ACF-INTERNATIONAL — USTB

MANUAL

Composting Manual for Cold Climate Countries

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Manual

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Action contre la Faim-France
School of Civil & Environmental Engineering
University of Science and Technology Beijing

ACF-INTERNATIONAL — USTB

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1 - INTRODUCTION

1.1 SCIENTIFIC BACKGROUND

Composting is defined as the controlled biological decomposition and stabilization of organic substrates under a set of factors (e.g., temperature, moisture content, carbon-nitrogen ratio, degree of aeration, pH level, and physical structure of the raw materials), which allow development of thermophilic conditions as a result of biologically produced heat. The final product should be stable, free of pathogens and plant seeds, and beneficial when applied to land as bio-fertilizer [1, 2, 3].

The composting process destroys pathogens, converts nitrogen from unstable ammonia to stable organic form, reduces the mass, volume and water content, and also improves the nature of the waste [4, 5].

In addition, it is not only an 'approach' to handling organic waste in an environmentally friendly manner, but also a way to recover resources and nutrients for sustainable development. Composting as a sustainable sanitation approach has been widely used in managing and treating human excreta especially for developing countries due to its accessibility, low environmental pollution, low cost of operation and maintenance and significant pathogen reduction [6, 7].

Co-composting is a controlled aerobic degradation of more than one organic material, such that by the combination of materials (e.g., fecal sludge and organic solid waste, human faeces and straw, aquatic plants and sawdust) benefits can be gained in terms of process optimization. Human excreta is high in nitrogen content and moisture, while garbage is high in organic (carbon) content and have good bulking qualities; therefore these can be converted together into a useful product [8]. Co-composting of sewage sludge with fly ash can significantly reduce the availability of heavy metals in the composted sludge [9]. Wastes can be categorized according to their five main sources [6, 10, 11, 12, 13, 14]:

- Animal and human (e.g., cow-dung, poultry litter, pig and horse dung, human faeces), kitchen waste, pulp and paper mill waste),
- Aquatic and other plants (e.g., Hydrilla, water hyacinth, and tobacco waste),
- Yard trimmings and other organic detritus (e.g., grass clippings, herbs, shrubs, leaves wood-chips).

1.2 BENEFITS OF COMPOST FOR ECO- CITY

The concept of Eco-City (later eco-communities, eco-village, and eco-town) was developed around four decades ago. Various principles, dimensions, and ideas of Eco-City have been applied and included in many studies [15, 16, 17]. Urban metabolism (such as circle of energy, waste and emissions, as well as the protection of the environment) was considered in the first concept of Eco-City in urban context [17].

The process can be expressed by the following equation [18] and the input and output of composting process can be explained in the Figure 1.

$$\text{FRESH ORGANIC WASTE} + O_2 \xrightarrow{\text{MICROBIAL METABOLISM}} \text{STABILIZED ORGANIC MATERIAL} + CO_2 + H_2O + \text{HEAT}$$

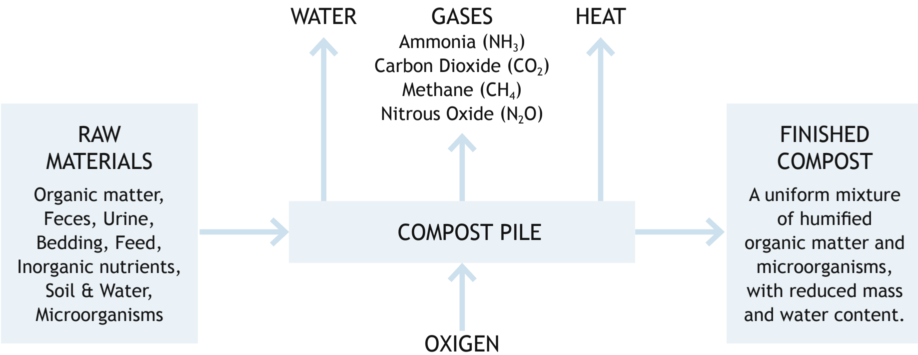


FIGURE 1: INPUT-OUTPUT OF COMPOSTING PROCESS.

Chinese Eco-City, for instance, Dongtan has target for world's first purpose-built Eco-City, which was designed to be considered as socially, culturally, economically and environmentally sustainable city. Renewable energy, waste recycling and reuse including human sewage were considered, the aim was to collect 100% of all waste in the city and recover up to 90% of collected waste. Human sewage was to be processed for energy recovery, irrigation and composting to greatly reduce or entirely eliminate landfill sites [18, 19]. Following are some principles of Eco-City listed in the Urban Ecology Study [15]:

- Revise land-use priorities to create compact diverse, green, safe, pleasant, and vital mixed-use communities near transit nodes and other transportation;
- Revise transportation priorities to favor foot, bicycle, cart, and transit over autos, and to emphasize access by the proximity;
- Restore damaged urban environments, especially creeks, shore lines, ridgelines and wetlands;
- Create decent, affordable, safe, convenient, multicultural and economically mixed housing;
- Nurture social justice and create improved opportunities for women;
- Support local agriculture, urban greening project and community gardening;

- Promote recycling, innovative appropriate technology, and resource conservation while reducing pollution and hazardous wastes;
- Work with businesses to support ecologically sound economic activity while discouraging pollution, waste, and the use and production of hazardous materials;
- Promote voluntary simplicity and discharge excessive consumption of material goods;
- Increase awareness of the local environment and bio-region through activist and educational projects that increase public awareness of ecological sustainability issues.

In practice controlled aerobic degradation of organic waste in the scope of sustainable solid waste management and development of eco-cities has to evaluate and plan according to the following factors:

- Land requirement;
- Type and amount of organic material and feedstock;
- Scale and logistics;
- Operational controls (odor, air, climate conditions and troubleshooting);
- Economic feasibility (includes capital cost, operating cost, permit fees, maintenance & upkeep, taxes and distribution of end products).

2.1 GENERAL OVERVIEW OF COMPOSTING METHODS

Biological decomposition of organic matter naturally happens in the environment, nevertheless, composting process can be divided into three types according to the difference in heat retention: hot; cold and vermi-compost. Figure 2 presents these composting types and their different implementation designs that are common in practice.

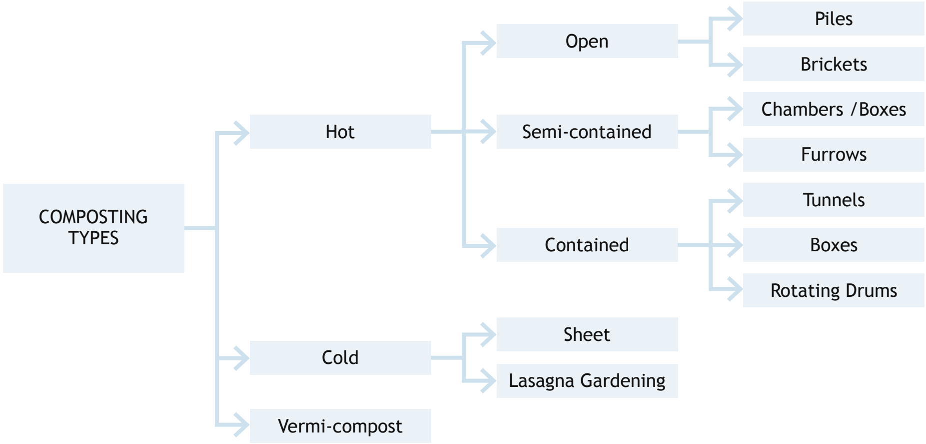


FIGURE 2: TYPES OF COMPOSTING BY TEMPERATURE.

Hot (active) composting is primarily aerobic natural process where combination of feedstock generates significant amount of heat during microbial breakdown. Active composting requires more maintenance to keep the C:N (see Chapter 3.1.4) balance, turning and sometimes watering. But it has advantage of destroying pathogens. Whereas, *cold (passive) composting* is decomposition that occurs in the nature where microbial heat is lost in the air and materials do not get a chance to heat up significantly. Even without significant heat microbes, fungi and specialized bacteria slowly breakdown the materials such as plants, leaves and fallen trees and reduce it to stable organic matter over longer periods of un-maintained process. Most cold composting is aerobic but still some anaerobic organisms decompose materials in environments without or little oxygen (swamps and septic tanks). But the metabolic processes used by these microorganisms often emit foul odors and undesirable by-products [20]. This process has lowest maintenance, operation and management but there's no pathogen reduction due to low heat retention.

Lastly, *vermi-composting* is usage of various worms and microorganisms to breakdown organic matter. Composting worms are sold online or can be collected from compost and manure piles. Most commonly red worms are placed into bins with organic matter in order to break it down into high-value compost. Worm bins are easy to construct (also commercially available) and can be adapted to accommodate the volume of food scraps generated [21]. Piles should be no higher than 0.5- 1m, though widths and lengths are only limited by system design.

PHOTO 1: INDOOR WORM BOX.
SOURCE: [60].

Design can encompass single units designed for home use up to large scale industrial systems, utilizing multiple rows of insulated units and equipped with shredders, screens, heating, cooling and ventilation. Be able of processing up to a ton or more of organic materials per day [21].

Hot composting processes can be divided into following types:

1. Windrow composting: Organic waste is formed into rows of long piles called "windrows" and aerated by turning the pile periodically (see Chapter 3.4.2), either manually or mechanically. The ideal pile height, which is between 1-2m, allows for a pile to be large enough for sufficient heat generation and to maintain temperatures (e.g. important for pathogens reduction, see also chapter 3.4.2), yet to be small enough allows oxygen flow to the windrow's core. The ideal pile width is between 4-5m [21].

PHOTO 2: WINDROWS PILES.
SOURCE: [61]

a. Passive windrow: Turning is not required for aeration. Air is supplied to the organic material through perforated pipes embedded in the pile by chimney effect. A porous base is built out of peat, compost, straw or grass. Because there is no turning and remixing in this method, the materials must be thoroughly pre-mixed before being placed in the windrow. Windrows constructed in this method generally are 1-2m high, no wider than 3m and can be any length [21].

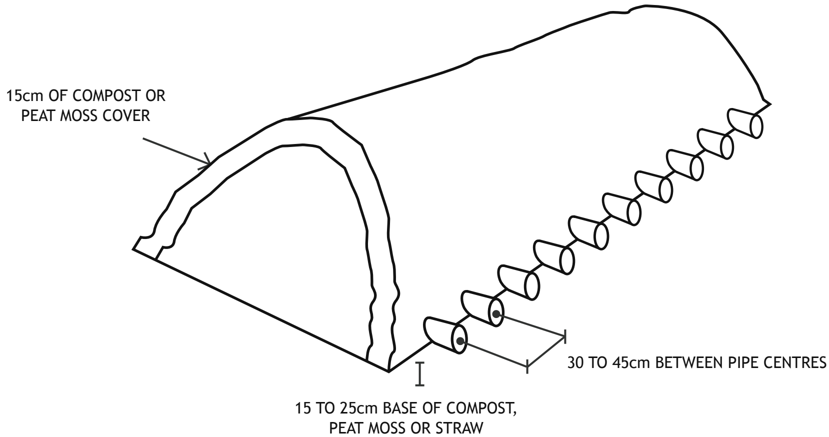


FIGURE 3: TYPICAL PASSIVELY AERATED WINDROW.
SOURCE: [23]

b. Actively aerated (turned) windrow: are elongated piles that are agitated or turned on a regular basis with a machine such as a front-end loader or specially designed equipment. It can vary in size, depending on space availability and type of material being composted. The recommended size is 2m high, 3-4m wide, and as long as is appropriate for the site [21].

PHOTO 3: FRONT-END LOADER TURNING WINDROWS PILES.
SOURCE: [64]

2. Static pile: Organic waste is mixed with bulking agent in a pile, instead of rows and left for decomposition for two to three years.

PHOTO 4: TYPICAL STATIC PILE.
SOURCE: [65]

a. Passive static pile: The piles are not turned; the initial mixture of food scraps and bulking materials must be porous enough to allow air to penetrate and circulate. Static piles can be as long as space allows, but should generally be no higher than 2m or wider than 4m. This method takes longer time but requires least amount of maintenance [21].

b. Aerated static piles: Layers of loosely piled bulking agents (e.g., wood chips, shredded newspaper) are added, so that air can pass from the bottom to the top of the pile. The piles also can be placed over a network of pipes that deliver air into or draw air out of the pile. Ventilation might be activated by timer or temperature sensor [20]. Piles can be bigger, generally 2-2.5m high and 3-5m wide. The width of the piles depends on the layout of the pipes; some piles are very wide with multiple pipes running through them [21].

PHOTO 5: AERATED STATIC PILE.
SOURCE: [62]

3. In-vessel composting: Organic materials are fed into a drum, silo, concrete-lined trench, or similar completely encapsulated equipment where the environmental conditions- including temperature, moisture, and aeration-are closely controlled.

PHOTO 6: SMALL-SCALE ROTATING DRUM SYSTEM.
SOURCE: [66]

PHOTO 7: STATIC CONTAINER COMPOSTING SYSTEM.
SOURCE: [63]

The method usually has a mechanism to turn or agitate the material for proper aeration. In-vessel composters vary in size and capacity [20].

PHOTO 8: IN-VESSEL COMPOSTING.
SOURCE: [67]

Figure 4 shows that the simplest composting system is the passive static pile that needs least amount of maintenance and assistance but requires longer process time. The high intensity methods would require more investment, complex equipments and high maintenance however shorter process time. These factors will play important role in choosing which methods or which systems to implement.

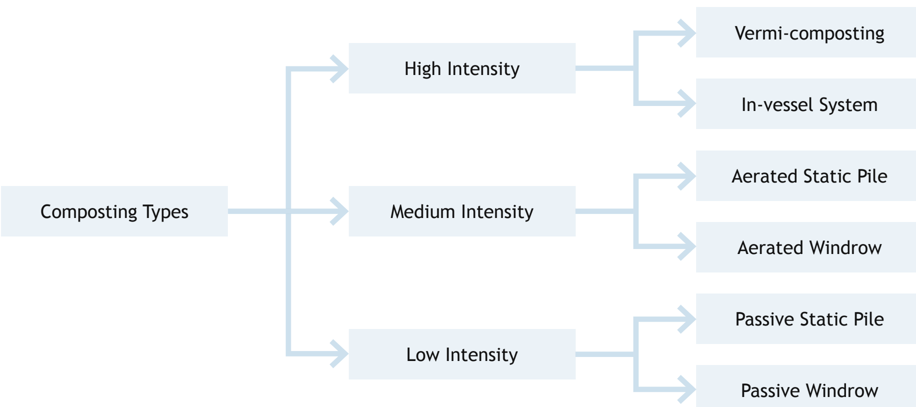


FIGURE 4: COMPOSTING METHODS BY INTENSITY.
SOURCE: [23]

Each of these systems has advantages and disadvantages therefore, individual locations and situations have to conduct assessments before planning.

Following Table 1 shows the advantages and disadvantages of each method.

TABLE 1: ADVANTAGES AND DISADVANTAGES OF COMPOSTING METHODS

ADVANTAGES	DISADVANTAGES	COSTS
PASSIVE STATIC PILE		
• Least amount of maintenance. • No turning required.	• Longest composting time. • Care must be taken with initial mixture to ensure porosity and air circulation. • Must have available space to let piles sit for long periods of time.	• Capital investment: Low • Operating cost: Low • High land requirement.
PASSIVE WINDROW		
• Able to handle large volumes. • Faster composting time than Passive Static Pile. • No turning required. • Rapid drying with high temperatures. • High degree of pathogen and weed seed kill. • Piping network underneath pile speeds up process. • Drier product, resulting in easier handling of material. • Good product stabilization.	• Requires a porous foundation and a cover layer to absorb moisture and insulate the windrow. • Must have available space to let piles sit for long periods of time. • More labor intensive that aerated piles. • Vulnerable to climate changes.	• Capital investment: Low • Operating cost: Low • High land requirement.
AERATED WINDROW		
• Able to handle large volumes. • Regular turning and mixing speeds up process. • High degree of pathogen and weed seed kill. • Effective in areas with freezing winter temperatures. • Good odor control.	• Front-end loader or specially designed equipment and labor is necessary. • Placement of aeration system may present operational difficulties. • More labor intensive that aerated piles. • Vulnerable to climate changes. • Odor released when turned.	• Capital investment: Average (depending on available machinery) • Operating cost: Low • High land requirement.

ADVANTAGES	DISADVANTAGES	COSTS
AERATED STATIC PILE		
• Able to handle large volumes. • Does not require turning. • Network of pipes and blowers speeds up process, allows better control over moisture and temperature. • High degree of pathogen and weed seed kill. • Piles can be larger due to forced aeration. • Good odor control. • Nearly all of the nitrogen can be conserved. • Demonstrated efficiency in cold and wet climates	• Placement of aeration system may present operational difficulties. • Vulnerable to climate changes. • Odor released when turned.	• Capital investment: Low in small systems; can become high in large systems. • Operating cost: Higher overhead than other methods, i.e., electricity, blower and pipe network. • High land requirement.
IN-VESSEL SYSTEM		
• Space efficient. • High degree of process control. • Mechanical or automated control systems. • Fastest method of composting. • High degree of pathogen and weed seed kill. • Potentially good odor control. • Predictable, uniform product. • Transportable composting containers effective for urban areas. • Potentially not visible. • Can be designed as a continuous process rather than a batch process. • Protection from severe weather	• Operation and maintenance also require greater expense. • Careful management required. • Higher level of knowledge and skill required. • Less flexibility in operation than with other methods.	• Capital investment: High (cost of equipment, buildings, and overhead). • Operating cost: Generally low • Low space requirement can increase if windrow drying or curing is required.
VERMI-COMPOSTING		
• No turning required. • Many different systems available, from single units to multiple rows.	• Initial mixture must include appropriate bedding and adequate moisture and oxygen to sustain worm habitat. • Moderate temperatures required for outdoor use. • Due to low temperatures, additional heating required.	• Capital investment: Low to mid range depending on available systems. • Operating cost: Low. • Low space requirement.

SOURCE: DEVELOPED FROM [22, 23, 24]

2.2 COUNTRY CASES

2.2.1 FINLAND

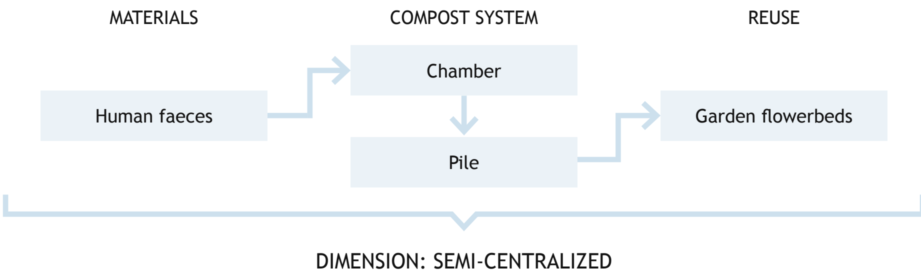


FIGURE 5: COMPOSTING SET UP IN FINLAND.
SOURCE: ADAPTED FROM [25, 26]

Kangasala Communal Village is located in south Finland, about 20 km to Tampere, next major city. Construction of the village began in 1997 based on defined ecological criteria. The village has residential area of 1,9ha of building area and 2ha of fields. At the present, nine households or around 32 people live in the village community [26].

From the very beginning the community had chosen the Ecosan approach. The reason for their choice was to save freshwater and recover nutrients, which is part of living according to ecological principles. Each household has a urine-diverting dry toilet system, in various designs suitable for their own needs. Community already has 13 years of experience with the ecological sanitation and by their own admission, very satisfied [26].

Community collects and treats urine and faeces separately. Urine is collected and stored in one of two communal underground containers (5 and 9m^3). After the storage the urine is pumped out from the containers and applied, in pure or/and diluted (with water) form as a fertilizer to lawns, pastures and gardens. The application of fertilizer is one liter of urine per one m^2, in the growing season [26].

> **ECOSAN:**
> *Short for* **Ecological Sanitation.** *Is a cycle—a sustainable, closed-loop system, which closes the gap between sanitation and agriculture. The Ecosan approach is resource minded and represents a holistic concept towards ecologically and economically sound sanitation* [27].

For faeces, the storage and collection takes place inside the collection chambers, mixed with raking wastes: dry leaves, peat, chopped straw, or as mixture of all kinds of carbon sources according to the moisture regulation. Residents lower application of ash, according to their own experiences, to prevent compost from turning too alkaline, which affects the composting process [23].

Three different designs of collection chamber been applied in the community: room-like container with sloping ground, large vertical on-site tanks and replaceable containers such as barrels. The removal of faeces applied in the first two chamber-designs carried out by the shovel. In the third option removal happens by simple exchange of the barrels. All chambers are equipped with the ventilation system and insulation, to provide airflow and to prevent freezing during the winter season [23].

The faeces in the fixed collection chambers are emptied (depending on the size) in intervals from once in a year /in four years. In this case the faeces is not removed completely, the freshest materials still remains inside. Replacement of the barrels takes place when the barrel is full, however the barrels are not carried out to the compost facility immediately; instead they stay indoors for another eight months. An additional advantage is that the barrels are easier to handle after this period of time [23].

After emptying collection chamber, all faeces is taken for further composting in an open shelter, known as central composting facility of the community. The shelter has a concrete base and sides to prevent any leakage to the environment and roof to protect compost from the rain. The compost is stored in the pile for another one to two years before being used as a fertilizer at the vegetable gardens and flowerbeds of the community [23].

INFORMATION BOX

GENERAL

CLIMATE Cold Climate	LOCATION Kangsala, Finland
PROJECT NAME Kangasala Comunal Village	RESIDENTS ca. 34 → START 1994
ADDRESS Kangasala Ekokyla Siitamaentie 752, 36120 Suinula, Finland	
MOTIVATION Reduce use of fresh water; Nutrient recovery.	

COMPOST

MATERIAL Feces	CARBON SOURCE Raking waste, dry leaves, peat, chopped straw.
METHOD 1. Compost Chamber 2. Pile Composting	COMPOSTING TIME 1. 8 months 2. 1 - 2 years
APPLICATION Garden and flowerbeds	

CONTACT DETAILS

WEBSITE
www.yhteiskyla.net/index_en.htm

EMAIL
op@arkinor.fi

FIGURE 6: FINLAND INFORMATION BOX.

2.2.2 KYRGYZSTAN

Between 2006 and 2008, Women of Europe for Common Future (WECF) realized together with four other Kyrgyz NGOs - members of WECF network, the implementation of 16 Urine Diverting Dry Toilets (UDDT) under the project “A sustainable decentralized wastewater management for Kyrgyzstan". The implementation of the project took place in the area of Issik-kul Lake, Issikkulskaya region. The motivation was the bad state of the current toilets, related to the odor, also some of the farmer-oriented households showed high interest in free fertilizers [28].

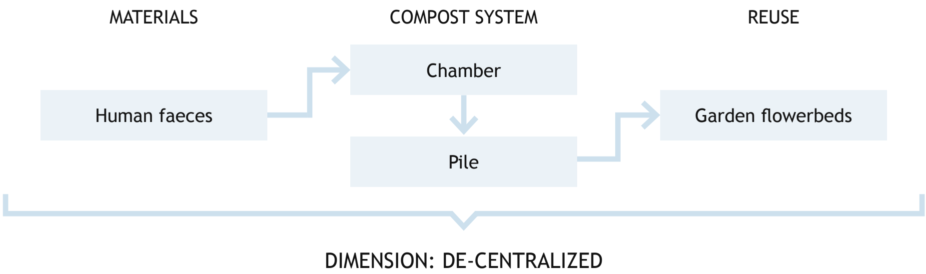


FIGURE 7: COMPOSTING SET UP IN KYRGYZSTAN.
SOURCE: ADAPTED FROM [25, 28]

UDDT works without use of fresh water and separates collection of urine and faeces. Two different designs for UDDT where applied: Single Vault and Double Vault UDDT. The difference between these two designs is the number of the collection chambers for faeces located below the toilets [28].

The single vault UDDT has one chamber, and another collection container for faeces is placed inside. When the collection container is full, the owner replaces it with an empty one. The full container is left until the faeces is dry. After the drying process, the faeces is emptied at the family's own compost pile [28].

Double Vault UDDT has two collection chambers below, when first chamber is full, the second vault is used. The faeces dry in the first chamber and don't require additional effort from the owners to replace the collection container. After drying the content is emptied at the compost pile [28].

The urine is stored in separate collection tank. The volume of canisters used as a collection tank is generally from 10-20l, it allows carrying and applying urine easier for the users in their own gardens. At the household level no retention time for urine was considered before application. Nevertheless it has been recommended to use larger collection tanks, if possible, because of the longer storage time during the winter when the application of urine is more inconvenient and there's no need for fertilizers. If the urine is used at larger scale as a fertilizer, it is necessary to ensure the storage for up to six months for sanitation reasons, and recommended for even longer periods in cold climates [28].

Majority applied urine as a fertilizer at home gardens, in long "psychological distances" between application for consumption in edible plants and at short "psychological distance" for the fruit trees. Some owners only applied it to the bushes, flowerbeds or compost piles. Obviously farming oriented households used urine most effectively, during the growing season, when the nitrogen demand is highest. When it was not used for fertilizer the urine was also applied to the compost heap, this practice increases the content of nitrogen in the compost.

This effect is also been described by another study "Experience in improving fertilizer value of compost by enriching of urine" by Heinz-Peter Mang. In Kyrgyzstan it was proven that the use of fresh urine is safe for application according to World Health Organization (WHO) guidelines. Also the fertilizing effect of the urine was demonstrated at experiment field and shown that the yield of the field was 20-30% higher than without application [28].

INFORMATION BOX

GENERAL

CLIMATE
Cold Winter Climate

LOCATION
Issik Kul area, Kyrgyztan

PROJECT NAME
Sustainable decentralized waterwaste management for Kyrgyztan

HOUSEHOLDS
16

START
2006

MOTIVATION
Improve toilet situation; Nutrient recovery.

COMPOST

MATERIAL
Feces

CARBON SOURCE
Sawdust, half ashes & black soil.

METHOD
1. Collection Chamber
2. Pile Composting

COMPOSTING TIME
1. Until is dry
2. 2 years

APPLICATION
Garden (trees, flowerbeds)

CONTACT DETAILS

WEBSITE
http://www.wecf.eu

EMAIL
wecf@wecf.eu

FIGURE 8: KYRGYZSTAN INFORMATION BOX.

In case of faeces, the collection and storage took place in containers or chambers, mixed with sawdust, ashes (half the amount compared to sawdust) and sometimes also with black soil, to prevent the odors and as a carbon source for composting process. After drying, the content is emptied at the compost pile for further composting for another two years. Afterward, it is safe for application as soil conditioner. Some households planned to extend the recommended composting time before the actual use [28].

At the time when the study was conducted, only one farmer had applied his compost around fruit trees; three households, who were familiar with composting, wanted to compost the faeces together with other organic wastes, and to apply it later in gardens on edible plants. Others wanted to use it only for trees or flowers [28].

2.2.3 LATVIA

The municipalities of Stopini and Kekava, Latvia, implemented composting project for high quality compost from biodegradable municipal wastes at the pre-industrial scale from 2003 till 2005. The project was targeting to reduce the volume of dumped waste to landfills and related negative environmental impacts, also at the same time to gain a high quality fertilizer [29].

By implementing source separation system for biodegradable waste, the collected amount of organic waste was around 60m^3 per month among the total population of 10,000 residents in both municipalities [29].

In this case two different methods were applied, open air composting and closed bioreactor vessel.

As a carbon source following materials were added to the process: peat, sawdust, shredded straw, and dry leaves [29].

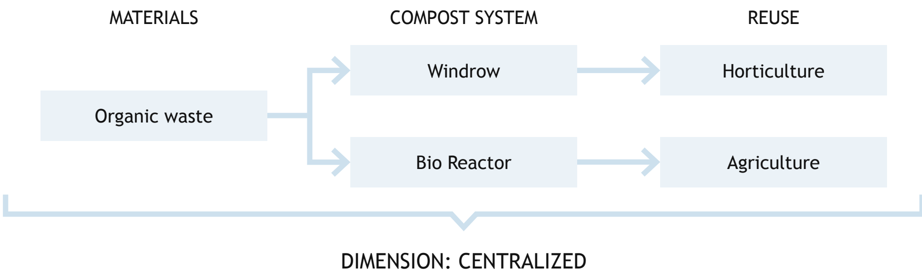


FIGURE 9: COMPOSTING SET UP IN LATVIA.
SOURCE: ADAPTED FROM [25, 29]

The applied method for open air composting was pile with 2-3m and windrows with 1,5m height. To improve the aeration, piles and windrows were mixed in intervals of 7 to 10 days. After four months of composting time, some pathogens still remained. But the quality was suitable for applying the compost for covering activities and re-cultivation [29].

The pilot bioreactor vessel has a capacity to treat 25m^3 of bio-waste per week. The treatment of the bio-waste was under constant temperature of 60°C achieved by constant regulation of the aeration inside the reactor. Composting processes was disturbed when the outside temperature dropped below minus 10°C. Quality of compost was high and the product met the European regulation and could be applied in the gardens or fields [29].

During the monitoring phase of the project, between 2003 – 2005, 588t of bio-waste was collected and composted, thus prevented 736m^3 volume of waste to be disposed at landfills and saved emission of greenhouse gases by 1,29 millions m^3 [29].

INFORMATION BOX

GENERAL

CLIMATE
Cold Climate

LOCATION
Stopini & Kekava municipalities, Latvia

PROJECT NAME
LIFE03 ENV/LV/000448

PEOPLE
10.000

START
2003

ADDRESS
Waste Management Association of Latvia. Kursu street 9-2, Riga, LV-1006, Latvia

MOTIVATION
Reduce of landfill waste; Reduce environmental impacts; Nutrient recovery.

COMPOST

MATERIAL
Biodegradable municipal waste.

CARBON SOURCE
Dry leaves, sawdust, peat, chopped straw.

METHOD
1. Open Air (pile, windrow).
2. Bio reactor.

COMPOSTING TIME
1. 4 months (warm period).
2. 1 week (warm period).

APPLICATION
1. Covering, recultivation.
2. Gardens and fields.

CONTACT DETAILS

WEBSITE
www.lasa.lv/life

EMAIL
bendere@edi.lv

FIGURE 10: LATVIA INFORMATION BOX.

2.2.4 NORWAY

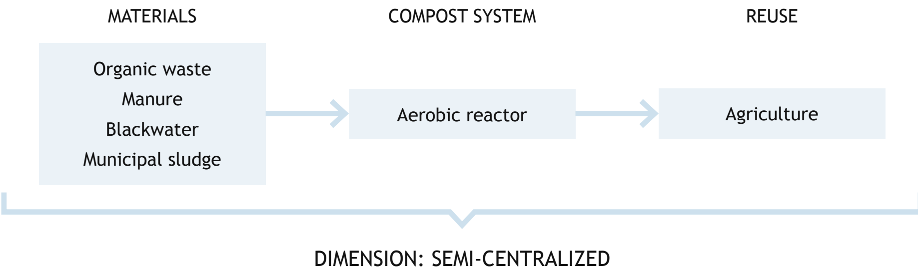


FIGURE 11: COMPOSTING SET UP IN NORWAY.
SOURCE: ADAPTED FROM [25, 30]

Aas is located around 30km from Oslo, Norway. In this area, local farmers treat food waste and municipal sludge. Therefore, not only waste is sanitized but also the nutrient cycle is closed and the farmers are able to generate an extra income, from treatment of the organic wastes and saving money for fertilizers [30].

Organic waste from 750 households is collected and treated in thermopiles aerobic reactor with volume of $32m^2$ by the method of liquid composting. After the treatment two final products are available: sanitized fertilizer (liquid compost) suitable for application on the fields and heat, that can be utilized [31].

Following composting materials can be used in aerobic digester: black water, municipal sludge, animal manure and food waste as a co- substrate. The collection of the materials can be carried out once per one/two years. In this case organic waste is stored by residents for the required period of time. The storage takes place in specially designed closed subsurface tanks, where almost no degradation of biomass can occur, and no production of greenhouse gas, methane. The storage of sludge is in the septic tank. Contents can be emptied out by a truck. The collecting intervals are low, which reduce the operation costs [30].

Thermopile aerobic reactor works within temperature range of 55–65°C, where pathogens contained in the municipal sludge can be removed efficiently. Chopped organic food waste is added to increase the concentration of organic matter and to accelerate the composting process. The amount of Total Solids (TS) in the reactor needs to be in the range between 2-10%. The defined hydraulic retention time is 7 days, to ensure that the municipal sludge fulfills and meets sanitation and stabilization requirements of of European standards. Treatment removes odors and the end product is liquid fertilizer, which can be applied on 30-40ha of farmers fields. By 2005, seven plants were operating on Norwegian farms [31].

The application of liquid compost on the fields takes place with tractor-mounted injection system, which has been designed for this purpose. In the processes the ground is not penetrated, rather high pressure injects the sanitized slurry into the soil. This method assures more efficient use of the fertilizers, compared with traditional methods [30].

The liquid compost method has high investment cost because of advanced technology. However, it allows farmers to generate income through appropriate fees for waste and water treatment under favorable conditions, and allows generating valuable local fertilizer. This approach is especially suitable for areas without existing sewage systems [30].

INFORMATION BOX

GENERAL

CLIMATE Cold Climate	LOCATION Aas, Norway
PROJECT NAME Farmer Operated System	HOUSEHOLDS 750 → START ca. 1998
MOTIVATION Additional/alternative earn possibilities	

COMPOST

MATERIAL Black water, municipal sludge, organic food waste.	
METHOD Liquid composting (thermopiles aerobic reactor).	
HYDRAULIC RETANTION TIME 7 days.	APPLICATION Agricultural use.

FIGURE 12: NORWAY INFORMATION BOX.

2.2.5 RUSSIA

MATERIALS		COMPOST SYSTEM		REUSE
Manure Organic waste	→	Vermi-composting	→	Agriculture

DIMENSION: DE-CENTRALIZED

FIGURE 13: COMPOSTING SET UP IN RUSSIA.
SOURCE: ADAPTED FROM [25, 26]

Ecovillage Nevoecoville is located in the Republic of Karelia, 20km from the Karelian city Sortavala (close to the Finnish border). Nevoecoville was founded in 1994 during the Perestroika. About 10 families live in the village, in an union of individual households. Nevoecoville has a very poor soil quality and cold climate. These are challenging factors for agriculture, therefore all year around production of worm humus is so favorable and been implemented by residents [26].

The composting process occurs in special bins, prepared for worm composting inside the house. For humus production residents use cow manure and food waste and afterwards apply the compost in their gardens to improve soil conditions. Additional advantages are a volume reduction and stabilization of biological wastes. It is also a sustainable method for treating biological solid wastes all year around under difficult environmental conditions. This biological waste management practice requires for households to carry high degree of responsibility. However, there are other eco-villages that apply the same method but on larger-scale to share the responsiblity at the community level [26].

The production occurs in special Vermi-composting bins that are assembled by the owners. Composting bins are made of two stacked cubic modules, which are placed on a tray. Each module has a volume of around 40l and is made out of commercial plastic boxes for storage. Drilled holes at the bottom with diameter of 2cm, in 4-6cm distance from each other, enable the water to flow down to the collection container. The container is the same plastic box like the composting module, only without drilled holes at the bottom. Integrated water valve allows emptying of the container in a convenient way and the collected compost tea can be applied as fertilizer on the plants or for watering of the compost itself in case it's too dry [26].

Usually, worms prefer semi-rotten waste and it is suggested for achieving optimal humus production. Therefore, the compost process can be divided into a two-step process. First, the manure or organic food waste is collected at the composting site. Then pre-treated semi rotten waste is brought inside for further humus production. For the winter the residents need to prepare a stock of organic waste, to ensure the food source for the worms [26].

Each module for compost production is filled with substrate for composting (Manure, Kitchen Waste, etc.) and need to be moisturized with a bit of water (or compost tea) to achieve preferable humid environment for the worms, with moisture content around 80-90%, extra water will simply flow down to the collection container. The substrate is mixed with few thousand worms (500g of worms are able to process about 250g of organic waste). Additionally, other bedding materials can be applied such as straw, paper, dead leaves or sawdust. Over the time the population will be stabilized at the maximum level respectively to the volume of the container. The production of the humus appears at the top layers of the box, worms use the top layer within the bin as a "toilet"- and the content is nothing else but humus. Their "canteen" and "living space" is at the bottom of the bin. Once all the food supply is consumed, the worms move down through the drilled openings into other module and the humus is ready. Before application users sort the remaining worms out from the humus and apply the humus in their gardens. The empty modules are filled up again with the substrate and placed at the bottom while the former bottom becomes the upper one [26].

The time for humus production depends on different factors: the population of worms, temperature, humidity, and the season.

INFORMATION BOX	
GENERAL	
CLIMATE Cold Winter Climate	LOCATION Republic of Karelia, Russia
PROJECT NAME Nevoecoville	HOUSEHOLDS 10 START 1994
MOTIVATION Improve soil conditions.	
COMPOST	
MATERIAL Manure, food waste.	CARBON SOURCE Sawdust, dry leaves, paper.
METHOD Vermicomposting	COMPOSTING TIME 2 weeks (optimal performance)
APPLICATION Agricultural use	
CONTACT DETAILS	
EMAIL obruch@nwgsm.ru	

FIGURE 14: RUSSIA INFORMATION BOX.

In described case the owners replace the modules every second week, since the optimal performance was achieved [26].

The selected worms for composting in Nevoecovillage are the Russian manure worms, collected in the surrounding area. Even if the Californian red worm seems to be the most productive species for the composting propose, their disadvantages are that they are only efficient at temperatures above 15°C, thus are well suited for warm climate. Instead the Russian manure worms, are still active down to a temperature of 6°C. Another consideration is that the California red worms need to be purchased; instead the local species are collected at the manure pile in the village [26].

2.2.6 SWEDEN

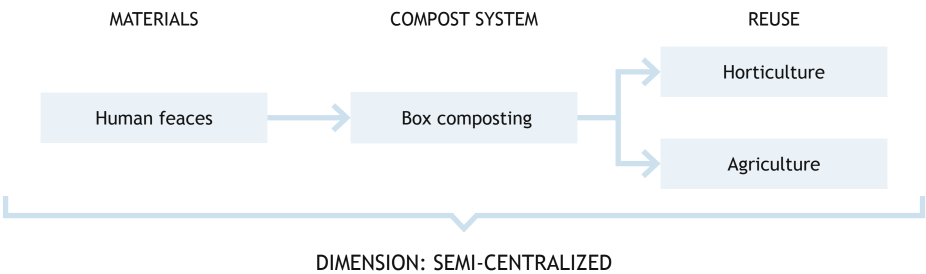


FIGURE 15: COMPOSTING SET UP SWEDEN.
SOURCE: ADAPTED FROM [25, 32]

The Gebers house project is located in the country-like area, in Orhem, about 15km southeast of the center of Stockholm, Sweden. Since late 1990s, around 80 people organized as a collective lived in 32 apartments in Gebers. The collective's motivation to live in balance with the nature resulted in rehabilitation of old houses with sustainable systems. The ecological and technical features of these houses are ecological sanitation system that uses UDDTs and resources recovery oriented management system. This system includes separated collection of the urine and faeces. After six months of storage for hygienic reasons the urine is applied to the fields by local farmers as a fertilizer. The faeces are carried over by the residents to the composting station, located about 150m from the building [25, 32].

The composting method applied in this case, is a wooden compost box, divided into two compounds. The composting station has a waterproof concrete floor and lid made out of corrugated iron. This is not only to ensure the protection from rain and to prevent nutrient leakage, but also to cover the human faeces from exposure. The walls of the box are low, to make it easier during emptying of the household collection bins or bags. In addition, the front of the compost box can be removed for emptying. Each composting chamber is large enough to store the faeces for 5 to 6 years. Composting materials are human faeces with toilet paper, mixed with sawdust or ashes, additionally together with carbon rich materials added in layers such as dead leaves or straw [25, 32].

The compost is planned to be used as a fertilizer and will be applied on the field to grow animal fodder. So far, the compost has not been applied on the field yet, because of little amount after 5 years. However, some compost has been applied to cover a constructed embankment with grass. Organic food waste is collected and composted separately [32].

INFORMATION BOX

GENERAL

CLIMATE
Cold Climate

LOCATION
Orhem, Sweden

PROJECT NAME
Gebers House Project

RESIDENTS
ca. 80

START
1998

ADDRESS
EKBO (Ecological and Collective Housing in Orhem) Gebervagen 20-30 S-12865 Orhem, Sweden

MOTIVATION
Resources recovery; Reduce use of fresh water; Environmental protection.

COMPOST

MATERIAL
Human feces (incl. toilet paper)

CARBON SOURCE
Dry leaves, straw, ash and sawdust.

METHOD
Compost Box (2 chambers)

COMPOSTING TIME
5 - 6 years

APPLICATION
Growing animal fodder; Horticultural use.

CONTACT DETAILS

WEBSITE
gebers.se

FIGURE 16: SWEDEN INFORMATION BOX.

3 - IMPLEMENTING A COMPOST PROJECT

3.1. CHALLENGES IN IMPLEMENTATION

3.1.1. SECONDARY POLLUTION AND EMISSIONS

Besides all positive aspects of composting, there are also some negative impacts on the environment and human health associated with production and usage of compost that needs to be considered. These impacts depend on both, technical approach for compost production and composition of input materials. Workers health and product safety are issues of main concerns of composting process, especially in context of feacal composting.

PROCESS

AIR

Ammonia (NH_3) loss always happen during composting process, NH^3 is a colourless gas with strong pungent smell, which has the ability to acidify rain and in return cause excess of nitrogen (N) in surrounding area accompanied with foul odours [33].

Greenhouse gases methane (CH_4) and nitrous oxide (N_2O) are emissions into the atmosphere, responsible for greenhouse effect, and of concern (not only) for compost production. However, if the aerobic environment is maintained well, by proper moisture and aeration to support aerobic decomposition of the organisms, the process does not generate significant quantities of methane (CH_4). In this case the main gas will be CO_2. After all, only the CO_2 released by the use of fossil fuels (e.g. diesel and petroleum) during transporting and processing contributes to global warming. Generated CO_2 during the composting process itself is a part of the natural carbon cycle. In contrast under anaerobic conditions methane (CH_4) is generated with 20 times higher greenhouse gas potential than carbon dioxide. The emission of nitrous oxide (N_2O) is generated during denitrification of nitrite and nitrate. The level of N_2O and CH_4 emissions depends on different factors: types of organic materials, method of composting, amount of material and the processing circumstances (moisture, temperature and structure) [34].

Composting can contribute to a global warming reduction by keeping organics out of landfills [35]. For example, one study carried out in Egypt shows, that compost production generates 90% less emission compared with landfills or open dumps, without energy recovery [36]. But even if the capture of methane from landfills occurs, it would never be 100% and this is the reason why the landfills would always release potent methane gases [35]. Another study identifies pit latrines as one of the major sources of the greenhouse gas methane (CH_4) caused by anaerobic decomposition and suggest implementation of compost toilets as competent method for its mitigation [37].

Odours are produced by decomposition of organic waste and often the most noticeable concern of air quality. Even at well-managed compost facilities the generation of odours cannot be completely avoided. Generation of odours may increase during compost operations like turning and mixing or when the composting process becomes anaerobic, characterized by strong and foul odours. Therefore, providing proper aeration to compost can minimize odours and prevent anaerobic degradation. Chemical compounds responsible for odour generally does not affect human health. However excessive odours can result in symptoms such as nausea which, also negatively influence public attitudes toward composting facilities. [34].

WATER

Leachate is result of high moisture content in organic waste and occurs during the composting process or storage. In the first three weeks of the process, the highest amount of leachate is released, generally under thermophilic conditions. Leached may contain pathogens but usually contains high concentration of BOD (biological oxygen demand) and phenols (by- product of the decomposition of lignin in leaves) that can pollute surface and ground water and subsequently affect the plant life by causing excess nitrogen [33].

PRODUCT

WATER

Intensive applications of compost may release more nitrogen than utilized by the plants, with subsequent risk of groundwater pollution [34].

3.1.2. WORKERS HEALTH AND SAFETY

HEALTH CONCERNS

Ammonia (NH_3) could be present at high concentrations especially at indoor compost facilities and cause irritation of eyes, skin and respiratory systems of workers. The level of irritation may vary between individuals depending upon concentration of ammonia and the duration of exposure [33].

Bio-aerosols referred also as organic dust, are organisms or biological agents transported through the air. Because of their small size (PM_{10}) these particles are of health concern at composting facilities. Bio-aerosols include bacteria, fungi, and actinomycetesare, which are able to reach and penetrate the lungs. Those of main concern at composting facilities are *aspergillus fumigatus* and endotoxins, which are present in various kinds of decaying organic matter and can cause allergic reactions among sensitive individuals. Concentrations of bio-aerosols are the highest during dust production activities, such as shredding, screening and the mixing of composting materials [33].

Organic dust released during composting is mostly limited to that area and have minimal impact beyond 100m [33].

Endotoxins are metabolised products of microorganisms, remaining in the bacteria after they died. Endotoxins are not known to be toxic but can cause symptoms such as nausea, headache and diarrhoea among sensitive individuals [33].

Pathogens are microorganisms, which can be found in the organic waste and may occur at high levels and cause diseases. Pathogens can be divided into two groups: primary and secondary pathogens. Primary pathogens, which are generally present in raw waste, include: bacteria, viruses, protozoa and helminths eggs. They can cause infections in healthy individuals. Most common infections are diarrhoea and dysentery, transmitted via faecal-oral transmission routes [38].

Secondary pathogens are microorganisms: fungi and acid-producing bacteria that grow during biological decomposition (see also bio-aerosols). These pathogens are less of concern, but still able to cause primary infections and respiratory diseases, usually in people with weak immune system [38].

SAFETY PREVENTIVE MEASURES

Composting of organic waste is not inherently dangerous activity. Proper attention to health and safety can minimize most of occupational risks at composting site and prevent possible injuries and illness.

- Training in safe operation of power equipments and handling decomposing organic matter [35].
- Operation of power equipments and handling must be avoided if certain types of medication is taken or under influence of alcohol [35].
- The most effective preventative measure is, use of proper personal protective equipments (PPE): protective clothing and equipment, such as waterproof and durable gloves, boots and overalls, eye, hearing, and respiratory (that can filter small particles at least PM_{10}) protection gears. The PPE must be provided to the person together with user instructions [33].
- In case of emergency, a first aid kit must be available at the compost site [33].
- Mixture of wastes with balanced C:N ratios (Chapter 3.1.4) could help prevent ammonia loss and related irritation of eyes, skin and respiratory systems among workers, and reduces odours. It is only effective if the carbon (C) is easily degradable, for example, mixtures with dry leaves, paper or straw. High ammonia losses are also related with obtaining compost with a low agronomical quality [33].
- To avoid generation of toxic hydrogen sulphide (H_2S) pH of compost should not exceed 7.5 [35].
- Indoor compost facilities need to be equipped with adequate ventilation system [35].
- Dust prevention during operation can reduce the formation of airborne microorganisms (see dust prevention) [35].
- Pathogen reduction occurs in treatments at elevated temperatures (Chapter 3.4.2) during certain periods of time. The high temperatures are effective to reduce the number of pathogenic organisms more effectively, while at the same time protecting the health of workers and public [38].

- Special care should be taken when dealing with untreated waste. In this case workers should be wearing protective clothing and use appropriate respiratory equipments [35].
- Hygienic facilities should be provided for workers to ensure the personal hygiene and change of clothes [35].
- Cleaning of the vehicles is part of good hygiene practice [35].
- Attention should be paid to lifting activities also. People should not exceed carrying load of 25kg, otherwise equipment and tools need to be provided [39].

The final product can be safely handled if the process was carried out properly.

3.1.3. PROCESS AND PRODUCT SAFETY

PROCESS

Odour effect can arise from poorly managed stockpiles of raw organics and/or organic products. To prevent the odours at the composting site following steps are recommended:

- Use of the right raw materials mixture to ensure optimal C:N ratio between 25:1 and 30:1; ratio below 25:1 promotes ammonia volatilization. In that case, adding high carbon bedding material can reduce the ammonia odours. It is recommended to have a stock of high carbon material on hand for mixing to ensure optimal C:N ratio during composting process [35].
- Moisture levels of compost should not exceed 60%. High moisture prevents air circulation and encourages odours [33].
- Static piles could be covered with mature compost (ca 15cm), which acts as a bio-filter, barrier for pests and fire [33].
- Good practice of maintaining aerobic conditions are to turn or to aerate compost material which prevents creation of anaerobic conditions [33].
- Integrated drainage at the bottom of the pile or windrow enables flow of leachate, regulates moisture and prevents anaerobic conditions [33].
- Good practice of regular cleaning of operational area such as roads and drainage channels prevents odour generation from old degrading materials [33].
- Turning of piles should be avoided on hot or windy days [33].
- Greater distance between composting site and sensitive areas will lessen the impact of any odours generated on site [33].

Leachate management is important for safe composting process and should include following steps:

- Composting process must be performed on waterproof surface, such as a concrete pad and requires protection from the rain [35].

- Integrated drainage at the bottom of the pile or windrow enables the flow and collection of leachate via collection system [33].
- Collected leachate can be re-circulated into composting process. If re-circulation of leachate is considered, it is important that the application is only at the beginning of the composting cycle to avoid pathogen contamination of the final product [33].
- Any leachate that is not re-circulated into composting process, must be collected and treated [35].
- Leachate collection system needs to be protected from the rain, to avoid the overflow and the volume increase [33].
- Unprotected leachate containers or pools may act as a breeding site for flies, mosquitoes and create odours, therefore, need to be protected [33].
- Stockpiles of raw organics and processed compost may generate leachate caused by excessive moisture (for example through rain). Therefore, rain protection is required [35].

Dust prevention is important for protection of human health and maintaining good work environment, thus following measurements can be applied:

- Maintaining moisture content over 40% helps to reduce dust formation at all stages of the composting process (production and storage) [35].
- Avoid operational activities like screening, shredding or turning of materials in days with strong wind to reduce dust generation [33].
- Sweeping the surfaces such as roads and flours prevent dust [35].
- Installation of physical barriers such as mounds [33].
- To ensure that roads are constructed to allow vehicles access to every part of the processing site that needs to be reached [35].

Fire can occur during composting process because of dry materials and high temperatures e.g. high level of carbon based materials and low moisture content. These settings are usually more prevalent within large, undisturbed piles containing raw feedstock or finished compost rather than in active composting systems. Therefore fire safety measures needs to be taken into account [33].

- Organic materials can combust spontaneously at low moisture contents between 25% and 35% [35].

Keeping the piles under 3m tall (large piles, limited air flow and time for temperature to build up) and aerating the compost when temperatures exceed 71°C, is not only good practice, but also provides fire protection [33].

- Ensure that there is always enough water stored at the compost site for moisturizing the piles and in case of fire [35].

- Ban smoking at compost site. Sparks from cigarettes are reported being one of the most common causes of fire at composting facilities [35].
- Keep space between piles, to prevent rapid spreading of fire [35].

Greenhouse gas prevention is a good composting practice and can be applied by following methods:

- Maintaining optimal compost conditions by proper mixture of C:N (25:1-40:1), moisture (<60%) and oxygen content (>16%) [35].
- Responsible personnel must carefully monitor the quality of the input material, and keep track of the inflows, outflows, turning schedules, and maturing times to ensure a high quality product and greenhouse gas reduction [35] (Chapter 3.4).
- Forced aeration systems must be carefully controlled and monitored. Portable equipment to measure oxygen levels and temperatures deep within composting organics are recommended for monitoring of temperature and oxygen levels [35] (Chapter 3.4).
- Stockpiles may also generate offensive odours, because excessive moisture will encourage anaerobic conditions. Therefore rain protection is recommended [35].

Pests such as vermin, insects, or scavengers can be potential disease vectors. Housekeeping and good practice prevents spreading of pests. For better prevention following steps can be implemented:

- Establishing barrier for pests by covering piles with matured compost [33].
- Ensure high temperatures (Chapter 3.4.2 and Annex) [33].
- Control fly expansion by frequent turning of compost piles through destruction of flies larvae in high temperatures (Chapter 3.4.2) [33].

PRODUCT

High levels of contaminants, pathogens, pests or toxins in organic products will degrade the quality and value of compost and increase the risk of the use. Contaminants may limit or prevent the application of the product and lower its acceptance by public [35].

Organic chemicals such persistent organo-chlorine pesticides (e.g. DDT) or polycyclic aromatic hydrocarbons are of minor concern in compost derived from domestic waste [38].

Heavy metal compounds, such a, cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), nickel (Ni) and zinc (Zn) tend to accumulate and may have short-term and long-term toxic effects on organisms in the environment and could necessitate a costly remediation or even require storage of intractably contaminated soil [35].

The sources of heavy metals are found constantly throughout the environment. Soils, plants and water contain various (low) amounts of heavy metals, depending on geological sources and atmospheric depositions. Toxic organic chemicals and metal compounds can be present in the products and may not degrade during the composting process and lead to higher concentrations in the final product. Significant health hazards can rise if contaminated composts are applied to agricultural and residential land and if heavy metals enter the food chain. The presence of contaminants can put at risk domestic animals, wildlife, plants and other living organisms and may have serious ecological consequences. Contaminated products or organics and process residues should not be stockpiled because they can contaminate organics in the process and/or the final product and need to be disposed of in landfills that are licensed to accept them [35].

Biological contaminants are pathogens, which may still remain in the end product if the compost temperature of 50-60°C was not well maintained [33].

Physical contaminants such a shredded plastic and broken glass create risk for injury or affect the quality of final products. Especially affected are products from mixed residential waste [33].

3.1.4 FEEDSTOCK CHARACTERISTICS

Many different materials can be composted but the time of composting and the product quality of it is largely dependent upon selection and mixing of the organic by-products or waste materials. The management of these materials affects the environmental conditions within the compost pile. The environmental conditions mean the adequate food, water, air and the appropriate temperature needed for microbes to thrive.

Therefore, it is important to know different characteristics of feedstock that can be used. To achieve desired compost quality several materials can be combined in a suitable proportion and is sometimes called a recipe. The recipe can carry a primary waste material that needs a treatment with one or more amendments added to it; or it can be a "co-composting", where several materials are composted simultaneously.

ALTERNATE FEEDSTOCK TERMS USED IN COMPOSTING:

"High carbon feedstocks" are often called **browns** *and "high nitrogen feedstocks" are called* **greens** *because the materials frequently are these colors. Sometimes "high carbon feedstocks" are called* **bulking materials** *and "high nitrogen feedstocks" are called* **energy materials***, but these names can cause confusion since some high carbon feedstocks have no bulking properties and both high carbon materials and high nitrogen materials contribute energy to the microbes* [20].

Whichever recipe is used, the desirable range of characteristics that required is listed in the Table 2.

SOME RECIPES USED IN COLD CLIMATE COUNTRIES
The carbon parts are dry weight and the nitrogen parts are by wet weight.

RECIPE N° 1
2 parts dry leaves
2 parts straw or wood
shavings 1 part manure
1 part grass clippings
1 part fresh garden weeds
1 part food scraps (fresh)

RECIPE N° 2
3 parts dry leaves
1 part fresh garden weeds
1 part fresh grass clippings
1 part food scraps (green)

RECIPE N° 3
1 part dry leaves
1 part fresh grass clippings

RECIPE N° 4
2 parts dry leaves
1 part food scraps (green)
1 part fresh grass clippings

RECIPE N° 5*
1 part dry grass clippings
1 part fresh grass clippings

RECIPE N° 6
1 part fish waste (carcass)
1 part saw dust
1 part green materials

RECIPE N° 7**
½—1 part straw
1 part faeces
1 part saw dust

RECIPE N° 8
1 part wet food scraps
1 part saw dust
½ part straw

* *Best used with bulking agents and frequent turning. Do not use if clippings are moldy or at risk of becoming moldy.*

** *Must maintain strict safety and temperature monitoring [20].*

TABLE 2: RANGE OF PREFERRED CHARACTERISTICS FOR RAW COMPOST MIX.

CHARACTERISTICS	REASONABLE RANGE *	PREFERRED RANGE
Carbon to Nitrogen (C:N) ratio	20:1-40:1	25:1-30:1
Moisture content	40-65%	50-60%
Particle size	0.8-1.2cm	Varies **
Porosity	30-50%	35-45%
Bulk densit	< 640 kg/m^3	-
Oxygen concentrations	> 5%	> 5%
pH	5.5-7.5	6.5-7.5
Temperature	45-65°C	55-60°C

* THESE RECOMMENDATIONS ARE FOR RAPID COMPOSTING.
CONDITIONS OUTSIDE THESE RANGES CAN ALSO YIELD SUCCESSFUL RESULTS.

** DEPENDS ON THE SPECIFIC MATERIALS, PILE SIZE, AND/OR WEATHER CONDITIONS.
THESE PARAMETERS ARE REQUIRED TO ACCURATELY CALCULATE BLENDS OF RAW COMPOST.

SOURCE: DEVELOPED FROM [40]

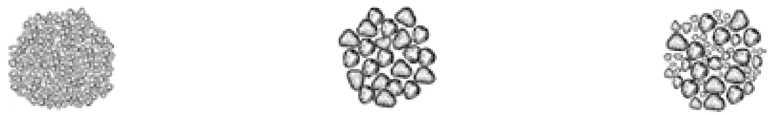
Factors that affect compost mix recipe are:

C:N ratio: The carbon and nitrogen ratio is when microorganisms responsible for breaking down the organic matter into compost use amount of carbon as an energy source and cellular building block, compared to the use of nitrogen too build proteins. If total C:N ratio is to low the pile may get too hot or the pile will use up its oxygen too fast and anaerobic decomposition process releases nitrogen as ammonia, resulting in nitrogen loss to the atmosphere and a strong ammonia odor. But if the C:N ratio is too high the decomposition process will proceed very slowly since there is no adequate nitrogen to quickly use the available carbon and it is difficult to achieve the proper temperature in the pile [20]. Not only that, C:N ratio affects the speed of decomposition as microbes and bacteria can work through pure carbon faster than tougher forms of carbon. Calculating C:N ratio is not a hard science and there's a lot of learn-as-you-go in the process, so beginners can start with "guestimating" the recipe ratios. There are many practical resources available online for free, calculators (http://www.klickitatcounty.org/SolidWaste/fileshtml/organics/compostCalc.htm) or reference charts (example follows in the chapter). Also most compost is considered finished when C:N ratio is in the range of 12:22 unless coarse woody materials are used in the raw feed stocks and are still present [22].

Moisture content: It provides the mechanism for microbe movement, nutrient transport and chemical reactions. Too much moisture, and the composting pile can become anaerobic, too little moisture and microorganisms that make composting work become dehydrated and die off [39]. The initial moisture content for composting is between 50-65%, and the final moisture content of mature compost in most applications is between 35-40%. To measure if the pile has preferred moisture content, it should be damp enough so that a handful feels moist to the touch, but dry enough that a hard squeeze produces no more than a drop or two of liquid [39].

Temperature: To produce high quality compost in the shortest time and to destroy pathogens, the compost mix needs to reach and maintain preferred degree of heat. Of course, when organisms decompose they generate heat. Nevertheless, many circumstances can affect the temperature in the pile such as moisture, oxygen and microbial activity. (Chapter 3.4.2 and Annex).

Degradability or particle size: Characteristics and particle size affect the speed of degradation. Shredding, clipping or even avoiding courser, heavier and larger materials is advised. However, reducing its size generally will expose more material to digestion; accelerate decomposition and build much higher temperature [20].



VERY FINE PARTICLES
Very small air spaces
Very poor air exchange

LARGE PARTICLES SIZE
Very large air spaces
Poor water and heat retention

MIXED PARTICLES SIZE
Large and small air spaces
Holds water and moves air

FIGURE 17: PARTICLE SIZE.
SOURCE: [20]

Oxygen supply or aeration: All desirable microbes that decompose organic matter are "aerobes" or oxygen breathers. If there is no air the "aerobes" die off and anaerobic bacteria takes over to create foul smell and other toxic substances. Therefore, mix of different particle sized materials is ideal to supply air, and also retain the surface area for bacteria's work. Sometimes these coarser materials are called bulking agents and added to create air pockets alongside with helping keep the moisture at 50% range by weight. In addition, composters can turn the mix from time-to-time to mix the outer-cooler layer into the core while providing aeration and controlling the temperature.

Odor potential: Smelly materials described in Table 3, that turn rancid quickly needs special handling or altogether should be avoided. It is not to say that these materials do not decompose. There are cases and examples of composting these materials but they need stringent management or bigger scale composting.

TABLE 3.: SMELLY MATERIALS.

Bones	Cat/Dog Manure	Peanut Butter
Butter	Salad Dressing	Cheese
Fish Scarps	Sour Cream	Chicken
Mayonaise	Vegetable Oil	Lard
Meat	Milk	Fats or oils

SOURCE: [42]

Cleanness: The end use of the compost determines what can be added to the recipe, but contamination of chemicals, heavy metals, pesticide residues, human pathogens or organisms that pose risks to health and environment, face strict regulations.

In addition, availability in the surrounding area of 80km is more cost-controllable.

TABLE 4: COMMON PESTICIDES.

COMMON NAME	TRADE NAMES	LONGEVITY IN SOIL (MONTHS)
Benefin	Balan, Balfin	4-8
DCPA	Dacthal	4-8
Bensulide	Betasan, Prefar	6-12
Glyphosate	Roundup, Kleenup	Less than 1
2,4-D	(many formulations)	1-2
MCPP	(many formulations)	1-2
Dicamba	Banvel	3-12

SOURCE: [41]

Following is the list of some common organic materials and their C:N ratio.

TABLE 5: C:N RATIO OF COMMON FEEDSTOCK.
SOURCE: DEVELOPED FROM [43]

MATERIAL	SOURCE	C:N (By weight)	COMMENTS
MATERIALS WITH HIGH NITROGEN VALUES (WET MATERIALS)			
Coffee grounds	Restaurants, offices	20:1	Good source of nitrogen (N).
Feathers, feather meal and feather dust	Farms	More than manures	See hair.
Fertilizer and Urea	Garden waste		Concentrated nitrogen sources that sometimes added to lower the C:N ratio of high carbon materials such as leaves.
Faeces	Ecotoilets, UDD toilets, public empty-able toilets	5-10:1	Must maintain high constant temperature (at least 55°C for 7 days) to destroy pathogens; odor prevention steps must be undertaken; Workers should employ PSP diligently (See also Chapter 3.4.2).
Food waste	Canneries, restaurants, households, sorted garbage, catering waste	20:1	Facilitates the decomposition of less potent materials. Moderate to wet, moderate to low C:N. Poor to fair structure. High risk of odors, vermin, contaminants from machinery. Good to poor composting material.
Fruit wastes	Canneries, restaurants, market dumps, fruit production industries	35:1	Banana peels are rich in K. Moderate to wet, moderate to low C:N. Poor to fair structure. Slight to moderate odor problems. Good to fair compost material.
Grass clippings	Lawn mowing, lawn services, neighbors bags set at curbside	12-25:1	Use only herbicide-free clippings; high in N; decompose rapidly and help heat up compost pile; smelly unless blended with C-rich materials.
Hair	Barber shop, beauty salon, or poodle grooming business	More than manures	Resists absorbing moisture and readily compresses, mats, and sheds water; needs to be mixed with other wetter materials.
Manure	Farms, stables, poultry houses, feedlots, animal husbandry	Cow manure 20:1 Horse manure 25:1 Horse manure with litter 30-60:1 Poultry manure (fresh) 10:1 Poultry manure (with litter) 13-18:1 Pig manure 5-7:1	From high to low N: pigeon, chicken, duck, horse, rabbit, pig, cow, sheep. Very wet to moderately moist, requires large amount of dry, high C amendment. Decomposes quickly. Odor potential is high if not composted quickly and well.

MATERIAL	SOURCE	C:N (By weight)	COMMENTS
MATERIALS WITH HIGH NITROGEN VALUES (WET MATERIALS)			
Sod*	Lawn clippings, gardens		Slow to decompose. Break into small clumps, mix thoroughly with other materials or cover top of the pile with roots up, grass down (better in fall), or compost separately with roots side up, water thoroughly, cover with a dark tarp.
Vegetable waste	Canneries, restaurants, sorted garbage, food stores, farms, market dump	12-20:1	Pea pods very high in N.
Weeds*, other	Gardens, fields, pond dredgings	30:1	Nutrient content is highly variable depending on the species and age of the plant. Tender young weeds are as rich in nitrogen as spring grass. Weed seeds hard to kill. Best to use when green and no seed heads present or leave in hot pile (55-60°C) at least one week. Cut before seeds set, or use in hot compost pile; purslane is high in N (Chapter 3.4.2).
MATERIALS WITH HIGH CARBON VALUES (DRY MATERIALS)			
Bark	Woods, dumpings in parks or at curbside, streets	100-130:1	Contains slightly more N than wood chips. Easily degradable but composting time is long. Good bulking agent.
Cardboard* (non-recyclable, shredded)	Office, publishing houses	350:1	Dry. Slow to decompose. Good degradability, moisture abruption and structure. Shred into small pieces. If desired, put in water and add a drop of detergent to further speed decomposition.
Corncobs and stalks*	Farms, canneries, garden refuse	60-75:1	Slow to decompose. Run through shredder or chop into very small pieces, mix with nitrogen rich material. Best when ground or used as a mulch texturizer; high in C.
Foliage (Leaves)	Woods, dumpings in parks or at curbside, streets	30-80:1	Moderate moisture absorption, low odor potential. Can contain trash, rocks, plastic bags. Leaf mold (decomposed leaves) an excellent soil texturizer; contain growth inhibitors if not first composted; shred before adding to pile.

MATERIAL	SOURCE	C:N (By weight)	COMMENTS
MATERIALS WITH HIGH CARBON VALUES (DRY MATERIALS)			
Grass clippings with chemicals*	Gardens, fields, pond dredging	25:1	Pesticides and herbicides are a concern, degradability ranges from one to twelve months. Leave grass clippings on the lawn (best) or add to pile if material composts for at least 12 months or wait 2-3 weeks before using clippings from lawn after chemicals applied. Do not use clippings as garden mulch for at least 2-3 weeks (or after 2 mowings) after chemical application.
Hay	Farms, fields	25:1	Bulky; high in C; alfalfa highest in N; tend to mat if not well broken and mixed in. require more turning.
Newspaper	Office, publishing houses	400:1	Dry. Moderate degradability because of its high lignin content. Some caution should still be used with glossy magazines, which sometimes use heavy metal based inks to produce vivid colors. Good moisture absorption but poor structure and porosity.
Nut shells* – walnut, pecan, peanut	Peanut butter processors	35:1	Slow to decompose. Pulverize with shredder. Good soil texturizer with moderate humus potential; slow to breakdown; high in C and K.
Paper (mixed, non-recyclable)	Office, publishing houses	150-200:1	Almost pure cellulose and has a very high C:N like straw or sawdust. Valuable source of bulk for composting mulch. Shred or grind it. Layers of paper will compress into airless mats. Can be shredded by hand, easily ripped into narrow strips by tearing whole sections along the grain of the paper, not fighting against it. Provides good absorption, but not much airspace.
Pine Cones*	Woods, evergreen plantings		Slow to decompose. Shred or chop into very small pieces.
Pine needles*	Woods, evergreen plantings	60:1-110:1	Slow to decompose. Mix thoroughly with other materials, add in small quantities. Highly acid N source; use on acid loving crops or with neutralizer.
Sawdust, shavings, woodchips*	Lumberyards, tree surgeons, sawmills, carpentry shops	100-500:1	Agent for forced aeration. High in C; exceedingly slow to break down; never add fresh sawdust directly to soil; can negatively affect aeration. Work into pile in thin sprinklings, mix with nitrogen rich material; turn frequently. Good moisture and odor absorption.

MATERIAL	SOURCE	C:N (By weight)	COMMENTS
MATERIALS WITH HIGH CARBON VALUES (DRY MATERIALS)			
Walnut leaves*	Walnut farms, Gardens, fields, walnut processors	25:1	Contain juglone which can be toxic to plants. Add in small quantities, mix thoroughly; toxin will biodegrade in 30 to 40 days.
Weeds, pernicious*	Gardens, fields, pond dredging	25:1	Rhizomatous root system hard to kill. Sun-bake in plastic bag until thoroughly dried or omit from pile. Weeds that propagate through underground stems or rhizomes like quack-grass, Johnson grass, bittersweet, and the like are better burnt.
Wheat straw, oat straw	Farms, fields	40-100:1	High in C; slow to break down, provides very good structure and odor absorption. If used as bedding, it can precondition manure for composting.
OTHER (OR BOTH C & N)			
Eggshells	Egg farms, restaurants	0, Alkalizer	Calcium and N source.
Finished compost	Composting facility	Moderate to low C:N	Moderately dry. Amendment for wet wastes. Good initial supply of microorganisms. Lowers mix moisture content without raising C:N ratio.
Fish and shellfish scraps*	Fish markets, restaurants, fishery	6:1	Proteinaceous, high-nitrogen and trace-mineral-rich material, but smelly. Fresh seafood wastes must be immediately mixed with large quantities of dry, high C:N material.
Lime*	Farm supply stores, hardware stores, greenhouses, nursery	0, Alkalizer	Changes pile chemistry, causes nitrogen loss, and too much lime hurts bacteria and other microorganisms. Omit from pile or use very sparingly in thin layers, if pile is going anaerobic (do not mix with manure). But in a very acid and bacterial fermentation is inhibited to correct low pH can be used ca 11 kg at one ton of dry weight.
Peat moss*	Aquarium, turf, topsoil and peat suppliers, gardens, garden center, nursery	0, low in nutrients	Acidic fibrous material, highly absorbent of water (can hold 10 times its weight in water), nutrients and odor, slow to decompose. Mix thoroughly with other materials, add in small quantities. If possible, soak peat moss in warm water before adding to pile.
Soil*	Turf, topsoil and peat suppliers, gardens, garden center, nursery	0, Activator source	Can make finished compost heavy. Add small quantities in thin layers as soil activator or omit from pile (finished compost produces the same results and typically weighs less).

MATERIAL	SOURCE	C:N (By weight)	COMMENTS
OTHER (OR BOTH C & N)			
Stable bedding, sweepings	Stables, farm	C&N	Better nutrient balance than manure alone.
Wood ash*	Fireplaces, wood stoves, wood furnaces, bonfires	25:1; O, Alkalizer, potash	Changes pile chemistry, can cause nutrient imbalance. Use very sparingly in thin layers; do not use on top of pile or omit from pile. K and P but no N; use sparingly (strongly alkaline); don't use ashes from fires started with charcoal or painted wood.

N = NITROGEN; P = PHOSPHORUS; C = CARBON; K = POTASSIUM;
* COMPOSTABLE MATERIALS THAT REQUIRE SPECIAL HANDLING.

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3.1.5 SEASON MANAGEMENT AND WEATHER

There are number of strategies one can use to adjust composting process to the climate and seasonal weather conditions. Under climate conditions particularly temperature, wind and rainfall needs to be managed depending on place and system. Composting occurs in every climate and in every location naturally. The only difference is the speed of the progress and average quality of the compost. Organic material itself has high insulating properties that come in handy to face climate conditions. In a pile system the outer layer can stay cold but insulate the core where decomposition process would still continue. In this case, the temperature difference can be observed per cm of the material in cold climate. Turning does not need to happen often and then temperature recovery period followed in the pile. Example of pile size [20].

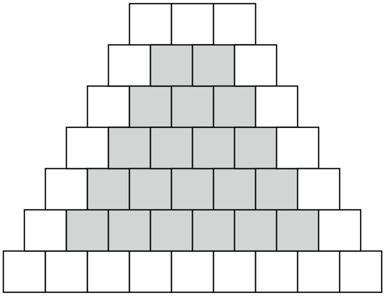

FIGURE 18: PILE SIZE-BIG.
CORE = 1.9 – 3.9 m^2.
OUTSIDE INSULATION = 1.4 – 3.9 m^2.
SOURCE: [20]

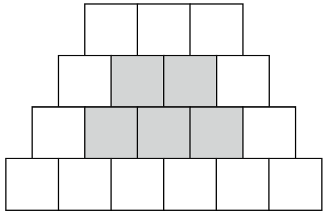

FIGURE 19: PILE SIZE-SMALL.
CORE = 0.5 – 1.7 m^2.
OUTSIDE INSULATION = 0.8 – 1.7 m^2.
SOURCE: [20]

According to Solomon S., wind both lowers temperature and dries out a pile, therefore; if possible, compost in a sheltered location [41]. In addition, making the particle size of the materials about 5cm and wetting the exterior on the windward side will create homogeneous mass that will stop wind penetration and help expand high-temperature zone from the core to the surface [44].

Using bins or other compost structures can hold heat that might otherwise be lost from the sides of unprotected heaps [41] (See Annex, included are practical examples of common bins and other compost structures).

Heavy, cold rains can chill and waterlog a pile. The piles can be finished with a rounded top and adequate drainage so that water can ran off. Larger sized piles can easily withstand these and temperature challenges with monitoring and subsequent turning. In rainy areas, pits should be lined with concrete, brick, or masonry, and provided with tile drains. Alternatively, roofs could be built over the bins or pits to protect them from rain [44]. Composting under a roof will also keep hot sun from baking moisture out of a pile, in summer. Nevertheless, composting can be done in relatively cold climates or rainfall with minimum roofed buildings.

Not only composting process but also pre-treatment should be managed to face weather challenges. Feedstock stacking or piling, sorting, storage, and shredding or grinding should not be done under rain; therefore, adequate short-term facilities must be planned.

According to WSU Extension, heavy snowfall will greatly hinder continuous composting operations and removal of snow from the composting piles or bins will usually be required. Material will not become anaerobic or create an odor nuisance during cold weather. Hence, if an ample composting area is available, the material can be allowed to stand for long periods without turning until the weather is favorable.

Not all systems are sensitive to the climate conditions, for example indoors vermin-composting or in- vessel composting can operate all year-around and deal with kitchen waste during winter too. Insulation or thicker soil cover, can also help maintain high core temperature even if the surface is frozen.

PREPARING FOR WINTER

These practical suggestions by Haley Paul from Earth911 are worth mentioning here for composting project:

1. *Build a roof.* Control external environmental factors by protecting the pile from unwanted precipitation. Covering with plastic with holes is the cheapest method.

2. *Block it in.* As one desires to find a garage for their car in the winter, same concept applies to the composting unit. Bales, soil wall, cardboard, or leftover construction insulations e.g. EPS can be used for bins and piles. Even snow can be used as insulation.

3. *Lay down a tarp.* Putting a tarp over compost pile not only whisks away unwanted precipitation, but it also helps contain the internal heat.

4. *Make a bigger heap.* Extend the longevity of the pile by prepping early. According to the University of Illinois Extension, "During [the] fall months, making a good sized heap will help the composting process work longer into the winter season."

5. *Shred it.* According to the Texas AgriLife Extension Service, "Shredding the material in the pile to particles less than 5cm in size will allow [the pile] to heat more uniformly and will insulate it from outside temperature extremes".

6. *Dig a hole and bury it.* To utilize soil heat and insulation dig a trench in the garden or flowerbed and place compost bit there directly. Collect household organic wastes in a container with a lid and when it gets filled add it little by little into the trench pile; make sure to bury the waste after each addition.

Similarly, covering with a board or bricks until full of organic wastes, is another strategy to beat the winter cold and keep on composting [45].

3.2 METHODOLOGIES FOR PLANNING

It is essential for any kind of project, to be familiar with circumstances of the project area from the start and determine how they may influence the implementation success. Therefore, the information collection is indispensable part and of essential importance. The necessary information can be obtained from two different sources: primary and secondary.

Primary data is firsthand information collected from key informants [46].

Secondary data is already collected information by others [46].

The research concept can be divided in two types: quantitative and qualitative research. The quantitative research can help to identify the issue while quantitative method helps to understand the degree.

3.2.1 IDENTIFYING STAKEHOLDER INTERESTS DIFFERENT

OBJECTIVES:

- Identifying all relevant stakeholders;
- Identifying their needs and interests.

METHODS:

- Collecting the information from secondary data like newspapers and reports [46];
- Identifying the needs and interests of the stakeholders related to the project in open or one-on-one meetings [46];
- Evaluate collected information about stakeholders in the first risk assessment by using structured table which includes all relevant stakeholders. Furthermore, their positive (+) or negative (-) impacts and formulated potential chances or risks [46].

3.2.2 IDENTIFYING RELEVANT LAWS AND REGULATIONS

OBJECTIVE:

- Identifying relevant laws and regulations, which may affect implementation of the project.

METHOD:

- Reviewing and analyzing relevant laws and regulation for compost, if necessary the expertise can be obtained from a lawyer or other experts [46].

3.2.3 MARKET ANALYSIS

OBJECTIVE:

Assessing of potential markets.

METHODS:

- Collecting relevant information about [46]:
    a. Potential customers (must need and/or want the product and be willing and able to pay);
    b. Competition and competing products;
    c. Businesses environment (social, politic, economic and environment).
- Segmentation of the market will help to organize the information about the potential

customers by their needs, willingness and ability to pay for the product. Using fact sheets with all relevant information about each group will provide help in collecting and assessing the data [46];

- Analyzing the current environment will help to identify if conditions are favorable or not for setting up a compost production. Following factors can be crucial for the decision of implementing compost projects [46]:
  a. No demand for compost due to the availability of cheaper fertilizers;
  b. Constant water shortage;
  c. Lack of land

3.2.4 ASSESSING LAND AVAILABILITY AND COMMUNITY INTERESTS

OBJECTIVE

- Identify suitable location for the composting plant and cooperativeness of the community.

METHODS

- Participatory approaches with the target community can contribute to the successes of implementation and influence organizational setup. Therefore, organizing community meetings is an important tool to introduce the project to the community and to choose the right plot for the project. The content of the meeting should include following information [46]:
  a. Advantages and disadvantages of current situation;
  b. Vision and scope of the project;
  c. Successful examples;
  d. Tasks and duties of the community;
  e. Questions and answers;
  f. Objective discussions, without defending the project;
  g. Establishing committee, selected by the community members to represent the community interests.
- Conducting structured surveys, by using it as a tool to quantify the information collected in the meeting about the target community [46];
- Organize visits to the proposed compost site with relevant stakeholders (municipality officers and community committee) and discuss selection criteria [46];
- Signing a contract for the compost site with responsible parties [46];
- Signing a written agreement with all stakeholders in the form of Memorandum of Understanding (MoU) [46].

3.2.5 EVALUATING TOPOGRAPHY AND ROAD CONDITIONS

OBJECTIVE

- Collecting relevant information to prepare a decision for an appropriate waste collection vehicle.

METHODS

- Analyzing local topography and road conditions [46];
- Collecting information about the available types of vehicles for transporting goods [46].

3.2.6 COLLECTION OF RELEVANT INFORMATION FOR TECHNICAL DESIGN

OBJECTIVE

- Collecting data related to technical design of the compost plant.

METHODS

- Collecting data about composting material generation. Data could be obtained from already available information, however, may not contain local determining factors. Therefore not very accurate. Consequently, it is suggested to conduct own study about the target community, by organizing one-week survey among sufficient number of households randomly selected in the community [46];
- Define the number of the households covered by the compost plant, respectively to the planned compost size [46];
- Analyzing the composition of composting material, such as physical and chemical composition of waste. Physical composition is a ratio of organic and inorganic waste, density and moisture for chemical it is important to know the phosphate (P) and nitrogen (N) content of the materials [46]. (see also Chapter 3.1.4)

3.2.7 PREPARING BUSINESS PLAN

OBJECTIVES

- Develop appropriate business model;
- Determine the viability of the project;
- Develop contract.

METHODS

- Developing of business partnership, like any partnership should be based on common objectives, balanced power, clear agreement, mutual trust and understanding. Four different management models can be applied, depending on local situations [46]:

a. Municipally owned and operated;
b. Municipally owned and community operated;
c. Municipally owned and privately operated;
d. Privately owned and privately operated.

- Perform the cost-benefit analysis to assess the financial viability of the project. The analysis includes following steps [46]:

a. Set up a time frame for the project;
b. Determine annual project revenues;
c. Determine annual project costs;
d. Calculate annual project net benefits;
e. Determine appropriate discount rate;
f. Calculate the financial net present value;
g. Calculate the cost-benefit ratio.

- Develop the contracts after the appropriate business model, cost- benefit analysis and the approval to set up composting plant with all partners [46].

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3.3 METHODOLOGIES FOR IMPLEMENTATION

For successful implementation of the project all relevant information to make the right decisions, should already be available by this step.

3.3.1 DEVELOPMENT AND DESIGN OF THE COLLECTION SYSTEM

OBJECTIVES

- Select the most appropriate waste collection system;
- Mobilize community for participation and waste collection;
- Organize and introduce collection fees.

METHODS

- Compare different vehicles used for reliable transportation that are available at the local market and check if the vehicles fulfill the requirements and conditions [46];
- Choose appropriate collection system using the outcome of the target community surveys. Following models are possible [46]:
  a. House-to-house collection;
  b. Block/Bell collection;
  c. Sideway collection;
  d. Communal collection bins.
- Calculate the number of vehicles by considering following factors [46]:
  a. Volume of the collection vehicle;
  b. Collection frequency;
  c. Required time for one collection team;
  d. Number of collection teams necessary to cover the entire area.
  e. The calculation may need to be adapted after the first collection experience. Also, it is highly recommended to consider an additional backup vehicle.
- Contact community leaders and Community Committee to inform about the latest decisions (such as collection system) and future objectives [46];

- Contact households directly or at community meetings to inform about the launch of new collection system and related organizational set ups, with the help of simple flyers with collection schedules [46];
- Request staff for the new collection scheme, ideally from among the community members [46];
- Maintain the community interest and participation through regular information distribution, e.g. at least once a year [46];
- Introduce the collection fee periodically, e.g. monthly [46];
- Nominate official fee collectors [46];
- Ensure accountability and transparency [46];
- Promote source separation through following measures [46]:
  a. Preparing and distributing flyers among the household to describe the benefits;
  b. Placing posters with basic information to the collection vehicles;
  c. Organizing an open-house event, inviting the community to the composting plant.

3.3.2 DESIGN, CONSTRUCTION AND SET UP OF COMPOST FACILITY

OBJECTIVES

- Construction of compost facility;
- Set up operation monitoring and maintain process.

METHODS

- Planning and drawing the composting plant layout. The composting plant should be divided into the different zones and must be arranged to ensure the optimal workflow. The zones should contain space for [46]:
  a. Waste unloading and sorting;
  b. Composting;
  c. Maturation;
  d. Sieving and bagging of the compost;
  e. Storage space for compost;
  f. Sanitary facilities for the workers.
- The compost plant can be scaled up or down, however the maximum capacity of decentralized composting site should not exceed five tonnes per day [46].
- Planning required key features [46]:
  a. Onsite water supply is basic requirement on the composting site;

b. Composting area including the required roof construction;
c. Storage area for compost and the rejects including the roof construction;
d. A useful feature is a demonstration site;
e. Wastewater reuse system.

- Planning staff requirements [46];
- Planning additional equipment and expenditure [46];
- Setting up operation and monitoring processes. The operation process may include all following steps [46]:

a. Sorting;
b. Mixing;
c. Piling or filling of the waste materials;
d. Turning in case of windrow composting;
e. Temperature control;
f. Moisture control;
g. Maturing/Curing (incl. temperature and moisture control);
h. Screening, storage and bagging.

- Quality control needs to ensure providing information about nutrition content and invisible pollutants for the safe application. Following parameters need to be analyzed [46]:

a. Maturity;
b. Non-toxicity;
c. Balanced nutrient content.

3.3.3 COMPOST MARKETING

OBJECTIVE

- Develop marketing strategy for the compost.

METHOD

- Develop marketing strategy by applying the 4 P's [46]:

a. Product (Product features and quality);
b. Price (and terms of payments);
c. Place;
d. Promotion.

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3.4 METHODOLOGIES FOR MONITORING

In any type of composting there are three main parts where monitoring needs to be carried out [22]:

- Monitoring inflow and outflow (or input-output) of materials;
- Monitoring composting process: keeping track of key chemical / physical / biological parameters;
- Monitoring of operations and maintenance of the facility;
- And monitoring of product quality.

This sub-chapter gives detailed monitoring guidelines along with examples of helpful tools in the Annex. Good monitoring helps not only optimize the composting process by helping avoid problems (such as pathogen) and build experience in comparing different composting conditions, but also control operating cost and improve efficiency. Therefore, monitoring should always come together with good record keeping. In case of first-time composters or long-time practitioners, many diverse factors affect composting that only experience built upon monitoring could help troubleshooting in many cases. Record or logbook keeping shall apply in all three parts of composting and it should include following details [22]:

a. Quantities by weight or volume, types, and dates of materials received;

b. Composition/proportions of compost mixtures ages and locations of piles, turning;

c. Watering schedules, precipitation, moisture levels, ambient/room temperatures, outdoor and temperatures;

d. Curing time;

e. Maturity testing;

f. Equipment, time, labor, fuel, maintenance, and other overhead;

g. Distribution/use of materials composted, if applicable.

3.4.1 MONITORING OF INPUT AND OUTPUT MATERIALS

OBJECTIVES

- To ensure that a non-compostable material does not go in;
- To ensure C:N (25:1-30:1) ratio according to the amount or volume;
- To document input material quality for process safety and product quality;
- To ensure feedback system in the supply chain (at the community level).

METHOD

- Develop and maintain a logbook that will contain details of date and time; supplier (if at the community level i.e., restaurant, farm etc., or at the household level it would be location: i.e., kitchen waste, household etc.,) quantity or volume; actions taken for rejects (See an example form in the Annex) [22].

3.4.2 MONITORING OF COMPOSTING PROCESS

OBJECTIVES

- To ensure that correct compost recipe is achieved at the loading stage following preferred characteristic table mentioned above.
- Monitor curing stage;
- Ensure screening for product quality;
- Monitor maturity.

METHODS

Monitoring of composting process seems daunting, but it is one process where bacteria will do all the work if proper conditions are created and maintained. In many household and medium level composting temperature sensor, observation and a "nose" are only practical equipments needed to monitor the proper condition of composting process. Following are some guideline methods to ensure different parameters that can be considered in this stage according to Jean and Karen from Cornell Waste Management Institute [22]:

- Loading stage: To record the ages and locations of compost piles, contents, moisture and temperature data, turning, and watering schedules (See Annex for sample process logbook). If needed acquire an oxygen monitor, moisture analyzers, and temperature gauges (still the most common, and only, means of monitoring the process is temperature gauge).
  a. *Temperature:* Use thermometers with 1-1.5m probe to ensure efficient temperature of 55-60°C, and turning temperature of 71°C is reached (dual or digital types available). Track time of temperature change if needed daily. (Sample form is in the Annex).
  b. *Odor:* Smell and observe the pile. If smells such as rotten-eggs, ammonia or other putrid odors coming from pile, than is a necessity for troubleshooting.
  c. *Oxygen* levels between 5-15% are usually recommended. For static piles, oxygen is provided by air circulation through pore spaces. Oxygen sensor could be used for troubleshooting.
  a. *Moisture:* perform "squeeze" test to ensure preferred moisture level of 40-60% maintained.

d. *Pathogen control:* To ensure the destruction of bacteria and fungi, make sure to document following: :

- During turned windrow method, a minimum of 5 turnings is required during a period of 15 consecutive days when the temperature of the mixture is not less than 55ºC within 15-20cm below the surface of the pile. .

- During aerated static pile, the pile must be insulated (covered with a layer of bulking material or finished compost) and a temperature of not less than 55ºC must be maintained throughout the pile for at least 3 consecutive days, monitored 15-20cm from an outlet of an aeration pipe.

e. *Aspergillus fumigatus and other bio-aerosols:* Supply and maintain staff habit of using protective dust masks.

f. *pH*: Using a soil pH testing kit, or a pH meter to ensure pH range of 6-7.5 reached during decomposition, and pH 7 in the end product.

- Curing stage: When the temperature of the windrow no longer increases after turning, the curing stage can begins. The piles should be small enough to allow air circulation (usually 2-3m high and 4.5-6m wide) and can be placed closer together than those actively composting. It is recommended that the curing process take a minimum of one month and it is completed when measured temperature stays at or near ambient temperature [22].
- Screening: By moisture leve between 39-45% screening of unwanted materials that were not fully decomposed can take place also recovering of bulking materials for further reuse.
- Monitor maturity: The end use of the compost determines the degree of maturity required. But generally when compost is not emitting odors by becoming anaerobic or contains alcohol or acid then it considered to be matured [22].
- Conduct squeeze test to see if moisture is at 50% or using oxygen analyzing probe, the oxygen concentration should be greater than 5% at the center of the pile [22].
- A wet and sealed compost sample placed in a sealed plastic bag should emit a mild earthy odor when opened after a week of storage at temperatures between 20-30ºC [22].
- The temperature of the compost with 40-50% moisture stays at room temperature after several days when placed in a well-insulated, sealed container [22].

3.4.3 MONITORING OF OPERATION AND MAINTENANCE

OBJECTIVES

- To meet health and regulations;
- To follow internal work process steps;
- Strive for cost efficiency;
- Ensure transparency and clear accounting.

METHODS

- Utilize maintenance log (example in Annex) [22];
- Establish cost-revenue balance [22];
- Establish reporting and study-tour events for community [22];
- Establish a staff training and education scheme [22];

3.4.4 MONITORING OF COMPOST QUALITY

OBJECTIVES

- To measure chemical, biological, and physical properties;
- Heavy metal, organic chemical, and pathogen concentrations of the compost must be within the limits established regulations;
- Relevant nutrient labeling requirements must be met, if the compost is to be sold for use in agricultural or horticultural applications. The physical characteristics – color; texture, structure, porosity, and particle size - of compost are important factors in product marketability.

METHODS

- Keep accurate records [22];
- Establish end-product specifications [22];
- Institute sample analysis program [22].

3.5 BUDGETING

Depending on the scale of the composting project the budget can differ. For instance, the initial investment for a single family composting, one needs to determine the cost of compost bin according to the organic material generation and correct mix of brown versus green materials, pitchfork and water. In an overly simplified manner this example summarizes the main categories of expenses composting generally requires. In the Annex attached an example of cost calculations that can assist in creating a composting project budget in a bigger scale.

OBJECTIVE:

- Economic assesment of composting.

METHODS:

- General composting costs [47].
- Detailed assessment of current waste generation data using Waste Audit Form. Complete Cost-Benefit Analysis using Cost-Benefit Analysis form (see Annex) [47].

TABLE 6: GENERAL COMPOSTING COSTS, EXAMPLE OF CATTLE FARM.

RETURNS AND SAVINGS FROM COMPOSTING		
	MODEL	ACTUAL
ANNUAL INCOME RECEIVED		
Compost sales		
REDUCED EXPENSES		
Purchased bedding savings		
TOTAL RETURNS AND SAVINGS		
TOTAL COST		
VARIABLE EXPENSES		
Operating and maintenance cost		
Special machinery: (Payloader, skid steer, self- powered turner, tractor etc.)		
Separator, pipes & pumps		
Fuel		
Lubrication		
Repairs		
Electricity		
Record keeping		
Marketing		
Labor		
TOTAL VARIABLE EXPENSES		
FIXED EXPENSES		
Insurance		
Facility depreciation		
Composting equipment depreciation		
Average annual interest on investment		
Facility annualized cost		
Equipment annualized cost		
TOTAL FIXED EXPENSES		
TOTAL ECONOMIC COST (Sum of Above Expenses)		
ANNUAL COST (Less Savings and Generated Income)		

SOURCE: DEVELOPED FROM [20]

3.6 TROUBLESHOOTING

This chapter will offer some troubleshooting recommendations for the compost pile. As there is not one perfect recipe there are not many one-to-all solutions. Every compost pile will have their unique conditions that need to be considered. But the main parameters of balanced C:N ratio, right moisture content and adequate air supply are essential. Also location of the pile can bring challenges: is it in the sun that it's drying even though it additional heating? Is it in the wind that it's chilling? Is there a roof? A good drainage for rain water? Is it placed directly on soil or is it on a posthole? Is the soil and compost bacteria nitrogen?

TABLE 7: TROUBLESHOOTING.

PROBLEM	POSSIBLE CAUSES	SOLUTION
Rotten odor	• Anaerobic conditions – low temperatures o Materials too wet. - Poor structure. - Pile compacted. - Insufficient aeration. • Anaerobic conditions – high temperatures. - Pile too large. - Airflow uneven or short circuiting.	• Add dry amendments. • Add bulking materials. • Remix pile and add bulking material if needed. • Turn pile or increase the airflow rate. • Decrease pile size. • Remix pile; change recipe.
Ammonia odor	• Too much nitrogen C:N is 20:1. • pH too high - greater than 8.0. • Lack of or slowly available carbon source.	• Add high carbon materials (sawdust, woodchips, or straw). • Avoid alkaline ingredients, add acidic ones. • Add carbon material or use different one; If static pile, add high carbon materials.
Low pile temperature	• Pile too small. • Materials too dry. • Materials too wet. • Poor aeration. • Not enough nitrogen, or stable material. • Cold weather.	• Make pile bigger or insulate sides. • Add water while turning pile. • Add dry amendments and remix. • Turn pile. • Mix in nitrogen sources such as grass clippings or manure, change composting recipe. • Increase pile size or insulate pile with an extra layer of material such as straw, add highly degradable ingredients.
High pile temperature (over 70ºC) stops heating, smells	• Thermal destruction of microorganisms has occurred. • Pile too wet. • Insufficient aeration. • Pile too large.	• Turn pile 2 days in a row & monitor temperature. • Turn pile whenever temperature reaches 71ºC. • Reduce size.

PROBLEM	POSSIBLE CAUSES	SOLUTION
Standing water/surface ponding	• Inadequate slope. • Improper windrow/pile alignment. • Depression in high traffic areas.	• Establish 1-2% slope with proper grading. • Improve drainage, add absorbent Run windrows/piles down slope, not across. • Fill and regrade.
Inadequate composting rate	• Material too dry. • Material too wet; pile too large leading to anaerobic conditions. • Pile too small, leading to excessive heat loss. • Uneven distribution of air, moisture, or nutrients.	• Fill and regrade. • Add water initially, or as a corrective measure when turning Spread out to dry; remix, make pile smaller. • Make 0,5m high, colder regions may require greater heights. • Turn or shred pile, wetting if necessary.
Center is dry & contains tough materials	• Not enough water	• Chip woody materials, moisten & turn.
Pile has gotten very wet from rain or snow	• Excessive moisture has smothered or drowned microorganisms.	• Turn pile every day until it starts to heat again (do not add more bulking materials).
Animal infestation	• Food scraps exposed. • Materials spilled outside of pile.	• Process as soon as possible, add insulating cover. • Improve housekeeping, clean up spills. • Get a cat! • Plant tall grasses to discourage nesting of birds.
Mosquitoes/flies	• Presence of stagnant water. • Flies breeding in the fresh manure or food materials at the pile surface of the compost pile. • Flies breeding in wet raw materials stored on site more than 4 days.	• Eliminate ponding, grade site properly. • Remix weekly to turn surface eggs and maggots into hot interior where they will be destroyed. • Handle raw materials properly.
Non-compost pile odors	• Residuals left in receiving zone. • Organics spilled outside of pile. • Standing water, high in organic residue. • Build-up of food scraps on equipment.	• Practice good housekeeping, keep high traffic areas clean, remove residuals from equipment. • Clean up, reduce spills, cover with absorbent carbon sources. • Clean up spills, (see standing water/surface ponding). • Routinely wash equipment and remove food residuals.

DEVELOPED FROM COMPOST TROUBLESHOOTING GUIDE [22, 40, 47]
(COMPLEMENTARY PRACTICAL Q&A SECTION IS INCLUDED IN THE ANNEX).

4 - COMPOST SYSTEM ULAN BAATOR

4.1 INTRODUCTION

PHOTO 9: EMEELT COMPOST SITE, ULAAN BAATOR.
SOURCE: ACF.

The semi-centralized Emeelt compost site is located at the outskirts of Ulaanbaatar (UB), 30 km, away from the centre. Compost facility produces compost and treats human faeces at the same time, from the installed Ecosan toilets in the peri-urban area of UB.

Overall three composting facilities were constructed on-site, by Action Contra la Faim (ACF) Mongolia: Winter Composting Facility (WCF) in 2010, Green House Unit (GHU) in 2013 and Passive Aeration Platform (PAP) in 2014, the last two refer to summer compost facilities.

Additionally, Emeelt composting site features further facilities for adequate operation such as: storage facilities that include open air fenced area and “Dirty Storage” (DS) an indoor storage building; mixing platform; cleaning platform; another greenhouse for maturation; staff room equipped with a shower and washing machine; borehole for water supply and storage containers; security house and fence across the site with a sign.

4.2 FEEDSTOCK SYSTEM AND COLLECTION

Feedstock Materials are provided from the eco-toilet users in UB, installed by ACF since 2009 and accepted among users in the area. ACF together with University of Technology and Science Beijing (USTB) have developed and refined different designs of eco-toilets. The main difference between the first and the second models is the disposition from the ground, while 22 zip-zap toilets are based on the ground level and slide; the 348 raised-eco-toilets are about one meter above the ground level. Both designs consist of a base and buckets used for faeces collection. The second distinction is the size and amount of buckets for collection. 120 “old” eco-toilets that were built between 2009 and 2011 contain one bucket and 250 “new” eco-toilets constructed in 2013 contain two buckets beneath the substructure.

FIGURE 20: ECO-TOILET,
SOURCE FOR FEEDSTOCK MATERIALS.
SOURCE: ACF.

PHOTO 10: EMPTYING SERVICE.
SOURCE: ACF.

Collection System and Emptying Service of the faeces was carried out by ACF all year around using house to house collection system, in intervals of three/four months, depending on the amount of buckets. Toilets with one bucket were emptied in three months whereas toilets with two buckets in four months intervals. However, in case of toilets with two buckets system, the full one is required to be exchanged by the households themselves.

The collection is performed manually, by two people through exchanging of full 120l steel/ plastic containers beneath the toilet substructure by clean and empty one. Afterwards full containers are covered with lid, placed and transported by truck to the composting site for further treatment and hygienization. The capacity of the truck has been increased from 8 to 16 buckets per trip to reduce the cost and time for emptying service. After completing the emptying service the truck is cleaned on a daily basis.

The employer in charge of collection service have been trained in personal hygiene and protection, and provided with personal protective clothing to avoid the risk of pathogen transmission during the service.

To simplify logistics and required efforts in handling the faecal material, the urine is diverted and discharged into the ground since there is no market for its application in Mongolia. In addition, the users have been advised to apply sawdust after each defecation to reduce the moisture content and the weight of faeces. Application of sawdust provides carbon source for microorganisms to start the decomposition process. It covers the faeces and reduces odours. Besides, the users are been advised not to dispose any trash into the toilet, which can interrupt the composting process.

Since 2015, the emptying service was handed over to MonESIC a local NGO and emptying service fee was introduced to the toilet users. Even though, the need to introduce the fee was based on careful assessment and move towards sustainability the number of users that utilized the service has dropped significantly. The taboo perception of working with faeces, low acceptance of ecosan principles and along with lack of strong policies and regulations against soil and water pollution are creating bigger challenge in pursuing and continuing the work of turning waste to wealth. The local NGO is researching new ideas and incentives to attract more users to the emptying service.

PHOTO 11: DIRTY STORAGE (LEFT) AND FENCED STORAGE AREA (RIGHT).
SOURCE: ACF.

Storage occurs at the compost site. The containers are emptied manually with shovels and during the winter period with additional help of crowbars. The feedstock goes into larger barrel of 220l and afterwards covered with lid. During the summer the faeces are usually not stored or only for a very short period of time. During the winter period the barrels are stored inside an open-air fenced area or in Dirty Storage. The materials stay at the storage facility until they can be processed. The empty buckets and container are cleaned afterwards at the cleaning platform, especially constructed for this purpose.

PHOTO 12: MIXING ON THE PLATFORM.
SOURCE: ACF.

Mixing is based on a basic recipe, applied to achieve an optimal C:N ratio in case of indoor composting (GHU/WCF) it is one part of faeces, one part of sawdust and one part straw. Recipe applied for outdoor composting differs in the composition, because the unfrozen faeces tend to contain higher moisture level, therefore the sawdust needs to be added in the bigger quantities. However, the recipe used for the PAP contains: same parts of faeces and sawdust with flexible amounts of straw. All materials are mixed together manually at the mixing platform before composting.

During the testing phase, different recipes were tested under various conditions as showed in Table 8.

TABLE 8: COMPOST RECIPES.

TRIAL	FEEDSTOCK	RATIO	TESTING PERIOD
WCF			
1	Faeces (F) Sawdust (SD) Straw (ST)	1 1 1	July – August 2013
2	Faeces (F) Woodchips (W) Straw (ST)	1 1 1	
3	Faeces (F) Sawdust (SD) Woodchips (W)	1 1 1	
4	Faeces (F) Sawdust (SD)	1 1.5	
GHU			
5	Faeces (F) Sawdust (SD) Straw (ST) Food waste (FW)	1 1 1 1	Sept. – Nov. 2013

SOURCE: ACF.

4.3 WINTER COMPOSTING

PHOTO 13: WINTER COMPOST FACILITY OUTSIDE (LEFT) AND INSIDE (RIGHT).
SOURCE: ACF.

Winter Compost Facility (WCF), as the name already implies was designed to treat human faeces during the winter period with theoretical annual treatment capacity of 9,6m^3, if facility would operate throughout the year. The building contains three rooms, which ensure ambient average day temperature from 20-24ºC and during the night from 8-12ºC even when temperature drops up to minus 32ºC outside.

The method for composting applied in the facility is in-vessel composting, equipped with four composting bins, each one with the capacity of 660l. The bins are fully isolated with 150mm Styrofoam to prevent the heat loss, which can affect the composting process or even stop it, especially during the winter. Each bin is equipped with cross ventilation system that provides airflow from bottom to the top, simultaneously in 30 minute off & on intervals through a ventilation pipe of 10cm diameters.

The operational set up for turning intervals is: one time in seven days and occurs manually with pitchfork.The interval is chosen to enhance the nutrition supply for the microorganisms and ensures the pathogen destruction in all parts of compost. The duration of one compost cycle is one month.

Virtually, the WCF can be used all year around and has a maximum capacity to process 9.600l of faeces per year in total of over 12 cycles each year.

However, the compost unit was research based technology aiming to demonstrate that composting process can be pursued during winter conditions. But consumption of additional energy does not make it financially feasible option at this moment.

At the same time, during the testing trials results shows that the temperature could be maintained above 55°C for more than one week which satisfies WHO sanitation requirements, as Table 9 shows.

TABLE 9: WCF TIME/TEMPERATURE

TRIAL	DAYS OVER 55ºC	DAYS OVER 60ºC	WHO
1	11	3	> 50ºC > 7 days
2	15	8	
3	10	3	
4	16	5	

SOURCE: ACF.

4.4 SUMMER COMPOSTING

PHOTO 14: GREEN HOUSE UNIT OUTSIDE (LEFT) AND INSIDE (RIGHT).
SOURCE: ACF.

Green House Unit (GHU) compared to WCF works without additional energy source and reduces operation costs. At the same time, it is able to provide higher ambient temperature generated by solar energy in order to enhance the composting process and extend the period of compost production. The compost production takes places from April to November and lasts for 2 month, with maximum annual treatment capacity of 8m^3.

The composting method chosen for the GHU is pile composting, with five available slots each around 1.5m^3 and passive aeration system. For even distribution of air across the piles, airflow is been defused with help of blocks with holes, placed to the side and front of the pile. The front wall can be removed for turning and filling/emptying activities. The piles are covered with holed Styrofoam on the top, that is connected to attachable ventilation pipe to ensure that the odours and gasses can escape to the outside of the greenhouse.

The turning occurs when temperature drops below 50ºC, approximately in two weeks intervals. The manual turning of the compost pile takes places with pitchfork and requires physical effort; therefore the available volume of the slot is filled up only up to 80% or $1.2m^3$ with materials.

In Mongolian case it is possible to produce compost from April to November, in two-month cycles. Under the existing conditions the treatment capacity of the unit is 8000l faeces per year.

Also in case of GHU the temperature could be maintained successfully during the testing period and satisfy sanitation standards, as shown in Table 10.

TABLE 10: GHU TIME/TEMPERATURE.

TRIAL	DAYS OVER 55ºC	DAYS OVER 60ºC	WHO
5	14	3	> 50ºC > 7 days

SOURCE: ACF.

Passive Aeration Platform (PAP), is most optimal and the only system currently utilized in Mongolia with total annual treatment capacity of $5.4m^3$. It was constructed as another alternative to GHU to take advantage of summer season and minimize the operation costs and challenges. As mentioned above it was constructed in 2014 and has lower construction cost compared to passive green house units and also an advantage of operating in the open air, that reduces smell and odours during the turning and mixing of the pile.

PHOTO 15: PASSIVE AERATED PLATFORM DURING CONSTRUCTION.
SOURCE: ACF.

The PAP is in size of 5m x 10m in the outer frame and 4m x 9m with 50cm pipe openings every one meter in the inner work area. The end of the pipes which is the inlet of the passive aeration is 100cm in diameter and turned towards northwest side to receive prevalent wind during summer season. Otherwise all the inlets can be connected into one general pipe for active aeration through blowers.

The raw compost recipe for PAP is as mentioned above, equal amounts of faeces and sawdust with flexible amount of straw (enough to create air pockets). After it is manually mixed at one end of the PAP it is piled on top of 15-20cm of straw in the size of 1.2m x 1.2m x 2m (height, width and length) then covered again with 15-20cm of straw. The pile is covered by plastic that has poked holes for air and couple dial thermometers are inserted for monitoring.

In the current year around 2t of faeces was collected which is made into piles. PAP is used from June to September with composting time of four weeks and for maturation at least two months. When night temperature averages between 5-6ºC then the composting season begins. Turning occurs only when temperature goes below 50ºC (usually during second or third week). However, maturation occurs on the platform itself without moving the heap if no further compost cycle is carried out. The temperature of 70ºC over 10 day period is observed in all piles at the PAP. The monitoring of composting temperature is manual, once every 7-10 days.

4.5 MATURATION AND QUALITY OF COMPOST

PHOTO 16: GREEN HOUSE FOR MATURATION OUTSIDE (LEFT) AND INSIDE (RIGHT)
SOURCE: ACF.

Maturation Phase takes place in second green house (GH), built by ACF for this purpose. GH helps keep and extend the maturation period longer, without additional energy. The maturation process lasts at least for two months, to ensure that the compost is well stabilized and matured. Maturation phase begins when the temperature does not reheat anymore after turning, i.e. when there is steady decrease of compost temperature until it reaches the ambient. For maturation the compost product is moved into wooden boxes and covered by mosquito mesh, inside the GH with the exception of PAP. At PAP, maturation takes place directly on the platform.

Post treatment is conducted after two months of maturation; and the finished compost is screened to remove physical remaining.

To ensure the quality and safety of the compost, the final product is always tested for the nutrient content such as TN, P, K, Mg and Ca, the pH and for pathogens E-coli, Salmonella, faecal coli forms and helminth eggs before the distribution.

The results from all testing trails were satisfactory and free from pathogens, no biological indicator bacteria where found in compost produced by faecal materials. Conversely, the compost demonstrated satisfactory qualities also in terms of productivity.

In terms of heavy metal contents, all trails where below limits for save application according to standards in Germany as shown in the Table 11.

Results from the nutrient analysis Table 12, showed that higher P of 1996mg/kg was recovered from the trial 5 than the other samples and trials. Reason is the addition of food wastes in the composting system. On the other hand, 1354.8mg/kg and 869.9mg/kg of phosphorus can be recovered from the trials 2 and 3 respectively. The phosphorus content in the trials 1 and 4 were lower than the other samples, which may be due to the lack of digestible materials.

TABLE 11: RESULTS FOR HEAVY METALS CONTENT.

	As	Pb	Cd	Cr	Cu
TRIAL	mg/kg				
1	0.2	0.72	0.002	1.66	5.7
2	0.19	2.7	0.02	2.07	8.99
3	0.19	4.14	0.11	1.77	7.8
4	0.04	8.05	0.07	0.67	5.14
5	0.17	13.91	0.205	3.96	25.83
Ger.	**25**	**150**	**3**	**150**	**150**

SOURCE: ACF.

TABLE 12: RESULTS OF TN AND TP CONTENT.

	TN	TP
TRIAL	g/kg	
1	23	0.154
2	22.1	1.354
3	20.6	0.869
4	23.5	0.193
5	20.4	1.996

SOURCE: ACF.

4.6 ESTIMATION OF TOTAL OUTPUT

The total output of the project can be only estimated, because no exact volume of collected faeces is documented. This chapter includes three scenarios based on different estimations.

Scenario one: Based on estimation from experience of ACF staff from one collection cycle during October of 2013, 1m^3 or 1000l were collected from 120 toilets or 540 users. With four cycles per year and 370 toilets it equals to 12.3m^3 / 12,300l [48].

Scenario two: Based on estimation from ACF staff, according to the assumption that per cycle (3 months) from 30l up to 40l of faeces are collected. This corresponds roughly with 35l per toilet and cycle or in total 51.8 m3 or 51,800 l annually from 370 toilets [48].

Scenario three: Based on literature and use of median global production of 128g fresh faeces per person a day [49], density of the fresh faeces is around 1g/cm^3 or kg/l [50]. In this case, it is assumed that hypothetically 25.2m^3 could be produced. By dehydration of faeces the volume reduction can be expected up to 75% and is used for current estimation. Therefore, it can be assumed that 19.4m^3/19,425l can be expected per year from all 370 toilets. All three scenarios are summarized in Table 13.

However since 2015, when the emptying service fee was introduced a relevant drop of users for the emptying service was noticed. The final monitoring to identify the current number of users is being carried out at the moment of writing this manual.

The total annual treatment capacity of faecal materials for each unit is estimated according to the recipes, maximum possible cycles during one year for each unit and its capacity. To estimate the compost production based on the compost recipes the factors to represents the loss of rotting during the composting process was applied at 0.375 based on the experience of ACF. Converting from volume to weight is according the recommendations of Germany's Federal Compost Association with 0.65kg per litre and is applied in this estimation [51]. The annual possible output of compost and the total coverage for each scenario and compost unit is described in Table 14.

According to the estimation of the treatment capacity, each unit has an ability to cover the total faeces production expressed in percent in Table 15.

In the first scenario the total joint capacity of GHU and PAP already can treat all faeces from 370 toilets and produces around 9t of compost. In other two scenarios an additional facility is required. For WCF it is technically possible to operate 12 cycles per year and to produce 10.8m³ or 7t of compost from 9.6m³ of faecal matter. However, in third scenario it would be enough to treat the total faeces amount in 10 cycles and compost production could be increased up to 15.1t recovered from 19.4m³ of faeces if the WCF operation is required and economically feasible.

TABLE 13: ESTIMATED ANNUAL FAECES PRODUCTION (*).

SCENARIO	ESTIMATED ANNUAL FAECES PRODUCTION PER TOILET (m^3)	ESTIMATED TOTAL FAECES ANNUAL PRODUCTION (m^3)
1	0.03	12.3
1	0.14	51.8
1	0.05	19.4

TABLE 14: ANNUAL CAPACITY PER UNIT (*).

UNIT	MAX ANNUAL CAPACITY FOR FAECES TREATMENT
PAP	$5.4m^3$ or 5.400l
GHU	$8.0m^3$ or 8.000l
WCF	$9.6m^3$ or 9.600l
TOTAL	$23m^3$ or 23.000l

TABLE 15: COVERAGE PER INSTALLED CAPACITY (*).

SCENARIO	PAP	GHU	WCF	TOTAL
1	47%	65%	-	112%
2	10%	15%	19%	44%
3	28%	41%	50%	119%

TABLE 16: COMPOST OUTPUT PER UNIT (*).

UNIT	FAECES (m^3)	RECIPE	COMPOST (t)	TOTAL (t)
PAP	6	F:2, SD:3, ST:1	3.9	
GHU	8	F:1, SD:1, ST:1	5.9	16.8
WCF	9.6	F:1, SD:1, ST:1	7	

*** SOURCE: OWN CALCULATION.**

4.7 BENEFITS

In 2013, the Mongolian State University of Agriculture (MSUA) conducted field trials with the compost produced from human faeces in several variations (10t/ha; 20t/ha; 40t/ha and control groups without compost) were applied on the field to grow spinach and radish. In both cases the application of 20t/ha yielded best results: spinach was increased by 37% (or 1.4t) per hectare and radish yield by 40% (or 4.5t) per hectare compared to the control group. Based on the data of the MSUA, it is assumed that each unit can contribute to additional yield of the crops, which is described in Table 17.

TABLE 17: COVERAGE PER INSTALLED CAPACITY.

UNIT	FAECES (m^3)	COMPOST (t)	ADDITIONAL YIELDS	
			SPINACH (kg)	RADISH (kg)
1	6	3.9	260	780
2	8	5.9	150	520
3	9.6	7	308	945

SOURCE: OWN CALCULATION.

Annual GHU output with 5.9t of compost can be applied on 0.295ha fields for spinach and radish production to gain additional crop yield of spinach at 260kg and radish 780kg. In case of PAP 3.9t could applied on 0.195ha for vegetable production and contribute to additional crop yield with 150 kg of spinach and 520kg of radish. In case of WCF with maximum production of 7t per year, WCF could produce the compost for 0.35ha and with additional crop yield for spinach with 308kg and radish with 945kg. The total installed capacity could contribute additional yield of spinach with 718kg and 2.245kg of radish.

4.8 CONCLUSION

1. Composting under Mongolian climate conditions is possible even during the winter, however with additional energy and cost.
2. GHU can extend the composting production, without additional energy.
3. In terms of pathogens and heavy metals, the compost product meets international standards and safe for it application.
4. Addition of food waste as amendments maintain high temperature longer thus provides higher P recovery.
5. The application of compost is safe for food production and increases the productivity.

4.9 SWOT ANALYSES

4.9.1 WINTER COMPOST FACILITY

STRENGTH

1. Possible compost production all year around.
2. Good temperature and oxygen control.
3. Proper hygienezation of compost.
4. Good compost production and treatment performance
5. Less space requirement
6. Technically feasible under cold conditions.

WEAKNESS

1. High Investment and operation costs.
2. Advanced Technology.
3. Additional energy required.
4. Acceptance of compost from human faeces low.
5. Carbon based energy source for collection system.
6. Long distance between the source and treatment.
7. Can improve Health conditions and reduce environmental impact.

OPPORTUNITIES

1. System can be up scaled.
2. Cooperative system can be developed.
3. Future business opportunity can be created.
4. Local market for compost can be mobilized.
5. High compost price.
6. Competitive method for mitigation of GHG.

THREATS

1. Fuel price, for collection service.
2. Subsidised fertilizer.
3. Low compost price.
4. Poor maintenance of compost process can affect the health of the consumers and workers.

4.9.2 GREENHOUSE UNIT

STRENGTH

1. Composting period can be extended without additional energy.
2. Good temperature control.
3. Good compost production and treatment performance.
4. Less space requirement.
5. Technically and economically feasible.
6. Operational costs low.

WEAKNESS

1. High Investment cost.
2. During the winter compost production is not possible.
3. Aeration system depends on wind circulation, higher health risk for the workers.
4. Acceptance of compost from human faeces low.
5. Carbon based energy source for collection system.
6. Long distance between the source and treatment.

OPPORTUNITIES

1. System can be up scaled.
2. Cooperative system can be developed.
3. Future business opportunity can be created.
4. Local market for compost can be mobilized.
5. High compost price.
6. Competitive method for mitigation of GHG.
7. Can improving Health conditions and reduce environmental impacts.

THREATS

1. Fuel price, for collection service.
2. Subsidised fertilizer.
3. Low compost price.
4. Poor maintenance of compost process can affect the health of the consumers and workers.

4.9.3 PASSIVE AERATED PLATFORM

STRENGTH

1. Lowest capital and operation cost.
2. Good temperature control.
3. Good compost production and treatment performance.
4. Less space requirement.
5. Technically and economically feasible.
6. Safest operation and maintenance conditions for staff

WEAKNESS

1. During the winter compost production is not possible.
2. Aeration system depends on wind circulation.
3. Acceptance of compost from human faeces low.
4. Carbon based energy source for collection system.
5. Long distance between the source and treatment.

OPPORTUNITIES

1. System can be up scaled.
2. Cooperative system can be developed.
3. Future business opportunity can be created.
4. Local market for compost can be mobilized.
5. High compost price.
6. Improves Health conditions and reduces environmental impacts.

THREATS

1. Fuel price, for collection service.
2. Subsidised fertilizer.
3. Low compost price.
4. Poor maintenance of compost process can affect the health of the consumers and workers.

STANDARDS

1. RECOMMENDATIONS FOR STORAGE TREATMENT OF DRY EXCRETA AND FAECAL SLUDGE BEFORE USE AT THE HOUSEHOLD AND MUNICIPALITY LEVEL[52].

Treatment	Criteria	Comment
Storage ambient temperature 2 – 20°C	1,5 – 2 years	Will eliminate bacterial pathogens; regrowth of E.coli and Salmonella may be considered if rewetted: will reduce viruses and parasite protozoa below risk levels. Some soil-born ova may persist in low numbers.
Storage ambient temperature > 20 - 35°C	> 1 year	Substantial to total inactivation of viruses, bacteria and protozoa; inactivation of schistosome eggs (< 1 month); inactivation of nematode (roundworm) eggs e.g. hookworm (Ancylotsoma/Necator) and whipworm (Trichuris); survival of certain percentage (10-30%) of Ascaris eggs will occur within 1 year.
Alkaline Treatment	pH > 9 during > 6 month	If temperature > 35°C and moisture < 25 %, lower pH and/or wetter material will prolong the time for absolute elimination.

2. ADDITIONAL TREATMENTS OF EXCRETA AND FAECAL SLUDGE OFF-SITE, AT COLLECTION AND TREATMENT STATIONS FROM LARGE-SCALE SYSTEMS (MUNICIPAL LEVEL) [52].

Treatment	Criteria	Comment
Alkaline Treatment	pH > 9 during > 6 month	Temperature > 35°C and/or moisture < 25°C. Lower pH and/or wetter material will prolong elimination time.
Composting	Temperature > 50°C for 1 week	Minimum requirement. Longer time needed if temperature requirement cannot be ensured.
Incineration	Fully incinerated (< 10 % carbon in ash)	

3. GERMAN STANDARDS FOR HYGIENEZATION [53].

Moisture	pH	Temperature	Time
40%	7	> 55°C	2 weeks
		> 60°C	6 days
		> 65°C	3 days

4. GERMAN LIMITS FOR HEAVY METALS [53].

Pb	Cd	Cr	Cu	Ni	Hr	Zn
100	1	70	70	35	0.7	300

5. MONGOLIAN LIMITS FOR AGROCHEMICAL CHARACTERISTICS FOR FAECES COMPOST (BY MG/100G) [54].

Moisture	pH	N	P2O5	K2O	NH4-N+NO3-N
30-50 %	6.5 - 8.5	≥0.5	≥0.5	≥0.5	≥1.5

6. MONGOLIAN LIMITS FOR HEAVY METALS (MG/KG) [54].

Pb	As	Cd	Cr	Hg
100	6	3	150	0.8

7. GLOBAL COMPOST STANDARTS AS OF APRILL 1996 [55].

Country	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
USA (S)	41	39	1200	1500	300	17	420	2800
Canada (MO)	13	2.6	210	128	83	0.83	32	315
Ontario (SSMO)	10	3	50	60	150	0.15	60	500
Austria (MO)	-	4	150	400	500	4	100	1000
Belgium (SSMO)	-	1	70	90	120	0.7	20	280
Denmark	-	1.2	-	-	120	1.2	45	-
France (MO)	-	8	-	-	800	8	200	-
Germany	-	1	100	75	100	1	50	300
Switzerland	-	3	150	150	150	3	50	-
Spain	-	40	750	1750	1200	25	400	4000
Indonesia (proposed)	10	3	50	80	150	1	50	300

(S) refers to sewage slidge

(MO) refers to mixed organics

(SSMO) refers to source separated mixed organics

(proposed) refers to standards proposed by the World Bank —suggested for all developing countries as a good start point. (World Bank, 1997a)

COMMON COMPOSTING STRUCTURES AND BINS

Methods of containment can be considered to make turning easier and support microbial decomposition during colder months. Types of structures:

1. COMPOST BINS AND PILES

Static piles in size of 90cm x 90cm, 1.2 m x 1.2 m, 1.5m x 1.5 and 2.1m x 2.1m.

Windrows piles are similar to static piles but they are longer in length and should be in shape that is easier for machinery turning.

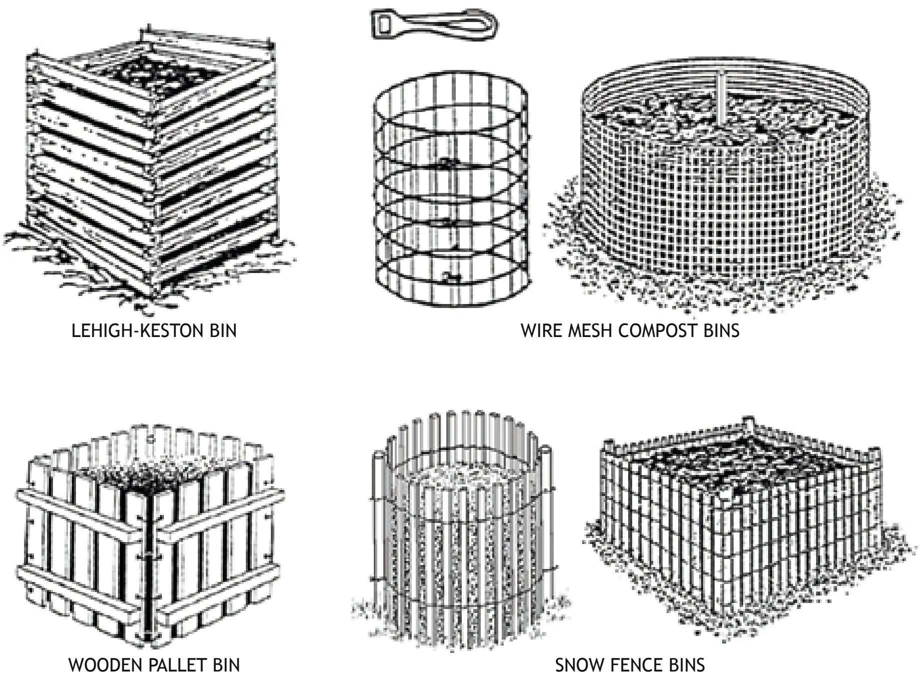

FIGURE A1: DIVERSITY OF COMPOST BINS IN DESIGN AND MATERIALS.
SOURCE: [20]

MAIN ADVANTAGES:

- Simple, low maintenance system. Better if turned regularly – it will compost faster.
- Ideal for homes with small gardens and for people who do not want to spend a lot of time working on their compost.
- Can also be used to compost turf/sod or leaves on their own [52].

2. TUMBLERS AND TURNING SYSTEMS

Turning systems can be multi-bin, tumblers or rolling spheres. The best way to operate these is to make a whole batch at once and then turn it every 5–10 days, depending on the system used.

MAIN ADVANTAGES:

- Produces high-quality compost in as little as weeks when done properly.
- Multi-bin systems are ideal for the avid gardener with lots of outdoor space who does not mind the work and wants all the compost the system can produce [56].

FIGURE A2: MULTI-BIN SYSTEM.
SOURCE: [20]

FIGURE A3: HOMEMADE ROTATING DRUM.
SOURCE: [39]

3. PIT AND TRENCHING

Ideal for food wastes that decompose faster. It’s simple and most effective use of wastes into nutrients for gardeners. The mixed raw compost mixture is placed in 10cm thick layer in a trench that is 30-40cm deep and 15-20cm wide and covered with dug out soil.

MAIN ADVANTAGES:

- Simple way to deal with food scraps.
- Decomposes in – months.
- Enriches soil over time.
- Ideal for allotment gardening. Can be done in conjunction with a rotation system in a veggie patch [56].

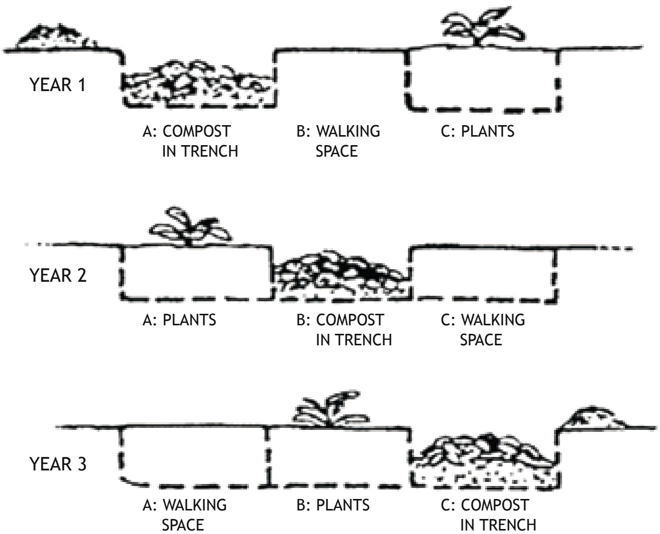

FIGURE A4: EXAMPLES OF SUSTAINABLE TRENCHING.
SOURCE: [56]

TOOLS FOR MONITORING

1. SAMPLE LOGBOOK FORM FOR INPUT MATERIAL[22].

	Supplier / location	Feedstock type, volume/amount	Dates				
			2015.11.10				
1	Restaurant	Vegetables	30				
2	School	Paper	25				
3	Butchers	Meat	10				

2. SAMPLE LOGBOOK FORM FOR PROCESS MONITORING. DEVELOPED FROM (RYNK, 1992) [58].

TEMPERATURE MONITORING RECORD								
Data collected by:				Weather (sunny, rainy, snowing, etc.):				
Ambient (air) T:				Wind direction:				
General observations:								
Date	Time	Pile # (windrow, cell, bucket, etc.)	Moisture rating	Odour rating	Temperature Distance from ends of pile			
					m	m	m	m

3. SAMPLE LOGBOOK FORM FOR FACILITY MAINTENANCE [59].

Facility inspection:	Contact	Comments
Date:		
Approval To Operate:		
Date:		
Repairs:		
Date:		

BUDGETING

These examples are from a supermarket Composting Handbook in Massachusetts [60].

1. SOLID WASTE AUDIT FORM

Company: Store Location: Square meters: N° of Employees:	Date Completed: Program Manager: Phone: E-Mail:

ANNUAL HAULING AND DISPOSAL COSTS									
	Tons / Year	Tip $ / Ton	Total Tip Cost	Hauls / Year	$ / Haul	Total Haul Cost	Total Cost	Container Type & Size (compactor, dumpster, toter)	Service Provider
Solid Waste									
Organics									
Cardboard									
Waxed Cardboard									
Office Paper									
Bottles & Cans									
Fluorescent Lamps									
Pallets									
Hard Plastics (pails, etc.)									
Plastic Film									
Other									
TOTAL									

ADDITIONAL ANNUAL OPERATING COSTS					
	Organics Recycling Costs	Solid Waste Costs	Other Recyclable Costs	Total Cost	Notes / Description
Equipment Rental					
Collection Container Replacements					
Collection Bags					
Signs/Labeling					
Staff Training					
Other					
TOTAL					

TOTAL ANNUAL OPERATING COSTS:
COST PER TON:
RECYCLING RATE:

2. COST BENEFIT ANALYSIS OF COMPACTOR SYSTEM

Company: Store Location:								
Square meters: N° of Employees:								
OPERATING COSTS OF CURRENT PROGRAM (from the waste audit form)								
	Actual % of Waste Stream	Total Tons/Year	Tip $ per Ton	Total Tip Cost	Hauls/Year	$/Haul	Total Haul Cost	Total Hauling & Disposal Cost
Solid Waste								
Organics								
Cardboard								
Waxed Cardboard								
Office Paper								
Bottles & Cans								
Fluorescent Lamps								
Pallets								
Hard Plastics (pails, etc.)								
Plastic Film								
Other								
TOTAL Hauling & Disposal								

ADDITIONAL OPERATING COSTS OF CURRENT PROGRAM (from the waste audit form)				
	Organics Recycling Costs	Solid Waste Costs	Other Recyclable Costs	Total Additional Operating Cost
Equipment Rental				
Collection Container Replacements				
Collection Bags				
Signs/Labeling				
Staff Training				
Other				
Additional Operating Costs				
TOTAL ESTIMATED ANNUAL OPERATING COSTS FOR CURRENT PROGRAM:				
COST PER TON FOR CURRENT PROGRAM:				

ESTIMATED NEW HAULING AND DISPOSAL COSTS FOR COMPACTOR PROGRAM								
	Estimated % of Waste Stream	Tons/Year	Tip $ per Ton	Total Tip Cost	Hauls/Year	$/Haul	Total Haul Cost	Total Cost
Solid Waste								
Organics								
Cardboard								
Waxed Cardboard								
Office Paper								
Bottles & Cans								
Fluorescent Lamps								
Pallets								
Hard Plastics (pails, etc.)								
Plastic Film								
Other								
TOTAL								

ESTIMATED NEW ANNUAL OPERATING COSTS FOR COMPACTOR PROGRAM				
	Organics Recycling Costs	Solid Waste Costs	Other Recyclable Costs	Total Additional Operating Cost
Equipment Rental				
Collection Container Replacements				
Collection Bags				
Signs/Labeling				
Staff Training				
Other				
TOTAL				
TOTAL ESTIMATED ANNUAL OPERATING COSTS FOR COMPACTOR PROGRAM:				
ESTIMATED ANNUAL OPERATING COST SAVING FOR COMPACTOR PROGRAM:				

ESTIMATED START-UP CAPITAL COSTS FOR COMPACTOR PROGRAM		
	Notes/Description	Costs
Collection Containers		
Compactor		
Concrete Pad		
Utilities		
Other		
TOTAL		

TOTAL ESTIMATED ANNUAL OPERATING COSTS FOR COMPACTOR PROGRAM WITH CAPITAL DEPRECIATION (7 years):	
ESTIMATED ANNUAL OPERATING COSTS SAVINGS FOR COMPACTOR PROGRAM WITH CAPITAL DEPRECIATION:	
ESTIMATED ANNUAL OPERATING COSTS SAVINGS FOR COMPACTOR PROGRAM BEGINNING YEAR 8:	
COST PER TON WITH CAPITAL DEPRECIATION:	
COST PER TON WITH BEGINNING YEAR 8:	
RECYCLING RATE:	

3. MONTHLY TRACKING FORM

Company: Store Location: Year:	Program Manager: Phone: E-Mail:

	Quantity in tons												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Year
Organics													
Cardboard													
Waxed Cardboard													
Office Paper													
Bottles & Cans													
Fluorescent Lamps													
Pallets													
Hard Plastics (pails, etc.)													
Plastic Film													
Other													
Total Recyclables													
Solid Waste													
Total Waste													
Recycling Rate													

4. YEAR-END WASTE AUDIT

Company: Store Location: Square meters: Nº of Employees:					Date Completed: Program Manager: Phone: E-Mail:				
ANNUAL HAULING AND DISPOSAL COSTS									
	Tons / Year	Tip $ / Ton	Total Tip Cost	Hauls / Year	$ / Haul	Total Haul Cost	Total Cost	Container Type & Size (compactor, dumpster, toter)	Service Provider
Solid Waste									
Organics									
Cardboard									
Waxed Cardboard									
Office Paper									
Bottles & Cans									
Fluorescent Lamps									
Pallets									
Hard Plastics (pails, etc.)									
Plastic Film									
Other									
TOTAL									
ADDITIONAL ANNUAL OPERATING COSTS									
	Organics Recycling Costs	Solid Waste Costs	Other Recyclable Costs	Total Cost	Notes / Description				
Equipment Rental									
Collection Container Replacements									
Collection Bags									
Signs/Labeling									
Staff Training									
Other									
TOTAL									
TOTAL ANNUAL OPERATING COSTS:									
COST PER TON:									
RECYCLING RATE:									

TROUBLESHOOTING

Some common Q&As. Compiled and developed from (Vogel, Home Composting, 2011), (Schwarz & Bonhotal, 2011) & (Smeenk J. , 2011).

Can I compost vacuum dust?

Yes. The fibers from synthetic carpeting will not decompose, but they will probably not be noticeable in the finished compost.

Can I compost glossy magazines, color inserts, colored pages from newspapers?

Some glossy papers contain toxic pigments, so these materials should not be composted. Colored newsprint is safe to compost.

Can I compost fireplace and barbeque ash?

Wood ash is an excellent source of Potassium, one of the major nutrients required for healthy plant growth. Wood ash may be safely added to compost piles in thin layers. Do not burn wood or use the ashes from wood treated with paints or wood preservatives. Charcoal (including mesquite) is just a partially burned form of wood, so as long as no other chemicals have been added, barbeque ash should be safe to compost. (Check labels on packaging to be sure). Avoid using ashes which are derived from burning large amounts of paper, these ashes may contain residues of heavy metals or chlorinated compounds.

Can I compost pet wastes?

Pet wastes (dog, cat, any carnivores) should be either buried in an ornamental garden area or compost them in their own worm bin. Compost made from pet wastes should not be put in a vegetable garden.

Can I compost Any diseased plants?

No diseased plant should be added to a home composting system. Diseases may live through the composting process and spread through the garden as compost is used. (Large scale composting systems may attain sufficient temperatures to kill diseases, but home composting systems do not reliably reach these temperatures 70˚C).

Can I compost Weeds?

How do you stop them from spreading in compost? Annual weeds, which have not gone to seed, may be composted. Do not compost weeds that have gone to seed. Many seeds will survive temperatures up to 60ºC. Even a well made “hot” home compost pile may not uniformly achieve this heat. Weeds that spread vegetatively through roots or runners, such as morning glory, quack grass, and buttercup – or ornamentals such as ivy – should not be put in compost piles even if they are shredded. Spread these plants on pavement to dry thoroughly (it may take months in moist seasons) before adding to compost.

Can I compost Limbs from trees with tent caterpillars?

Do not compost limbs or other parts of trees with tent caterpillars on them. Tent caterpillars lay eggs in patches on tree branches. The eggs will hatch the following spring unless they are burned or physically destroyed.

Can I compost wood chips?

Wood chips may be added to compost piles in limited quantities. They are very rich in carbon, and their limited surface area prevents bacteria from decomposing them quickly. They will not break down completely for a long time, but will become “biologically stable” and improve drainage and aeration in heavy clay soils.

Can I compost sawdust and wood shavings?

Sawdust and wood shavings are rich in carbon like wood chips, and they have more surface area for bacteria to work on than chips do, so these materials tend to rob more nitrogen from the soil or compost initially. Sawdust should be aged/weathered before adding it to the compost pile. To balance the nitrogen demands of one cubic yard of fresh sawdust, 14kg of actual nitrogen (8kg ammonium sulphate, 7kg blood meal, 5kg ammonium nitrate, or 4kg urea).

Can I compost waxy, evergreen yard wastes like pine needles?

Rose prunings, pine needles, holly, yews and other waxy leaves breakdown slower than many other wastes, but they do not pose any problem in the compost or in the garden (except rose thorns, which may attack you). Shredding these materials will help them to break down quicker and be less visible in the finished compost. Their texture and resistance to decomposition makes them excellent for mulching to protect tender plants from frost. Compost made from pine needles is not acidic.

Are rats and mice attracted to compost? How can I get rid of them?

Rats and mice are attracted to two aspects of compost:
1) Rats and mice are most often attracted to food wastes of all types including meats, fruits, vegetables, grains and dairy products. Food wastes should not be put into yard waste composting systems. Food wastes, excluding meat, fish and dairy products should be composted in worm bins with tight fitting lids to exclude rodents, or buried under at least 20cm of soil cover. Meat, fish and dairy products should be thrown out or run through an in-sink garbage disposal.
2) Sometimes rats and mice will nest in yard waste compost piles. This is not a common problem (usually they are attracted by some fruit or other food wastes which are in the pile). If rats and mice do nest in a compost pile, they can be discouraged by turning or otherwise disturbing the pile, moistening the pile, or heating up the pile through a combination of moistening, shredding, turning and adding nitrogen fertilizer.

Can a pile catch fire?

This can happen in a very rare situation where tinder-dry feedstocks are heated by an excessively hot pile. It is primarily a concern in large municipal compost piles, which exceed the recommended household size.

Can coffee filters and tea bags be composted in a worm bin?

Yes. Any uncoated paper product may be composted. Worms love coffee grounds and filters, as well as tea bags. Don’t try to compost coated papers such as glossy magazines or photographs, waxed paper, and treated copy paper.

Can compost be used as fertilizer?

Yes, because decomposed materials have some nitrogen, phosphorous, and potassium content even though in small amounts. However, there are not enough nutrients present in the compost to supply the needs of vegetable crops and ornamental plants. Adding garden fertilizers to speed up decomposition supplies some of the nutrients as well. In general, the lack of large amounts of nutrients in compost is far outweighed by the other advantage of the organic material.

Can I continue adding materials to my pile?

Unless it's continuous composting, no, it is important to build the pile all at once, and only add nutrients if absolutely necessary as described above. Additional feedstocks for composting should be used to start a new pile in another location.

Can sod be composted without continually resprouting?

Yes. Sod should be composted in piles covered with black plastic to exclude light and stop all growth. Other materials may be included in the pile, including vegetatively spreading weeds such as buttercup and quack grass which will also die without light. (Morning glory will not be killed this way).

Can yard wastes treated with chemical pesticides and herbicides be put in compost? What happens to them in the compost pile?

There are no simple, clear answers to this question. Individual chemicals react in different ways and break down under unique conditions. Decomposition of most pesticides and their by-products have not been studied thoroughly. Often the by-products are more toxic than the original chemicals. Some fungicides contain heavy metals which can build up in your soil. You should never purposely dump any chemical into a compost pile. Lawn clippings with herbicides on them may kill garden plants if used as a mulch or "young" compost. At a minimum, thoroughly compost yard wastes that have been treated with pesticides (or those uncertain origin) in a hot pile and leave to cure for a full year. Do not use compost made from wastes of unknown origin on food crops.

Do compost "tumblers" work?

Compost tumblers or "barrel turning units" work very efficiently if wastes are chopped, moistened and contain adequate nitrogen. Tumblers with flat sides or internal baffles (like a clothes drier) are recommended as they mix and aerate materials better than those with smooth sides.

Do compost piles attract slugs?

Slugs live happily in compost piles and help to break down organic wastes. Often they are so happy there that they don't bother garden plants. However compost piles can provide daytime hiding places for slugs who may graze in gardens at night. Place compost piles in areas away from vegetable gardens or create barriers (traps, metal flashing...) around the pile to contain slugs.

Do I need a bin to make compost?

No. Yard waste compost can be made in freestanding piles. However, bins help keep piles neat and free from disturbance by pests, and are appropriate for urban areas.

Do I need to add fertilizer to my garden if I use compost?

Yes. Compost is a soil conditioner, not a reliable source of major plant nutrients (Nitrogen, Phosphorous, Potassium). Compost helps to improve soil drainage and moisture retention, hold nutrients from fertilization in the soil for gradual use by plants, neutralizes acid soils, and adds small amounts of minerals needed for plant growth.

Do I need to add fertilizer to the compost pile?

Need for fertilizer depends on the material being composted. A mix of typical yard wastes (leaves, grass clippings, weeds, etc.) contains sufficient nitrogen for decomposition. Nitrogen fertilizers may be added to speed up decomposition of dry woody wastes such as twigs, dried grasses, waxy evergreen leaves or wood chips. Addition of rock phosphate or other high phosphorous fertilizer will benefit compost by reacting with other nutrients, making them more available to plants, and adding much needed phosphorous to our soils.

Do I need to use a shredder to make good compost?

Shredders are not needed to make compost out of many yard wastes. However, shredders are useful for creating mulch out of woody materials such as branches over 13cm diameter, waxy evergreen leaves, and large volumes of shrub prunings. Shredders are also useful to prepare cornstalks and other woody vegetable wastes for quick/hot composting. These wastes may also be broken up by chopping them with a machete or shovel, or by running them over with a rotary lawn mower.

Do I need to water my compost pile?

Providing adequate moisture is essential for quick composting, but if you are patient you can leave watering to nature. Untended, unwatered compost piles may take six months to two years to decompose. Occasional watering during dry seasons, along with covering piles with black plastic or old rug scraps will greatly speed up decomposition.

Does the compost pile have to be in the sun?

No, while the pile can be in the sun it doesn't have to be. Compost is heated by the microbes in the pile, not by the sun.

How can I stop flies and other insects from becoming pests around the compost pile?

Compost piles made entirely from yard wastes do not usually attract flies or other flying insect pests in large numbers. Flies are attracted to food scraps and animal manures. When such waste is used in compost pile, be sure to cover it with several inches of compost or soil – not just with loose yard wastes!

How can unfinished compost be reheated?

Relatively fresh materials will heat up if turned (with proper moisture and bruising or shredding). Older "brown" materials can be reheated by adding a high nitrogen fertilizer, green grass clippings, or manure when they are turned. Pouring liquid nitrogen fertilizer on a pile will also heat it up.

How can wood/bark chips be made to compost faster?

Re-chipping to open more surface area, and adding nitrogen will both speed up decomposition of wood chips.

How do I know if the compost is done?

Finished, or cured, compost should not have any recognizable feedstock materials remaining in it.

How do I know when the compost is "finished" and ready to use?

Compost is ready to use when most of the original plant materials are no longer recognizable (some tough woody materials may still be present – these may be sifted out and returned to the compost pile). It should have a granular structure and smell like fresh sweet soil, dark colored, crumbly and looks and feels like soil.

How does compost affect the acidity (pH) of soils?

Most yard waste composts are neutral to slightly basic, and have significant buffering capacities to offset acidity in soils.

Is it OK to garden in pure compost?

In compost mixed with fill soil? It is best to mix compost with mineral soils (clay loam, sandy loam) for gardening, to have ideal texture and provide anchorage for plant roots. Clean fill soil (not pure clay) and compost mixed in roughly equal amounts should provide a good growing medium. Plants do not root well in pure compost. Use of too much compost in the garden reportedly results in dangerous levels of nitrates in some crops.

Must compost be turned?

No. Turning speeds up the process, but is not necessary. Yard waste composted in a holding unit may take from three months to two years to decompose (longer for large unchipped branches), depending on the composition of the materials being composted, how they are prepared, and if the compost is turned periodically. If wastes are carefully combined to balance Nitrogen and Carbon, chopped, moistened and turned, compost can be made in as little as three weeks.

Should compost "starters" or soil be added to compost piles?

Starters are not essential for composting. Most "starters" are nitrogen fertilizers and/or dehydrated bacteria. The bacteria are already present on dead plant material and multiply rapidly. If a nitrogen source is needed, fertilizers are cheaper than "starters". Soil is not needed in a compost pile, but it is not detrimental either.

Should compost piles be covered?

A compost pile that has good moisture content to start with will benefit from coverage with plastic or carpet scraps. Covering piles helps to keep them moist in summer and prevents them from getting too soggy and having nutrients leach out in winter. However, if a pile is too dry or soggy to start with covering may make the problem worse.

Should I add limestone to compost?

Limestone is not needed for a good compost, and may contribute to smelly loss of nitrogen through ammonia gases. Most finished compost has a neutral to slightly alkaline pH.

What are the storage needs for compost from the average yard?

The amount of compost generated in a yard depends on the size of the yard, what is being grown there, how it is being composted, and other factors. Finished compost occupies only about 30% – 40% of the volume of raw wastes. Storage is not usually a problem. For small yards, a holding unit should handle all of the wastes generated. Larger yards and intensive gardens may require more than one holding unit, or a turning system.

What can be done about a smelly compost pile?

Smelly piles are most often caused by too much water and poor aeration. When kitchen wastes are added to yard waste compost piles they often are too wet and create odors. The bacteria, which live in such “anaerobic” piles produce a sulphuric, “rotten egg” smell. Smelly piles should be turned to introduce air and encourage “aerobic” bacteria. Wet, compacted materials should be broken up with a pitchfork, and course materials such as dry straw or corn stalks may be mixed in to aid drainage, absorb excess moisture, and create air spaces.

What can I do with composted grass if I don’t have a garden?

Grass clippings, composted or not composted, make an excellent mulch around shrubs, trees, and potted plants. Several cm of mulch may be added to these plantings each year. For trees planted in lawns, remove sod around the tree in a circle three feet or more in diameter to create an area for annual mulching. Finished compost may also be screened and spread on lawns. There is always a use for compost.

What happens if I skip the maturation phase?

You run the risk of damaging young plants (especially transplants) with some of the nitrogen compounds that have not yet stabilized.

Will mulching with wood chips or sawdust rob Nitrogen from plants?

Carbon rich woody wastes will not compete with plants for nitrogen if they are placed on the soil surface around plants. However, these wastes should not be mixed into the soil without adding nitrogen fertilizer. For this reason, it is best to use woody wastes only to mulch shrubs and trees, where the soil is not tilled and the mulch will stay on the surface. If you use sawdust in annual planting areas, add nitrogen fertilizer when turning it under. See previous answer recommendation for additions of nitrogen required to balance sawdust. Actual nitrogen “demand” of woody wastes depends on the size of the materials. Smaller particles (sawdust) have more surface area for bacteria to work on, so they demand more nitrogen than larger particles.

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