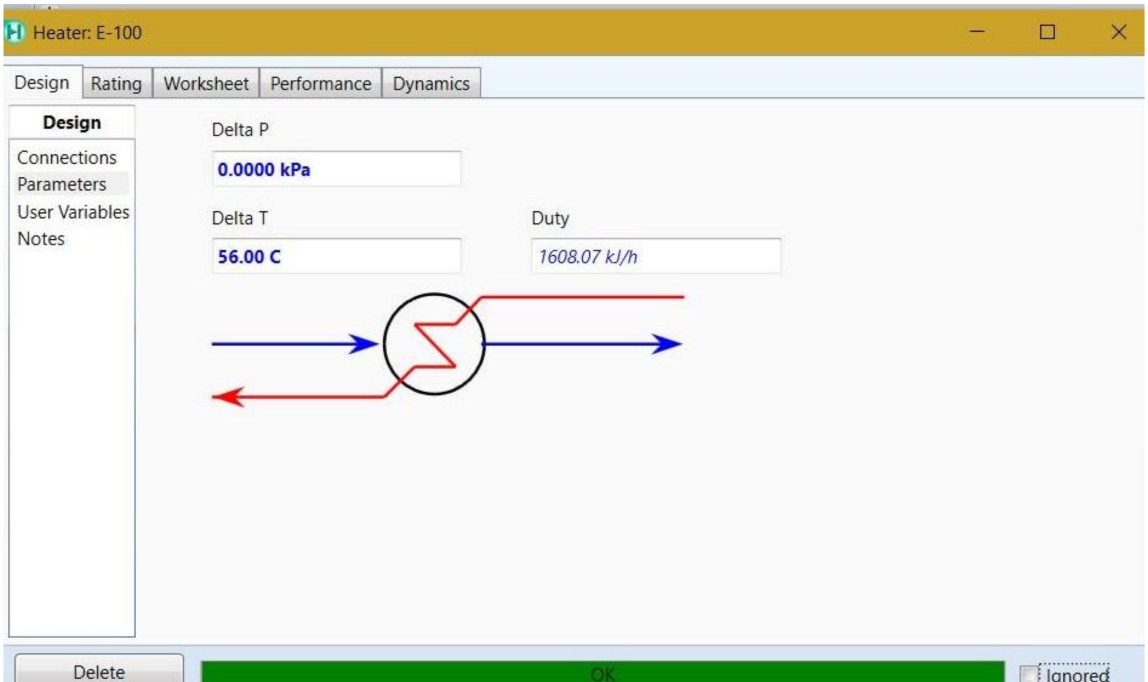



**Figure 3.4:** Heat duty

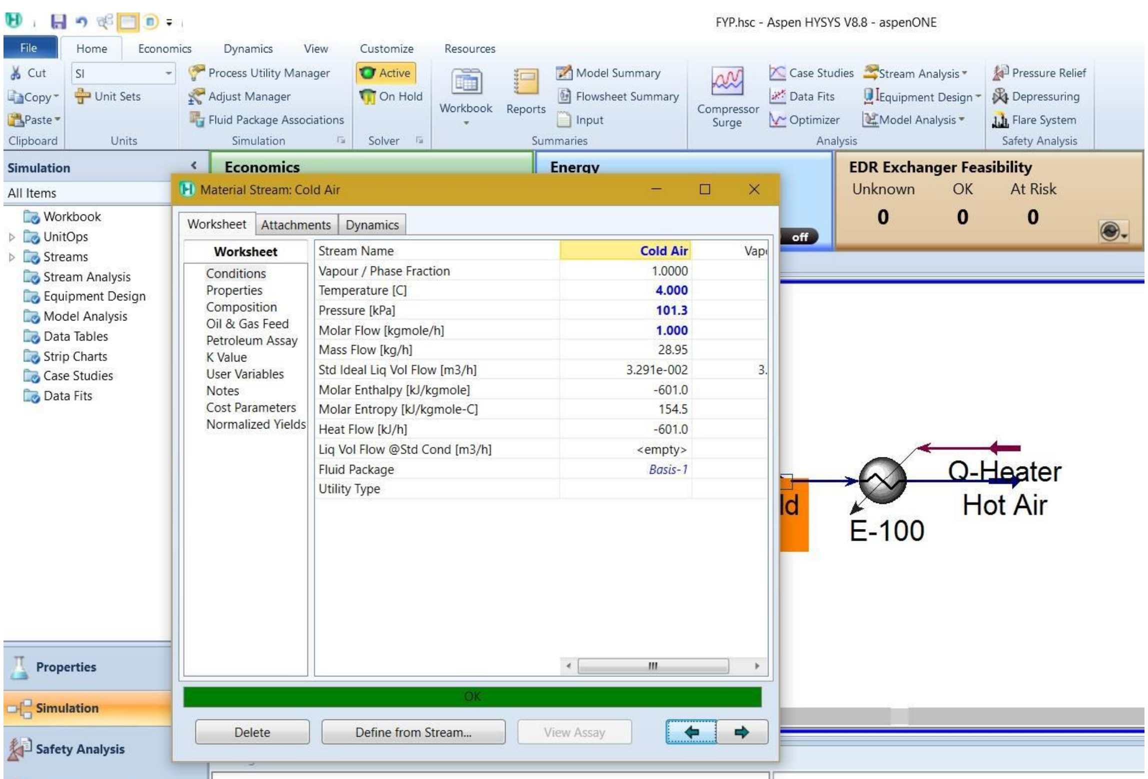



**Figure 3.5:** Inlet steam

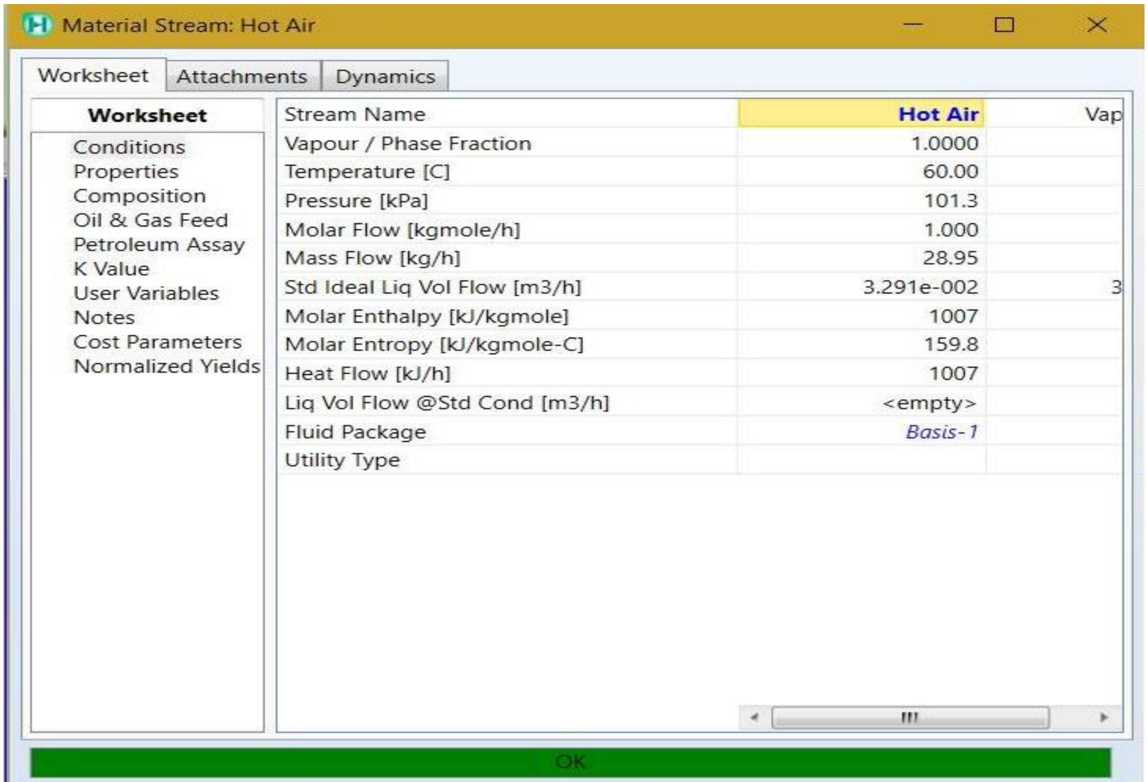



**Figure 3.6:** Outlet stream

The rate of aeration in the tumbler is the same as in the static aerated piles explained below.

### 3.3.3. <u>Area & Volume calculations for Static aerated piles:</u>

After the tumbler and before sending the compost over to the sorting screen, the tumbler output is stored in the form of cells to complete the decomposition process. The cells are provided with perforated pipes which are perpendicular to the length of the cells. The perforated pipes are connected to blowers which provide the air necessary for the aerobic process occurring. The dimensions of the cells are subject to availability of land area specified for composting. However, in the proposed design, the cell length and width can

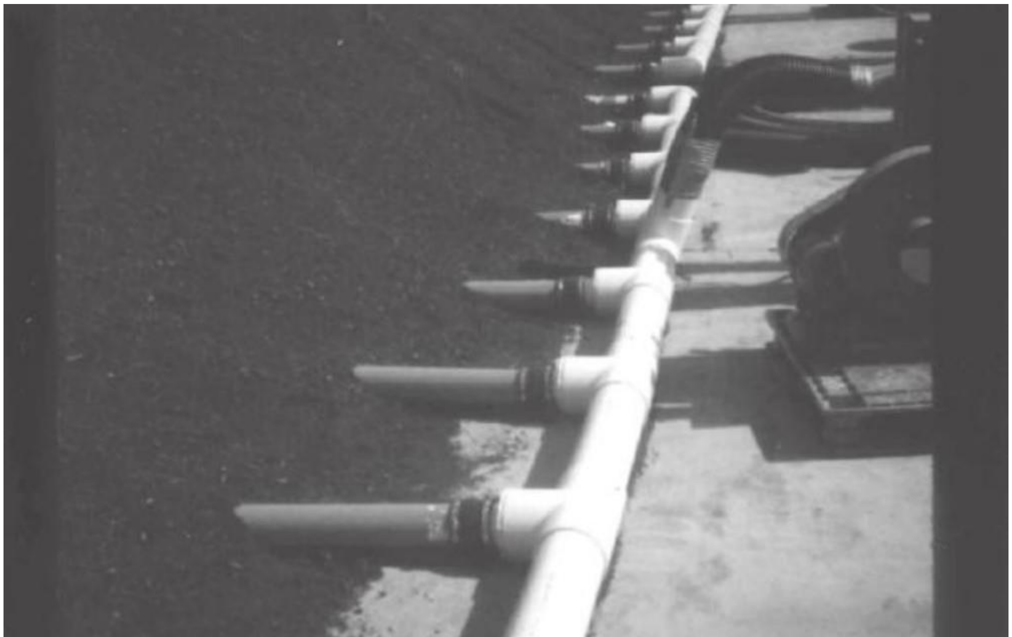


Figure 3.7: Aerated Static Pile

be varied according to area available. By standard practice, the height of the cell equals the width. The time of storage in the form of static aerated piles can be specified as well. The calculations made determine the total volume of feed and the cells and provides the number of cells required. It must be noted here that the number of cells can come out to be in decimals. However, if it does happen, the number of cells should be rounded off to the nearest whole number in order to maintain simplicity in the formation of cells.

| **Table 3.8: Static Aerated Pile Volume & Aeration Calculations** | | |
|---|---|---|
| **cell length** | **25** | ft |
| **cell width** | **4** | ft |
| **cell height** | **4** | ft |
| **composting period** | **30** | days |
| Distance b/w cells | 5 | ft |
| Access Distance | 15 | ft |
| **Total volume** | **127.9** | $ft^3$/day |
| **Cell volume** | 400 | $ft^3$ |
| **cells required** | 0.31975 | 1/day |

For the aeration requirement, certain rules of thumb have been adopted in order to simplify calculations. These adoptions play a trivial role in the overall design and can be used from literature directly. As already mentioned, the perforated pipes are perpendicular to the length of cells so that a single length of a pipe will pass through multiple cells.

Air flowrate required (approx.) = 130 $m^3$/tonne.hr

Pipe diameter = 6 inch

Distance between pipes = 6 inch

Length of pipe = dependent on the number of cells

Pipe perforation spacing = 4 inch

Perforation diameter = $(\text{pipe dia.}^2 * \text{hole spacing/ pipe length} * 12)^{1/2}$

From the above equation, the perforation diameter can be calculated for any length of the pipe. However, in general industrial practice, the length is specified and the perforations made before commissioning.

The volumetric flowrate of the air is calculated by the mass of the output coming out of the tumbler. The total land area required for the entire period of the static pile configuration is determined by simply multiplying the area required for the output of the tumbler each day by the total days for which the cells are to be made.

| **Table 3.9:** Aeration Requirement for cell | | |
|---|---|---|
| Pipe diameter | 6 | inch |
| dist. b/w pipe | 6 | inch |
| length of pipe | 2.87775 | ft |
| hole spacing | 4 | inch |
| **hole diameter** | **5** | **inch** |
| **Air volume required** | **430.8287** | $M^3$ /hr |
| **Standard blower volume rate** | **138** | $M^3$ /hr |
| **Total Blowers Required** | **3** | |

| After tumbling pile sizing & Aeration per day's feed | | |
|---|---|---|
| | | |
| cell width | 4 | (Typically b/w 4-6 ft) |
| cell height | 4 | Equal to width |
| composting period | 30 | (At most 30 days) |
| | | |
| Aeration Required | 515.2 | $M^3$ /hr |
| Standard Blowers req. | 3 | |
| | | |
| Total Area Required for composting period mentioned | 10125 | $ft^2$ |

### 3.3.4. **Area & Volume calculations for Curing piles:**

Similarly, we calculated the require area for curing phase. The curing phase usually lasts for 30 days. For 30 days we found the "total volume of curing compost" to be 1918.5 ft3 (table below). For pile height of 4 ft, width of 8 ft and length of 25 ft, we calculated the required no of rows and the area required.

*Volume of pile= 2/3 Length x Width x Height*

| **Land Area requirement calculation** | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| Total area occupied per cell | 225 | $ft^2$ | | | | |
| | | | | | | |
| Total Area required per day feed | 337.5 | $ft^2$ | | | | |

*Area of surface= Length x Width*

The table shows the results of our calculation. The total area require for curing is 844 ft2.

| **Table 3.10 :** Curing Pile Volume Calculations | | |
|---|---|---|
| Vol of curing compost | 63.95 | ft3/day |
| total volume of curing compost | 1918.5 | ft3/curing period |
| Height of Curing row | 4 | ft |
| Width of Curing row | 8 | ft |
| length of Curing row | 25 | ft |
| distance b/w rows | 5 | |
| no of rows | 3.597188 | |
| Required Area | 844.4375 | ft2 |

### 3.3.5. **Area & Volume calculations for storage piles:**

Method used was same as for curing. Results are shown below.

| **Table 3.11:** Storage Pile Volume Calculations | | |
|---|---|---|
| Storage Phase time | 90 | days |
| Vol of curing compost | 63.95 | ft3/day |
| total volume of curing compost | 3837 | ft3/curing period |
| Height of Curing row | 8 | ft |
| Width of Curing row | 12 | ft |
| length of Curing row | 25 | ft |
| distance b/w rows | 5 | |
| no of rows | 2.398125 | |
| Required Area | 844.4375 | ft2 |

### 3.3.6. **Leachate Detention Pond Design:**

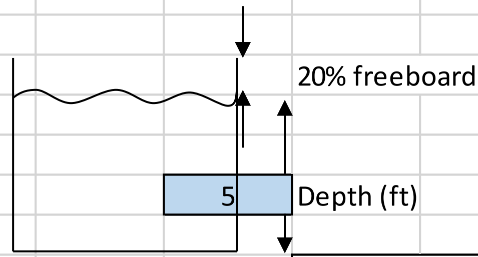
The pond is designed to hold runoff from the entire composting area. In order to calculate the require volume and surface area we used the following formulas.

*Pond Volume ($yd^3$) = 1.2 (depth) * 1/2 Annual Rainfall (in) * (1 ft / 12 in) * Pad Area (ft2) * (1 yd3 / 27 ft3)*

*Surface Area (ft2) = (Pond Volume * (27 ft3 / 1 yd3)) / Pond Depth*

Inputs are results are ase followed

Figure 3.8 **Leachet Detention Pond Calculations**




| | | | | |
|---|---|---|---|---|
| | | | total Depth (ft) | 6 |
| *Mean annual precipitation (in)* | | 10 | in | |
| Pond volume | 9617.969 | ft3 | | |
| S.A | 1602.995 | ft2 | | |

### 3.3.7. **<u>Screening design:</u>**

Area required is same as for storage

| Land Required for screening/strorage period | | |
|---|---|---|
| Land Required for storage/screeing | 844.4375 | ft2 |

For our operations the screening capacity required was 48 ft3/hr. We found the following model trammel screen to be suitable for our purpose. It is also able to handle larger amounts of feed.

| **Table 3.12:** Screening | | | Vol of cured pile / number of hour avaiable for screening per week | | TROM 406 |
|---|---|---|---|---|---|
| Require Capacity | 47.9625 | ft2/hr | | | |
| Company | Model | | Type of Screen | Capacity (ft3/hr) | Cost |
| USA Screen | TROM | | Trommel | 200 | 3,000,000 |

### 3.3.8. PUMP deisgn:

We will use a centrifugal pump for leachate handling as there will be solid particles present in the water. Therefore centrifugal pumps are best to handle these types of fluids. They use the centrifugal force to convert electrical energy to kinetic energy of the water.

There are 6 parts of pump:

1. **Impeller**
2. **Casing**
3. **Shaft and bearing assembly**
4. **Shaft sleeve**
5. **Shaft seal**

Impeller can be made by using an elastomeric or high chrome material as there will be solid particles so impeller should be strong enough to reduce wear and tear. Casing shape is semi-volute or concentric and casing halves of cast containing wear lines to make it operate under high pressure conditions. The diameter of shaft should be large with short overhung to reduce vibration. Corrosion resistant sleeves with mechanical seals protect the shaft at both ends.

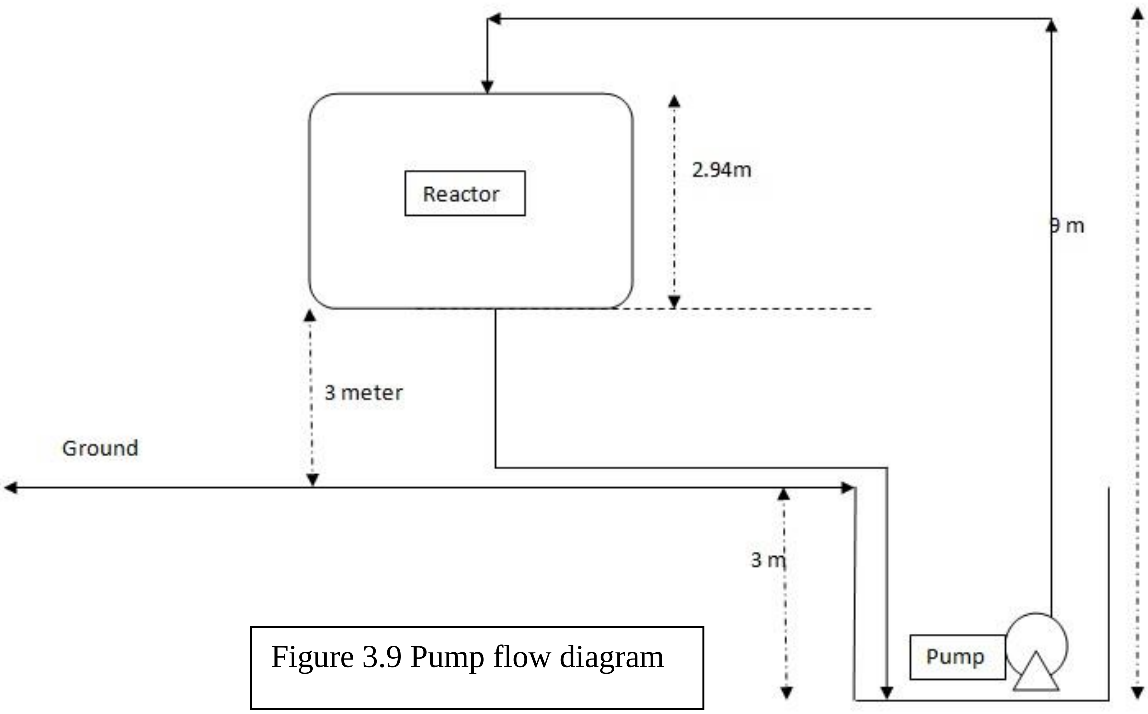


Figure 3.9 Pump flow diagram

We will use energy balance equation for the calculation of work and power of the pump.

Assumptions:

Consider the depth of the storage pond for leachate is 3 meters. Also consider the height of the reaction vessel from the ground level is 3 meters. Consider the outflow of the leachate from the pump is 2 cubic meter per seconds. Length of pipe above vessel is 0.6 meter.

## DATA:

SUPPOSE: V= 2 $m^3/s$

$Z_1$= 0

Total volume of feed calculated = 60$m^3$

We are making three equal sized vessels = 20 $m^3$

Radius of each vessel = 1.47 m (calculated)

Dia of each vessel = 2×1.47 = 2.94m

$Z_2$= height of the vessel above the ground + diameter of the vessel + depth of the pond

= 3 + 2.94 + 3 + 0.6 = 9 m

$\Delta$P = 0

$\rho$ = 998.2 kg/m$^3$

g = 9.8 m/s$^2$

Equation used:

$$\frac{\Delta P}{\rho g} + \Delta z + \frac{v^2}{2g} + w = 0$$

By putting the values of the variables and constants we have

W = 11.78 watt

Now for power we will use the formula

$$P = \frac{\dot{m} \times w}{\eta}$$

where

$$m =^{\cdot} \rho v d \text{ a}$$

**Required Head:**

$$\frac{\Delta P_f}{\partial} - \frac{\Delta P}{\partial} - \Delta z = Required\ Head$$

$$\Delta P_f = 4fL\,\partial\,u^2/D_i$$

Roughness = 0.046mm

Relative roughness = $(0.046 \times 10^{-3})/\ 0.0254$

= 0.0018

Friction factor = f = 0.00285

As there are four standard 90 degree elbows are being used so it will be equivalent length slightly more than the original one

$L = 12.6 + 4\times40\times10^{-3}$

L = 12.604 m

Velocity = u = V/A

Velocity = u = 3.94 m/s

Reynolds number = $Re = \frac{\partial uD}{\mu}$

Re = 11253.7

By putting the values in the formula we will get:

$$\Delta P_f = 87660.22\ n/m^2$$

Head = 87660.22/ (998.23×9.8) – (-9)

Head = 17.94 m

NPSH = $P/\rho g + H - P_f/\rho g - P_v/\rho g$

Here we have H = 0 m because pump is at bottom and at suction level height is zero.

P = 1 atm

$P_v$ = 23.8 torr = 3173.72 n/m$^2$

NPSH = 1.08m

$$g\Delta z + \Delta P/\rho g - \Delta P_f/\rho g = w$$

w = (-9) ×9.8 – 8.96×9.8

w= -176.008 J

$$P = \frac{\dot{m} \times w}{\eta}$$

η = 0.6 for pumps

m = 1.99 kg/s

w = 176.008 joule

by putting the values

P = 583.76 watts

# 4. Results

## 4.1 Facility Design

Engro had already specifed area for its composting activits. Using “google maps” we calculated the area of this land, that was found out to be 9.9 kanal. This area proves to be enough for composting activities.


Figure 4.1: Site area Calculations

Table 4.1 tablulates the results of all the areas required for cetain composting activity. The total area that is required os 7,600 ft square. However since the area avaiable to us is much more then this we have rescaled out site design accordingly to accommodate any changes in feeds. Our plant will be able to run 7 times more feed then that is generated in engro. The cost of upsizing is relatively less because there is not much investment required to build up compost piles. Main cost is assiated with shredderr and other machenical equipments.

| **Table 4.1: Required Area** | **Minimum Area ft2** |
|---|---|
| Active Composting Area | 2158 |
| Curing Area | 1169 |
| Screening | 1019 |
| Storage | 1019 |
| Leachate Detention Pond | 2235 |
| Total | 7600 |

We have generated an excel file that will automatically calculated the required area sizing and properties for the feed . Table 4.1, 4.2 and 4.3 gives such results for our current sample.

**Table 4.2: Material Characteristics**

| Material | Moisture Content(%) | Water mass(lb/day) | C/N | Nitrogen Content(% | Nitrogen mass(lb/day) | Carbon mass(lb/day) | Total mass(lb/day | Volume(ft $^3$/day) | Bulk Density(lb/ft$^3$ |
|---|---|---|---|---|---|---|---|---|---|
| Wood Chips | 30.0 | 4.2 | 600.0 | 0.1 | 0.0 | 2.0 | 14.0 | 0.7 | 20.0 |
| Straw | 10.0 | 0.0 | 80.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 8.0 |
| Corn Stalks | 10.0 | 0.0 | 65.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 |
| Food Waste | 70.0 | 594.7 | 15.0 | 2.4 | 6.1 | 91.8 | 849.6 | 47.2 | 18.0 |
| Paper (shredded) | 20.0 | 116.6 | 155.0 | 0.2 | 0.9 | 144.6 | 583.2 | 32.4 | 18.0 |
| Cardboard | 10.0 | 7.1 | 565.0 | 0.1 | 0.1 | 36.2 | 71.1 | 7.9 | 9.0 |
| Yard Waste | 45.0 | 214.4 | 40.0 | 1.8 | 4.7 | 188.7 | 476.4 | 39.7 | 12.0 |
| Grass Clippings | 80.0 | 0.0 | 17.0 | 3.4 | 0.0 | 0.0 | 0.0 | 0.0 | 20.0 |
| Leaves | 40.0 | 0.0 | 54.0 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 11.0 |
| Shrub Trimmings | 15.0 | 0.0 | 53.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.0 |
| Tree Trimmings | 70.0 | 0.0 | 16.0 | 3.1 | 0.0 | 0.0 | 0.0 | 0.0 | 48.0 |
| Paper Pulp | 82.0 | 0.0 | 90.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 52.0 |
| Other | 25.0 | 0.0 | 30.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Total** | **47.0** | **937.1** | **39.1** | **1.1** | **11.8** | **463.2** | **1994.3** | **127.9** | **15.6** |

Table 4.3 Feed property

| **Bulk Density (Net)** | **C/N (Net)** | **Moisture Cont.** |
|---|---|---|
| **15.6** | **39.1** | **47.0** |

Figure 4.2 is the final purposed plant layout for our technique of composting. Waste arrives at “Feed Arrival and hand screening” area. When the feed is hand sorted for non-biodegradable material.

Feed preparation area: feed is shredded and right proportion of waste components are added to give the appropriate Carbon to nitrogen ratio, moisture content and bulk density.

Waste is decomposed in the composting areas: Tumbling Composter, Active Composting and Curing Area.

Mature compost is screen and departed or stored.

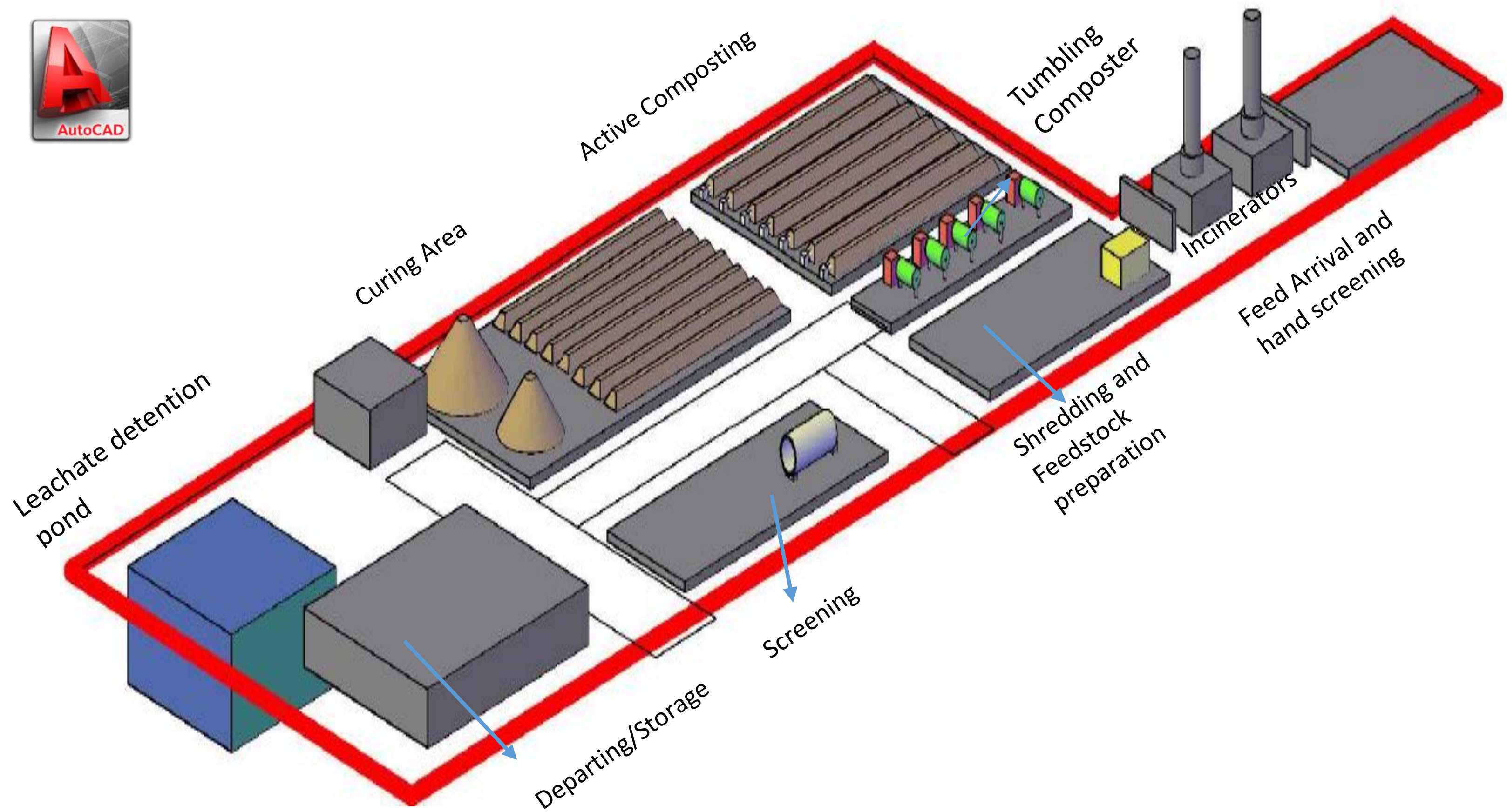



Figure 4.2: Engro Composting Facility Layout

## 4.2 Costing and Project Evaluation

The method we use for costing is **Detailed factorial estimates.** (Richard and Coulson vol.6)

### 4.2.1 The Purchased Equipment cost

Table 4.4

| Equipment Cost | | | | | |
|---|---|---|---|---|---|
| **Equipment** | Company | Model | Type | quantity | Purchased Cost |
| Shredder | SUNY | ZY-SS800 | organic waste shredder | 1 | PKR 2,000,000.00 |
| Bedminster | Custom | Custom | Platic | 5 | PKR 10,000.00 |
| Pump | OLDEN WATER PUMP | DD 1600 | Centrifugal Pump | 1 | PKR 4,500.00 |
| Blowers | | | Virtual Sun 6" Inline | 3 | PKR 6,000.00 |
| Screening | USA Screen | TROM 406 | Trommel | 1 | PKR 3,000,000.00 |
| Tractor | Massi-260 | Massi-260 | with bucket | 1 | PKR 800,000.00 |
| | | | | total | PKR 5,872,500.00 |

The total purchased cost of equipment is Rs 5,872,500.

We Calculate the total physical plant cost (PPC), using the factors given in Table 6.1

$$PPC = PCE\ (1 + \text{sum of PEC factors})$$

| Table 4.5: Physical Plant Cost | |
|---|---|
| Operation | PEC factors |
| Equipment erection | 0.2 |
| Piping | 0.1 |
| Electrical | 0.1 |
| Buildings, process | 0.05 |
| Utilities | 0.1 |
| Storages | 0.25 |
| Site development | 0.05 |
| Ancillary buildings | 0.01 |
| Total | 1.86 |
| PPC | PKR 10,922,850.00 |

Physical plant cost or the capital investment required was found to be 10,922,850 Rs. This include the cost of set up equipment, utilities , piping , storages, developing site and other ancillary buildings.

Table 6.1. Typical factors for estimation of project fixed capital cost

| Item | Process type: Fluids | Fluids–solids | Solids |
|---|---|---|---|
| 1. Major equipment, total purchase cost | PCE | PCE | PCE |
| $f_1$ Equipment erection | 0.4 | 0.45 | 0.50 |
| $f_2$ Piping | 0.70 | 0.45 | 0.20 |
| $f_3$ Instrumentation | 0.20 | 0.15 | 0.10 |
| $f_4$ Electrical | 0.10 | 0.10 | 0.10 |
| $f_5$ Buildings, process | 0.15 | 0.10 | 0.05 |
| * $f_6$ Utilities | 0.50 | 0.45 | 0.25 |
| * $f_7$ Storages | 0.15 | 0.20 | 0.25 |
| * $f_8$ Site development | 0.05 | 0.05 | 0.05 |
| * $f_9$ Ancillary buildings | 0.15 | 0.20 | 0.30 |
| 2. Total physical plant cost (PPC) $\text{PPC} = \text{PCE}\,(1 + f_1 + \cdots + f_9)$ | | | |
| $= \text{PCE} \times$ | 3.40 | 3.15 | 2.80 |
| $f_{10}$ Design and Engineering | 0.30 | 0.25 | 0.20 |
| $f_{11}$ Contractor's fee | 0.05 | 0.05 | 0.05 |
| $f_{12}$ Contingency | 0.10 | 0.10 | 0.10 |
| Fixed capital $= \text{PPC}\,(1 + f_{10} + f_{11} + f_{12})$ | | | |
| $= \text{PPC} \times$ | 1.45 | 1.40 | 1.35 |

*Omitted for minor extensions or additions to existing sites.

### 4.2.2 Operating cost

Please note that there are no acquiring and delivery cost of martials involved. The feedstock is simply free of cost.

The table below gives the requires costs to calculate the operating cost.

| | | |
|---|---|---|
| **Cost of compost (PRK/Ib)** | | 20 |
| **Labour Cost per hour** | PKR | 75.00 |
| **Available Labour hour per week (hr)** | | 40 |
| **electricity cost per Kwh** | | 20 |
| **Cost of diesel/ liter** | PKR | 70.00 |

Labor cost:

This plant will be operated by 5 unskilled workers. All engineering staff will be provided by Engro. The labor cost per day is calculated as follows.

*Labor cost = no of workers x labor hours per day x labor cost per hour*

| Table 4.6: Labor Cost | | | |
|---|---|---|---|
| No of unskilled Workers | labor hours per day | labor cost/ hr | Labor cost(PKR/day) |
| 5 | 8 | 75 | 3000 |

Electricity Cost:

Electricity cost= Quantity x Power rating x Operating hours per day * electricity cost per kwh

Table 4.7 Electricity cost

| Electricity cost | | | | |
|---|---|---|---|---|
| **Equipment** | quantity | power rating(kwh) | operating hour per day | cost (PKR/day) |
| Shredder | 1 | 190 | 4 | 15200 |
| Pump | 1 | 0.1178 | 8 | 18.848 |
| Blowers | 3 | 0.138 | 8 | 66.24 |
| Screening | 1 | 45 | 2 | 1800 |
| | | | Total | 17085.088 |

Tractor operating cost:

The tractor will use about 10 liters per day. Driver is included in unskilled worker. The cost calculated as followed

*Tractor operating cost = price of diesel/ liter x no of liters use per day*

| Table 4.8: Tractor Operating cost | |
|---|---|
| Fuel requirement (liters) | 10 |
| cost (PKR/day) | 700 |

Total operating cost is 21785 PRK/day

### 4.2.3 Project Evaluation

| | | |
|---|---|---|
| Daily Sale of compost | 29914.5 | PKR/day |
| Daily operational cost | 21785.088 | PKR/day |
| Daily net profit | 8129.412 | PKR/day |

| | | |
|---|---|---|
| Payback period | 1343.621162 | days |

The project initial investment will be recovered in 3 years and 6 months

## HAZOP Analysis:

HAZOP analysis refers to the study of hazards and operability of chemical processes. It is associated with the Health, safety and environment division of chemical plants. In order to avoid any accident and ensure smooth operation of the plant, HAZOP analysis is performed. It also helps in identifying and correcting any fault in troubleshoot situation. In order to simplify and plausibly organize the HAZOP study, there are seven guide words recommended by CIA. In addition to the guide words, there are other words which are provided by their exact definitions. These guide words are as follow:

*Intention:* the intention defines how the particular part of the process was intended to operate; the intention of the designer.

*Deviations:* these are departures from the designer's intention which are detected by the systematic application of the guide words.

*Causes:* reasons why, and how, the deviations could occur. Only if a deviation can be shown to have a realistic cause is it treated as meaningful.

*Consequences:* the results that follow from the occurrence of a meaningful deviation.

*Hazards:* consequences that can cause damage (loss) or injury.

| Guide Word | Meaning |
|---|---|
| NO/NOT | The complete negation of the intention |
| MORE / LESS | Quantitative increase/ decrease |
| AS WELL AS | A Qualitative increase |
| PART OF | A Qualitative decrease |
| REVERSE | The logical opposite of the intention |
| OTHER THAN | Complete substitution of the intention |

Using the technique jotted above, we performed the HAZOP study on our plant scale composting solution that we designed. Following is the analysis performed on each equipment that can potentially malfunction or cause a safety hazard.

Equipment—Shredder:

Intention: Rotate the blades at the designed RPM to handle the design capacity of feed.

| **Guide word** | **Deviation** | **Cause** | **Consequences & Actions** |
|---|---|---|---|
| NO/NOT | Rotation | Jamming, Driver failure, power outage | Possible failure of driver, risk of blade shaft bending: check driver to ensure power transmission. |
| MORE | Feed | Feed screen rupture, deviation from design input protocol | Overload of driver and potential failure, risk of damaging blades: add feed according to design conditions |
| LESS | Rotation | Jammed gear mechanism, fault in power transmission | Less feed processing, driver overload, increased power consumption |

Equipment—Blower:

Intention: To provide the required air flow for the aerobic process to proceed.

| Guide word | Deviation | Cause | Consequences & Actions |
|---|---|---|---|
| NO/NOT | Flow | Blower failure, power outage, open power circuit | Temperature increase in tumbler and pile, anaerobic reaction initiation, odor generation: Check power connections and blower driver |
| LESS | Flow | Blower discharge partially blocked, less power input | Gradual Temperature increase in tumbler & piles, delayed product formation, risk of anaerobic respiration: check blower discharge, check power connections |
| MORE | Flow | Increased power to driver | More power consumption costs, possible driver failure, temperature decrease in tumbler and piles: install a valve at blower discharge, check power output to blower driver. |

Equipment—Tumbler:

Intention: To maintain the temperature of the feed and aerate it properly.

| Guide word | Deviation | Cause | Consequences & Actions |
|---|---|---|---|
| NO/NOT | Flow | Blower failure, air channel blocked | Excessive temperature increase, anaerobic process initiation, odor generation: check blower operation, check to see if there is any blockage in air channel. |
| MORE | Flow | Less feed input, increased power output to blower, control valve stuck open | Temperature decrease slowing the reaction and potentially stopping it, risk of blower driver failure: check power output to blower, ensure the feed input is in accord with design capacity. |

Equipment--Screen:

Intention: To separate oversized and non-degradable waste from the finished compost.

| Guide word | Deviation | Cause | Consequences & Actions |
|---|---|---|---|

| | | | |
|---|---|---|---|
| NO/NOT | Operation | Power failure, Equipment driver failure | Product processing delay, product contamination: check power connection, check driver to ensure it is operational |
| LESS | Flow | Screen blockage | Reduced efficiency, increased equipment load: stop equipment operation to clear blockage, inspect screen for any weir and if so, attend to the damages. |

# Conclusion

The design proposed in this paper emphasizes on obtaining an agricultural product while at the same time handling the problem of waste generation. Using this technique, another new product line can be launched alongside the main fertilizers marketed by Engro fertilizers. This study is not simply proposing a waste disposal solution. But, it takes a step further and suggests a solution that transforms seemingly useless substances into a useful and marketable product.

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