Solid Waste Management in Garla Mare

Managing the beauty of the Danube Delta

Part 2:
Waste mangement techniques.

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This report is written in three parts. This is part two of the trilogie on waste mangement in Garla Mare.

- *The first part* dexcribes the contemporary solid waste mangement in Romania and in Garla Mare. The local situation, governmental organisation and legislation is described here. This part can be reused for other projects concerning Garla Mare.

- *The second* part deals with solid waste management techniques, such as biogas installations, composting, recycling of plastic and open burning of household waste. This part can be reused for other projects concerning waste management.

- *The third part* discusses the possible sollutions from which the villagers can choose to deal with their solid waste mangement in an environmental friendly way. There is a recommendation from the author, but local circumstances might still have some unxepected surprices, wo that another sollution might fit better. With the knowledge of this report, the villagers will be able to judge the situation and the proposed sollutions from all stakeholders better.

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6. Biogas

6.1 Biogas: the process

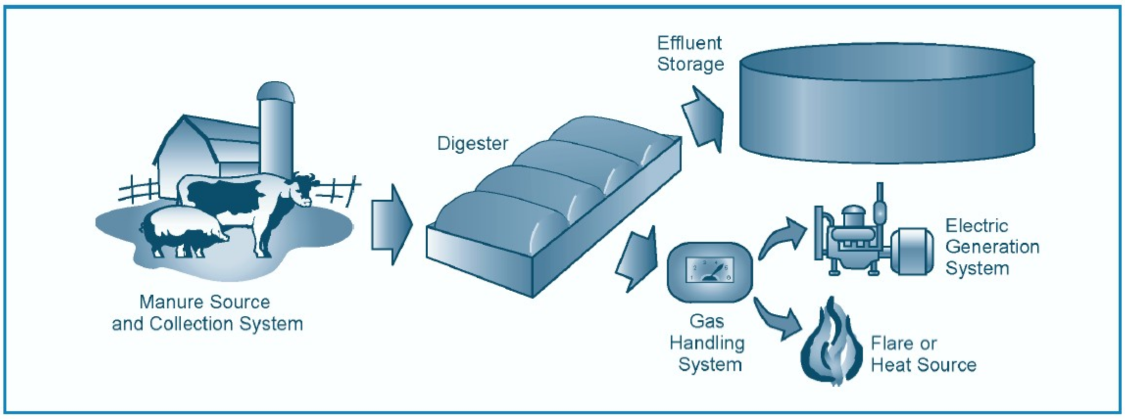


Fig. 16 *Scheme of a biogasplant. Source: United States Environmental Protection Agency, 2002.*

Microbes in organic waste produce, amongst other gases, methane. This gas can be used for heating and generating electrical power. To produce this gas, organic waste must be kept under anaerobic circumstances for some time. The container in which this is done is called the digester.(see fig. 16) All kinds of organics can de used in the digester for the production of biogas. Suggestions for organics are found in annex 3.

The gas producing process can be divided in several stages that coexist in the digester. First bacteria break down complex organic materials, this process is called hydrolises. Then the organic materials and CO_2 are either oxidised of reduced to CH_4 by methanogenic microorganisms.
Al Seadi T, 2000.
The produced biogas is a mixture of different gases such as methane (50-65%), CO_2 (30-40%), hydrogen sulfide (less than 1%) and other gases such as nitrogen, hydrogen and carbon monoxide in traces. Biogas also holds water vapour, which needs to be removed before using the gas.
Alam, 2003
Some of the components of biogas are either corrosive (H_2S), or add no energy (H_2O, CO_2) value, or could have an other value (NH_3), so it is desirable to have gas separation and removal systems. This is done in the gas handling system (see fig. 16). Mesh screens for dust removal and catalytic conversion can also play a role. High temperature and corrosion resistant materials are needed to deal with the unpleasant components or products of manure such as hydrogen sulfide.
Sheffield J., 2000
After the biogasproduction a slurry stays behind in the digester. This can be treated by nitrogen removal, sand removal, precipitation of heavy metals or separation into a solid and liquid fraction. The solid fraction can be composted if the heavy metal content is within the prescribed limits. The liquid fraction can be used as a fertiliser in agriculture or treated in a wastewater treatment plant. Before use, the slurry probably needs to be stored in the effluent storage (See fig. 16).
Al Seadi T, 2000.

For digesting (fermentating), besides air tightness, several conditions should be met, such as suitable temperature, necessary nutrients, water contents and a suitable pH balance. The maximum methane production is achieved at a pH near neutral towards 6. Here is a good example of what difference temperature can make: The temperature in the biogas installation can be raised by a pile of compost on the roof, this can make a difference of 2 °C and establishes 20% more biogas (methane) production.

A higher temperature also speeds up the fermentation. At temperatures between 35 °C and 45 °C it takes 20 to 30 days to complete fermentation. At temperatures between 45°C and 60°C this process takes 10 days. At fast changing temperatures the fermentation stops altogether.
Considering all these conditions makes biogas production more complicated than for example composting.

Alam, 2003

6.2 Biogas: Designing and constructing a biogasplant

Before designing a biogasplant, we have to account for different important aspects:

1. Type of input substrate

The necessary nutrients for proper biogasproduction are mostly defined as the ratio between C and N in the feedstock. A ratio between 20 and 30 should be met to optimize the gasproduction. The C/N ratio is small for human and animal waste and high for material from plants.

Substrate	**C/N**	**C-content %**	**N- content %**
Human waste	*3*	*2,5*	*0,85*
Cowdung	*25*	*7,3*	*0,29*
Horse waste	*24*	*10*	*0,42*
Sheep waste	*29*	*16*	*0,55*
Pig waste	*13*	*7,8*	*0,6*
Chicken waste	*6*	*?*	*?*
Grasses	*27*	*14*	*0,54*
Rye-grass	*53*	*40*	*0,75*
Wheat-grass	*87*	*46*	*0,53*

Table 2. *C/N ratios of different feedstock.*

Koranda C, 2004

2. Quantity of input substrate

According to the mayor of Garla Mare, these are the number of animals:

	Number of animals	Manure production in liter per week per animal.	Manure production per week in liter
Number of cows	380	250	95000
Number of horses	390	Manure not collected	
Number of pigs	1700	30	51000
Number of sheep	2800	Manure not collected	
Number of poultry	41000	1	41000
Total manure production per week in liters			187000

Table 3. *Liters manure per week.*

Data on the waste production per animal are found in annex 4. The feedstock also consists of waste from fields and gardens. Because of transportation costs these materials are now burnt on the spot or at the nearby landfills. But waste from corn and wineyards is available for biogas production.

3. Local circumstances (climate, location)

The climate is in winter very cold. This means that extra protection measures have to be taken to be able to use the biogas installation also in winter. Or there must be storage of manure during the winter. Protecting measures can be building the biogasplant in the soil, covering it with compost or using biogas for heating the feedstock.

Koranda C, 2004

The location of the biogasplant is not easy to determine. On the one hand farmers need the sludge to be nearby the fields for application, on the other hand do they need to transport the organic waste towards the biogasplant. There are plans for ecotourism, this means that the biogas plant must not be on spots where tourism activitities are planned. The wetlands are protected, the biogasplant can not be near that location. The Danube might overflow, this means that the location for a biogas plant might be best north of the village. The wind blows mostly from the west and northwest, this means that the possible odour problems flow in that direction.

4. Heat use

In some biogas projects in Germany the heat produced is used for heating stables.

5. Pasteurisation

During biogas production the sludge becomes heated. The sludge holds less pathogens, spores and seeds of weeds after the biogasproduction, this makes the sludge a better fertiliser or soil conditioner. (See also the topic on mesophilic or thermophilic process temperature.)

6. Automation

Probably it is a good idea to have a simple technical solution. In that case reparation can be done with local means. Knowledge about automation and complex technical solutions is not available in the village jet. Educating staff on the use and repair of a complex technical solution will ask time and money.

7. Mesophilic or thermophilic process temperature

There are two basic biogas producing processes: the mesophilic and the thermophilic process.The mesophilic proces is the most common process at 35 degrees Celsius. The thermophilic process takes place at a temperature of 50 degrees Celsius.
The methanogenic bacteria are more effective at temperature about 30 - 35 degree Celsius. The mesophilic proces produces more gas per liter waste, the thermophilic proces proceeds faster.
Alam, 2003.

Because of the high temperatures in the biogas installation animal and human waste become pasteurised. Most microorganisms are gone after the treatment in the biogas installation. For human waste there must be a temperature of 70 degrees Celsius to avoid pathogens infecting humans through the use of effluent on fields and gardens. Even the thermophilic process does not reacht such temperatures. A thermophilic process does not garantee pathogen free effluent from human waste. Also rests of medication might still show in the effluent.

Fisher T, 2004.

There seems to be no common accepted rules about the needed temperature for the production of pathogen free material from human or animal waste. The temperature of 70°C kills most pathogens at once (see fig. 17), but this temperature is only reached in waste incineration plants. During biogas

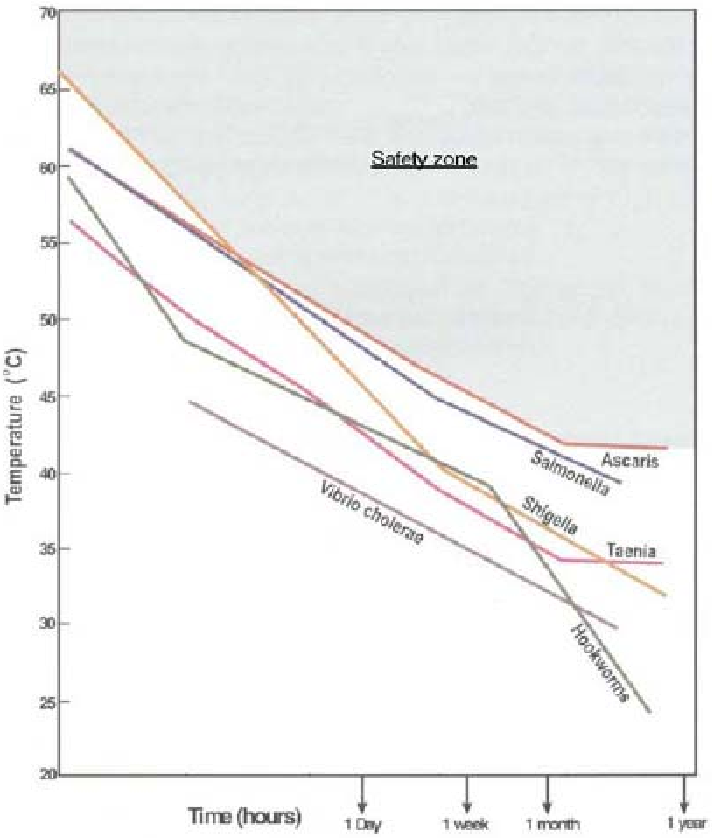


Fig 17 *Pathogen content versus time and temperature, source: S. Deegener, TUHH, 2004.*

production or composting at lower temperatures it takes more time to kill all the pathogens. Fig. 17 shows that safe sludge can be produced. Only virusses and rests from medication (also antibiotics from animals) are not taken into account in this figure.

The biogas production process destroys a wide range of pathogenic and faecal micro-organisms. Under the EU animal by-products regulation (1774/2002) biogas plants must be fitted with pasteurisation/hygienisation units of minimum treatment of 70°C for one hour. Such treatment will kill all pathogens and seeds, thereby eliminating cross-farm contamination of pathogens or weeds.
EPA Ireland, 2005

8. Type of feeding

Depending on the mixture of slurries (e.g. cattle, pig, poultry, etc) the nutrient balance of digestate may be more balanced for agricultural application. Biogas production transforms organic bound nutrients to a mineral form, which is readily available for crops. With a better nutrient balance and more accessible nutrients the requirement for artificial fertilisers may be lessened, which results in a cost saving to farmers.
EPA Ireland, 2005

9. Type of mixing

For an optimal biogas production the sludge must be stirred. See fig. 20,21 and 22 with examples of mixing types.

10. Type of heat input
11. Wet and dry fermentation

Biogas plants which operate with a watercontent higher then 85% are called wet digesters. If the water content in the tank is lower then 75-80%, the biogas plant is called a dry digesting system. These percentages are not choosen from a certain scientific point of view, they are picked randomly. Mixing of dry material takes more energy and requires a stronger installation, this makes dry digesting less

profitable compared to wet digestion. In some designs water is trickling through the organic material in the tank instead of the water being mixed through the material. This makes a very stabil system, the pH is rather stabil, but it is not an obtimal way of producing biogas because the water can't pass through larger amounts. The pressure from it's own weight makes the substance more solid.
Fisher T, 2004.

12. The use of the sludge

Biogas production increases the proportion of nutrients immediately available for uptake by plants in the digestate (sludge). During the digestion process nutrients are mineralised, which allows improved plant uptake. For instance, digestate has 25% more accessible inorganic nitrogen (NH4-N) and a higher pH value than untreated liquid manure, though some research suggests that in excess of 80% of the nitrogen in digestate can be available to plants. Total N, P and K content in the digested compound remain unchanged compared to the constituent slurries but dry matter is considerably reduced making slurry thinner, while ammonium (NH4-N) content and pH rises.
EPA Ireland, 2005

Based on these data the first basic technical design will be made. The result of this design process are:

1. **Gas prognoses**

In Vrata the proposed options with biogas would cover 8 – 20 % of the total energy need.
Koranda C, 2004

2. **Digester size**
3. **Layout design**

The University of Timisoara started a pilot study on a biogas installation in Finis, Province of Bihor, Romania. They built a small hydraulic biogasreactor with a digester of 5 m3. In this type of biogas installation there is no special biogastank, the gas is kept in the digester and distributed from there (see fig. 18 and 19). The feedstock would be cowdung and human waste. Due to constructive problems (some pipes broke) and the lack of a storage for effluent, the biogas installation wasn’t started up jet.

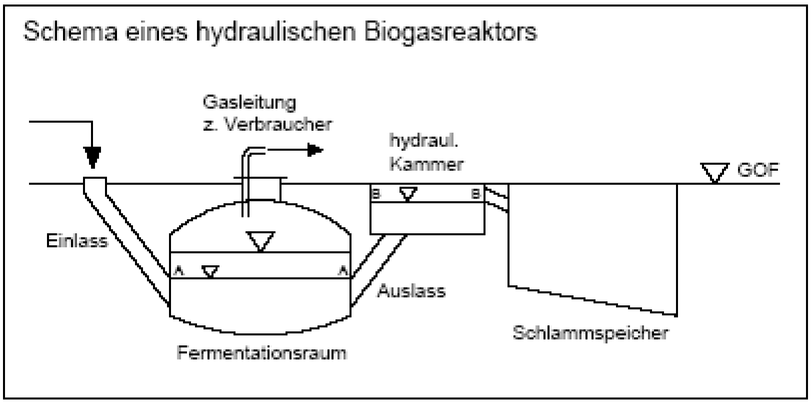


Fig. 18 *Scheme of a hydraulic Biogas installation.*

Abbildung 4a: hydraulischer Biogasreaktor in Finis, Rumänien

Fig. 19 *The hydraulic biogas installation in Finis.*

Koranda C, 2004

4. Cost assessment

The Technical University of Timisoara and the University of Wien conducted a research on the possibilities of waste(water) management in Vrata. Vrata is a neighbouring village of Garla Mare with 2000 inhabitants. In Vrata it is possible to built a decentral network of biogasinstallations or one central biogasinstallation. The biogasinstallations are part of a total concept for wastewater management in Vrata. The decentral network costs approximately 100.000 Euro, the central biogas installation will cost between 15.000 and 28.000 Euro.
Koranda C, 2004

The result is mostly a choice between the three most common types digesters:

Horizontal Digester: This is the most common digester for small biogas plants. The material is steel, old tanks can be used to cut on the costs. The standard volume is between 50 and 150 cubic meter. The retention time is 40 - 50 days, depending on the substrate. The temperature is mesophilic. This type is suitable for dung and poultry manure because of the good mixing qualities of the installation. Because of transporting conditions this type is only available in small sizes.

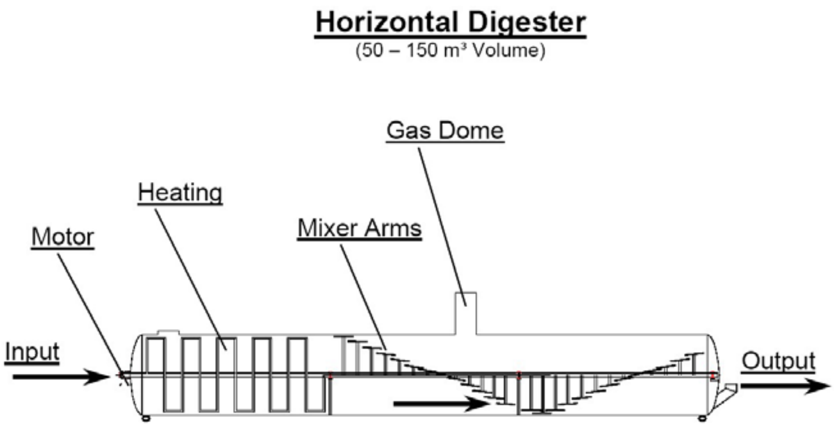


fig. 20 *Horizontal digester*.

Upright Standard Agricultural Digester: This digester is built out of concrete. The standard size differs between 500 and 1500 cubic meter. The height is often 5 to 6 meters, the diameter varies between 10 and 20 meters. The heating is done by waterpipes in the tankwall. Large tanks have two of more mixers. On the top of the roof is a double membrane, gas holder roof. The retention time varies between 40 and 80 days. This tank has a capacity of treating an input of 10.000 cubic meter per year.

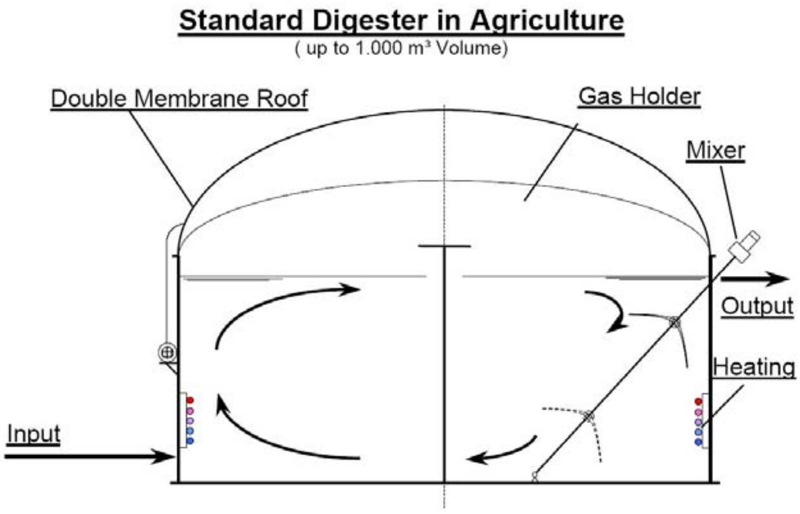


Fig. 21 *Standard Digester in Agriculture*

Kreek A, 2001.

Upright Large Digester: For quantities larger then 30.000 cubic meter input per year, this is the right tank. The building material is coated steel. The hight varies between 15 and 20 meter, the diameter between 10 and 18 meter. The input substrate is heated before entrance of the tank, the retention time is only 20 days because of the continuous mixing and the preheated input.

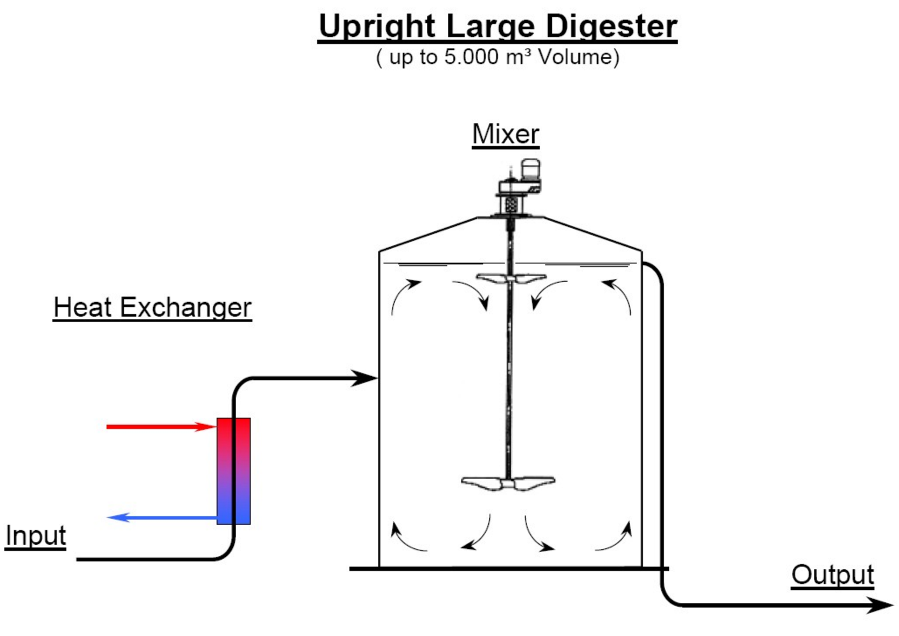


Fig. 22 *Upright Large Digester.*

The pictures show different mixing devices. Mixing the content is important because it avoids temperature differences, sedimentation and formation of a top layer. At the same time it provides an optimal distibution of organics and makes it easier for the gases to escape. Problems attached to the use of mixing devices is the possible destruction of bacterial colonies.

Kreek A, 2002.

6.3 Biogas: Advantages and disadvantages

Biogas production plants have a lot of advantages:

- increased recycling and resources saving.
- sanitation of wastes and manure and breaking the chain of pathogen transmission.
- energy savings through production of a renewable energy source - the biogas.
- utilisation of digestate as fertiliser and the fibre fraction as soil improver leads to energy savings from the production of mineral fertilisers and to saving rare sources of organic matter (e.g. peat).
- less greenhouse gas emission by displacement of fossil fuels by the CO2 neutral biogas.
- less air pollution by emissions of methane and ammonia and less leakage of nutrient salts to ground and surface water.
- Improved health when less woodfires are used for cooking. Use of biogas improves the indoor and outdoor air quality. (Acharya J, 2005.)

Al Seadi T, 2000.

However there are also some disadvantages

- risk of odours that can be solved by burning odorous components in the exhaustion air or other odour treatment techniques
- risk of explosion that must be solved by utilisation of explosion-proof equipment.

Al Seadi T, 2000.

- Given de local economical circumstances, a biogas installation is expensive.
- The manure must be gathered quickly, otherwise the methane is already produced in open air.
- The system is complex and needs daily care and maintenance.
- The local climate will probably stagnate production in winter, the biogas will be needed to heat the productionprocess. Extra room for storage of animal waste might be needed during that period.

7. Composting

7.1 Composting: process and benefits

Composting is defined as a method of waste management, in which organic waste materials decompose in a controlled environment. Composting is a natural micro-biological process where bacteria break down complex organic molecules and release water vapour and carbon dioxide resulting in organic materials and mineral nutrients to be used for improving soils and aiding in the growth of plants. Compost smells like earth and is not a fertiliser but a soil conditioner because the level of nutrients is rather low.

There are different kinds of compost. The concentration N, K and Ph can differ, so can the concentration of organic matter, particle size, stability and maturity. Other criteria, like salt content, heavy metal content and sand content influence the quality of the compost.

Improvement of the soil during application of compost has been researched. Throughout compost application trials a constant increase in Soil Organic Matter (SOM) was reported. The factors influencing the carbon content of the soil are the amount and type of material applied, the maturity of the compost and the soil properties. Composted manure leads to a higher SOM than using stable manure directly.

Compost improves water infiltration. Composted soil holds water in dry seasons, preventing crop from becoming dehydrated. It also holds water during rainy seasons, preventing mudstreams. Soil treated with compost can hold water and air longer and better, providing the roots with water and oxigen. Compost prevents erosion because it increases soil particle adhesion. The eroding effect of rain decreases because of the better absorbing power. This makes compost also good for final landfill cover. Compost can be used to re-establish soil where it has been completely lost. Eroded spots or pits can be treated with compost.
Dulac N, 2001

7.2 Composting: Nutrients

Nitrate is an important nutrient for plants. Mineralised nitrate dissolves in water easily and washes away in the groundwater. A slow release of nitrate is more favourable to plant growth in the long run, but total immobilisation stagnates plant growth. Immobilisation of N is supported by the use of less mature compost and compost with a high C/N ratio (>18). On fields, only 10 –15% of the nitrogen is avialable for crops in the year of application of compost. Subsequent compost additions can rise this figure up to 45%. Short term scale use of compost does not perform as a sufficient nitrogen source for actual plant nutrition at moderate rates of application. The nutrients of compost are released over a period of three to ten years. The compost lasts longer than mineral fertiser, but gives a lower yield nitrate per year with moderate application
Dulac N, 2001

Compost may replace mineral N fertiliser in an intensive maize production system when it its combined with slurry fertilisation. Using compost for an optimised N utilisation, interactions through crop rotation (including green manure (composted manure under anaerobic circumstances) and intercropping) must nonetheless be considered. Together with a mineral-N supplementation, compost can reach the same yield as a mineral NPK fertilisation. That supposes that compost is primarily to use as a substitute for phosphorus and potassium fertilisation and not as a substitute for nitrate fertilisation.

After continued compost application, total and for plants available phosphorus and potassium concentration in the soil is increased. Though the first year the plant availability of P is still lower than for mineral fertiliser. The figures of availability vary with soil and compost properties. The P and K total load should be considered in the nutrient balance of the fertiliser regime. For sulfur short term availability was reported after the use of compost. Long term composting increased the S mineralisation and S availability for the plants.
Federal Ministry of Agriculture, Forestry, Environment and Water Management, 2003

The use of compost lowers the costs of the use of mineral fertilisers and other chemicals. Because the compost provides an organic soil matrix that longer holds fertiliser, the mineral fertiliser is used

more effective. Mixing compost with fertiliser, herbicides and pesticides can reduce the requiered amounts of the chemicals.
Dulac N, 2001

Compost increases the biodiversity in the soil Indicators, such as specific respiration, microbial biomass C and several enzyme activities have been investigated frequently in compost trials. Significant positive effects of compost amendments have been found for the majority of these parameters.In addition investigations on soil fauna (e.g. earth worms, collembola) and feed activity show enhanced abundances and activity in compost plots as compared to control plots with and without mineral fertiliser.

The use of compost has suppresive effects on soil born plant diseases. Though single key factors which cause this effect systematically could not be identified. Anyhow the presence of specific antiphytopathogenic micro organisms or consortia is a pre-condition.

Compost application is likely to reduce the potential leaching of pesticide residues from soils. mineralisation of pollutants (PAH and PCB) was particularly noted from mature compost. On the other hand immature compost can create unextractable micro-pollutants in the soil environment, but mature compost only is capable of true degradation. Control of maturation and compost quality is therefore an important technical and regulatory objective. It was discussed in considering more complex micro-pollutants that fixation of unextractable residues can be enhanced at very high microbial activities. Compost enhances these microbial activities.
Federal Ministry of Agriculture, Forestry, Environment and Water Management, Austria, 2003

7.3. Compost: Effects on the yield

Yield is very much influenced by differences between (i) quantity and frequency of compost application, (ii) crop-rotational schedules, (iii) site specific yield potential and (iv) supplementary mineral N fertilisation. Many vegetables such as cabbage, lettuce, onions, cucumber show positive responses on compost amendments. Crops with long growing period show a better response. As compared to control plots (no fertilisation) compost provides enhanced yields. Especially in long term compost management, compost may be seen as a soil improver rather than an immediate supplier of plant nutrients, gradually enhancing soil fertility parameters and therefore stabilising productivity.

In several compost trials combined compost and mineral N fertilisation performed best whereas in the first years of compost amendment with higher quantities every 2 to 3 years led to advantages against yearly applications at low rates. It may be concluded that due to low N efficiency a positive yield effect of compost is achieved in the long term on soils, which are continuously managed with compost rather than after one or two applications.
Federal Ministry of Agriculture, Forestry, Environment and Water Management, 2003.

7.4 Composting: Techniques

The two main composting techniques are aerobic and anearobic composting.
For aerobic composting there are two main techniques:

1. **Enclosed system composting**: Composting is performed in a building, tank, vessel or container.

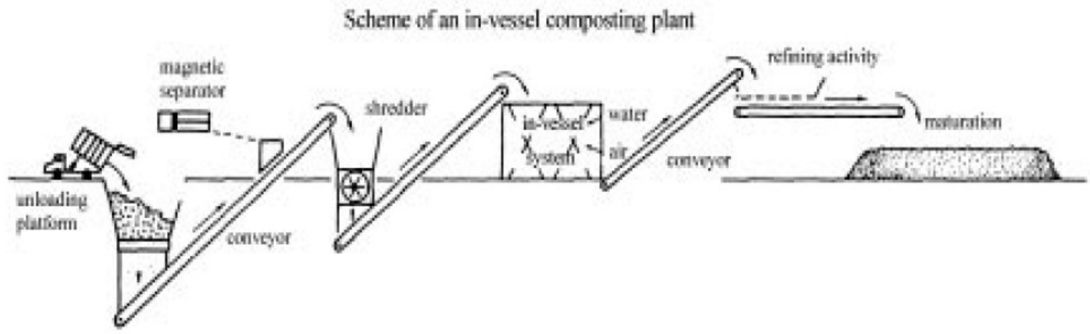


Fig. 23 *Scheme of an in-vessel composting plant.*

In-vessel systems require complex equipment. The systems are highly engineered, capital intensive and require day to day management. These systems use substantial amounts of energy, the on going operation and maintenance is critical. The advantage of these systems is the fast composting proces, minimum use of space and control of pests and odour. In-vessel systems are expensive, apart from the investment vary the operational costs from 40 to 100 Dollar per ton. The environmental advantages are a better control of water and air discharge and of vectors and pest attraction.

2. **Open or windrow composting**: which is done out of door with simple equipment.

This proces is the slower one of the two. Open windrow composting is more easy to operate, there is no complex engineering involved and it is cheaper than in-vessel composting.

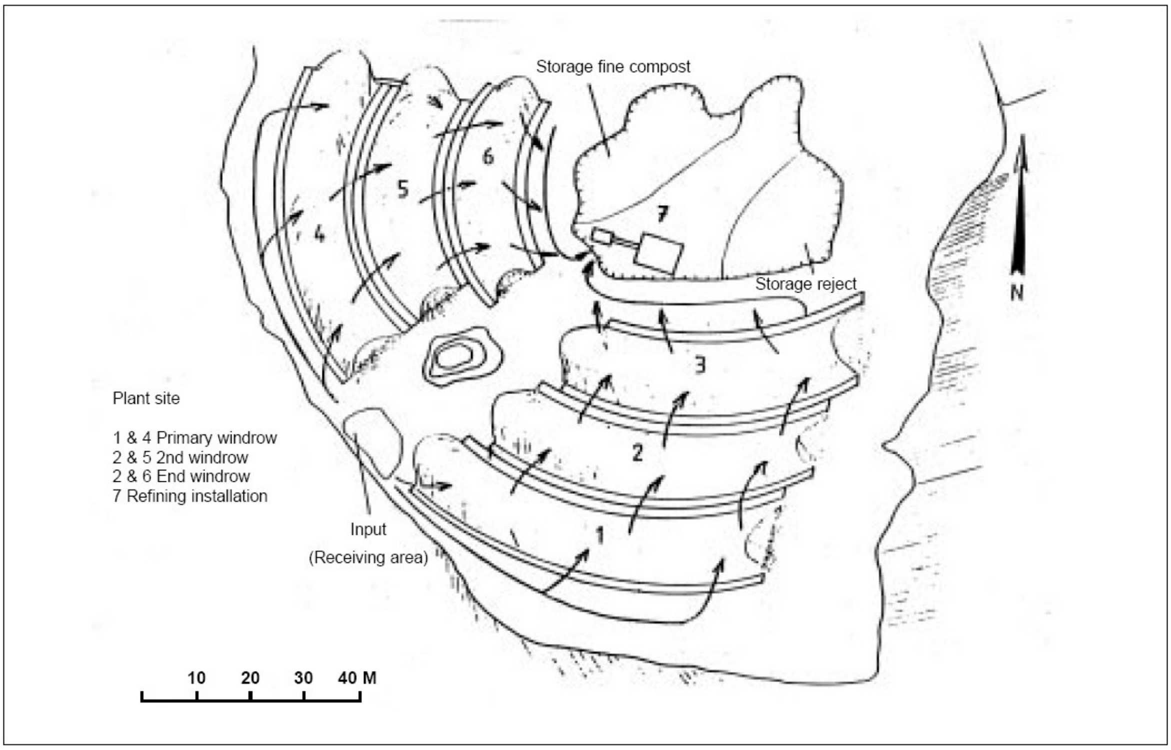


fig. 24 *A Windrow composting site.*

7.5 Compost: Feedstock

The choice of feedstock depends on the goal. Is the goal solid waste reduction, then all the solid waste is used. If the goal is production of compost, other wastes must be added to improve the quality of the compost. Adding industrial organic waste from aquaculture, agriculture, horticulture, livestock and slaughterhouse, food processing, forestry products or faecal matter from septage or latrine will improve the nutrient content of the compost. But these substances also complicate the composting proces and requier strikt control. Most common problems in feedstock are sand quantity, salt content, pathogens and heavy metals.

A good compost requiers a good foodstock recipe:

- The quantity of nitrogen should be sufficient.
- The C/N mixture should be in the range of 25:1 and 30:1.
- The initial moist content should be between 40% and 60% (for figures see annex 3).

A more practical approach is to mix slowly decomposing material (wheat straw, leaves, corn cobs) with fast composting (kitchen waste, manure) in a ratio of one to two.

Human waste
The decision to include a faecal waste stream does introduce important questions about collection, design, operations, and the type of compost that you are seeking to produce.
The choice to use excreta means that certain operational decisions have to follow. For example, turning the piles of compost has to be optimised to assure pathogen kill. The application of supplemental fertilisers may need to be reduced, since the nutrient content is higher. The compost will contain more water. With good management, composting can disinfect excreta. When human excreta is included, the resulting compost can be best used for growing trees, food grains, and cereals and on crops with high market value. However it has been observed that vegetables grown with composted excreta are underdeveloped and that pathogens may be present in the soil and on the crops after application of the compost.
Dulac N, 2001

If the human sludge is to be hygienised and stabilised by thermophilic (anaerobic or aerobic) digestion:
Sludge should be raised to at least 55°C for a continuous period of at least 4 hours after the last feed and before the next withdrawal. Plant should be designed to operate at a temperature of at least 55oC with a mean retention period sufficient to stabilise the sludge.
The time-temperature exposure conditions considered earlier hold good for batch reactors or plug flow reactors. For intermittently fed reactors where there is a frequent influx of new material and a corresponding outflow (e.g. digesters) the exposure conditions may need to be amended.

If the sludge is to be composted, with or without other material:
Windrow composting should be carried out in batches or in a 'plug-flow' system over a period sufficient to stabilise the sludge and produce an acceptable product. All material should be maintained at a temperature of at least 55oC for at least 4 hours between turnings. The number of turnings for a windrow system should be at least three, but more may be necessary to produce a stabilised compost. This process should be followed by a maturation period to complete the composting process.

If aerated pile and invessel composting is chosen. The batch has to be kept at a minimum of 40°C for at least 5 days and for 4 hours during this period at a minimum of 55°C. This has to be followed by a maturation period to complete the composting process.

Performing thermophilic digestion, the sludge shoud achieve a temperature of at least 55°C for a minimum period of 4 hours after the last feed and before the next withdrawal. The plant should be designed to operate at a temperature of at least 55°C with a mean retention period sufficient to stabilise the sludge.
Carrington, E G, 2001

See also the part on legislation on the use of human waste, part 1 of this report, chapter 4.2.
See also the part on biogas temperature and fig. 17 chapter 6.2 in this part of the report.
See Annex 5 for more information on the reuse of human waste

7.6 Compost: location and design

The location has to comply with the following criteria:

- There must be a rather large surface that is nearly flat (a 2-4% grade is ideal), and has a good distance from the groundwater.
- It is close to where the material is collected and used.
- Vehicles have a reliable and easy acces to the composting unit.
- There is access to water.
- It is not near wetlands or area that can be flooded.

The piles of organic waste and compost must be covered to protect from excessive rain, snow and sun. Plastic sheets are easy to use, but rather expensive. They last only one year and can be stolen. Other covering must be angled for drainage of rainwater. A roof can also be an option, that must be 50 – 150 mm higher than the pile, to provide natural ventilation. Be aware that equipment in action, must also fit under the roof or cover.

The site itself can be desigend in different ways. One is pictured in fig. 24. The other in the following picture 25.

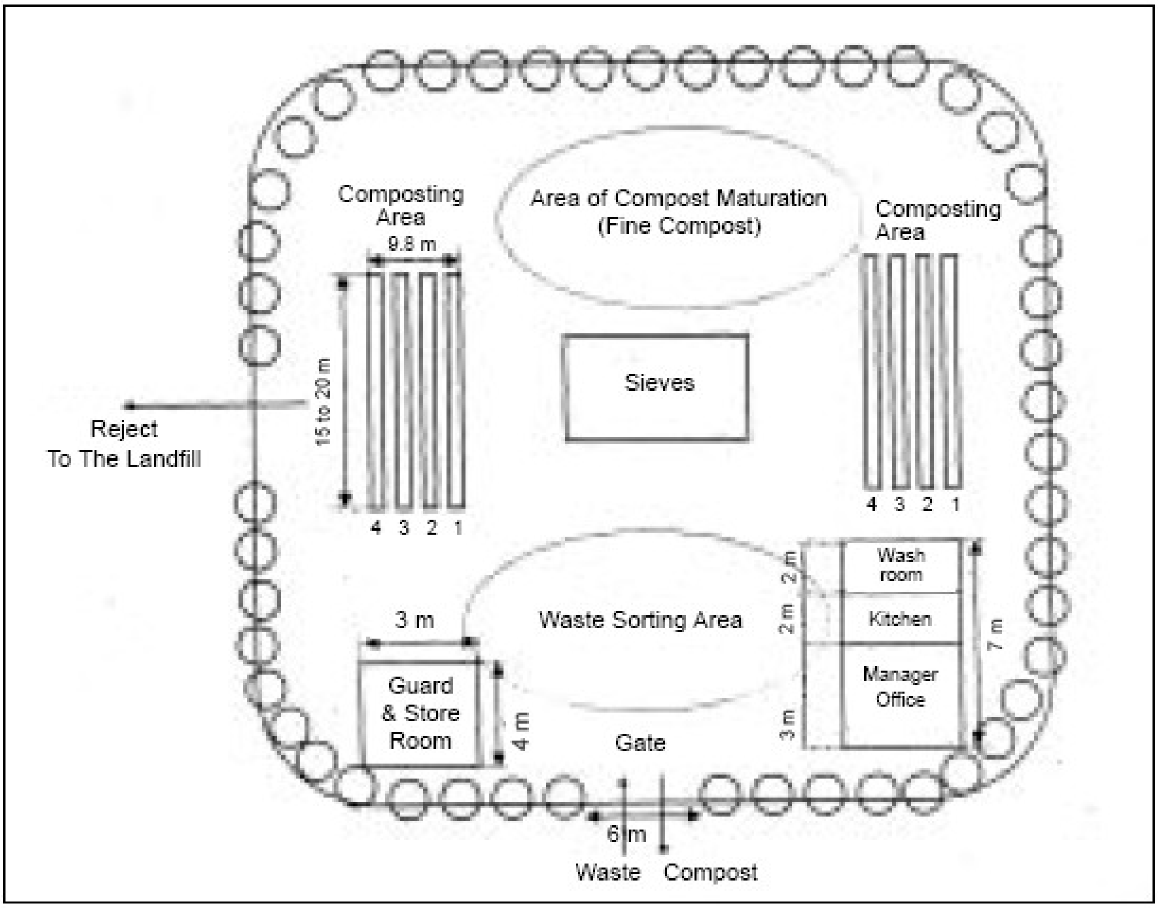


Fig. 25 *Design of a composting location.*

On the site there must be room for recieving the material. It is best to pile the material within 24 – 48 hours after recieving it, to avoid odour problems. Mostly the material is than sorted and reduced in size. Size reduction is an expensive operation, because it requiers drum shredders or mixers, it is also an energy consuming procedure.

Than the material can be:

1. mixed and piled up or it can be
2. piled up in layers.

1. Mixed piles

A mixed pile must always be remixed when the composting process ceases. During composting the oxigen concentration decreases, the bacterial processes stop and the temperature lowers. Turning piles can be done by hand. A bulldozer is no good machine for turning and mixing, it presses the material together, so that there is no oxigen in the compost pile after turning.

The number of turnings influences the temperature in the pile, and therefore the rate of pathogen suppression. Most compost regulations require maintaining the temperature of the compost process at 55 to 65 °C for three consecutive days, in order to achieve pathogen suppression. The average frequency of turning is once per week for 5 weeks. The temperature is highest at the top of the pile. After 5 turnings all material has been heated correctly.

During composting water needs to be added, mostly compost piles are too dry. Water is necessary to activate the micro-organisms during the active composting stage. During composting, on average, 34% of the water will be discharged as water vapour, and will need to be replaced. In areas where there is regular rainfall, piles can be watered by turning the piles during rainfall.

To find out if the pile is composting properly, there are simple methods to detect problems. With a stick thermometer we can measure the temperature and the bacterial activity. We can feel if the compost is dry or wet. The odour tells us if the process is still aerobe. In annex 6 is a schedule with tips.

After five turnings the temperature will decrease and no longer reach 55 °C. This stage is called ‘curing’. The compost can be piled up in large heaps now and left alone. To make a uniform compost it can be seaved, this is best done with a moisture content of 30 - 45%.

An initial volume of feedstock will lose between 20 to 60% of its content, depending on its compaction level, the period of activity of the micro-organisms (beginning and end of thermophilic phase) and the weather. The density of the material will increase, from 350 kg/m3 to 630 kg/m3.

Instead of turning mixed heaps there is also a method called **passively aerated windrow** method. Air is supplied to the organic material through perforated pipes embedded in the pile. The chimney effect created by the warm gases rising out of the windrow causes air to blow through the pipes. The base of the windrow should be porous and made out of straw, compost or grass. A grid of vertical and horizontal bamboo poles can be added as well as a cover on top of the pile to prevent heat and moisture losses.

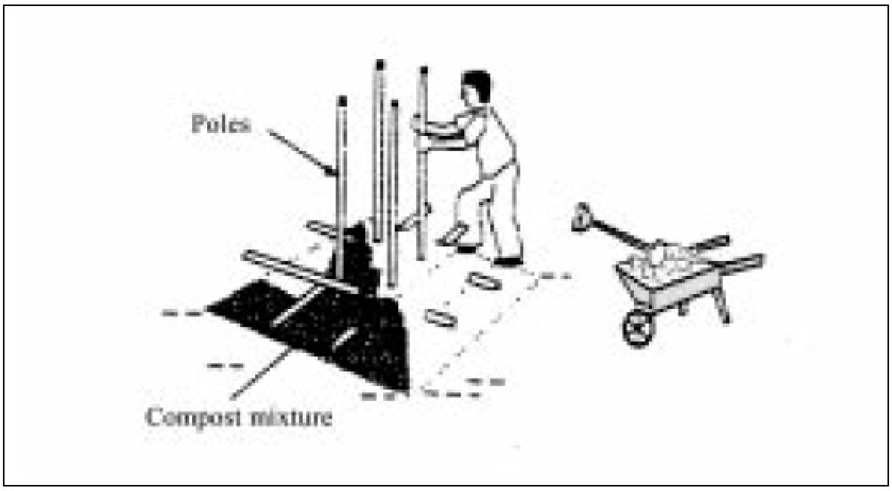


Fig 26 *A passively aerated windrow.*

2. Piles in layers
Piling compost in layers is a special technique to minimize the number of turnings. It is usual to start the bottom layer with a high carbon content using sawdust, branches etc. These larger peaces on the bottom make is possible for air to flow through the pile. This layer is followed by a layer of high nitrogen content which is mostly wetter and denser. Then the layers of 15 cm alternate carbon and nitrogen rich material. This construction absorbes moisture and avoids odours.

7.7 Protecting groundwater

During the process of selection a site for composting, it is usefull to consider the effects of the site on the groundwater. In areas with a high nitrate concentration in the groundwater, it is usefull the protect the groundwater from further contamination. Table 4 shows the effects of the soil on the infiltration of substances that are solvable in water, such as nitrates.

Average Annual Net Infiltration or Percolation Rate[2]		Soil Texture (Permeability Value Used in Calculating Velocity in Feet per Year)[5]	Estimated Velocity of Contaminant Migration (Feet per Year)[4]	Minimum Depth to the Water Table for a MSWLF With a 60-year Total Operating Life and Post-Closure Care Period (Feet)
Inches per Year	Feet per Year			
1	0.0834		0.6	36
5	0.417		2.5	150
10	0.834	Sand (6,000)	4.7	282
15	1.25		6.8	408
20	1.67		8.8	529
1	0.0834		0.4	24
5	0.417		1.7	102
10	0.834	Sandy loam (745)	3.3	198
15	1.25		4.8	288
20	1.67		6.2	372
1	0.0834		0.3	18
5	0.417		1.3	80
10	.834	Silt loam (196)	2.6	156
15	1.25		3.7	222
20	1.67		4.9	294
1	0.0834		0.2	12
5	0.417		1.1	66
10	0.834	Clay loam (66)	2.2	132
15	1.25		3.2	192
20	1.67		4.2	253
1	0.0834		0.2	12
5	0.417		1	60
10	0.834	Clay (17.5)	1.9	114
15	1.25		2.9	174
20	1.67		3.8	228

Table 4. *Influence of soil on the infiltration rate, source: EPA, 1998.*

Avoiding groundwater pollution can be done by choosing a good location with a particular soil, such as thick clay layers. These are not available on every location. In that case another solution might be considered using geosynthetic clay liners.

Geosynthetic Clay Liners (GCL) are sheats of textile and clay to prevent leachate from a landfill to enter the soil and reach the groundwater. The sheets can be applied under the landfill to prevent leachate pollution during the use of the landfill. The sheets can also be used to cover the landfill after use, to prevent the development of leachate by precipitation.
A GCL is a relatively thin layer of processed clay (typically bentonite) either bonded to a geomembrane or fixed between two sheets of geotextile. A geomembrane is a polymeric sheet material that is impervious to liquid as long as it maintains its integrity. A geotextile is a woven or nonwoven sheet material less impervious to liquid than a geomembrane, but more resistant to penetration damage. Both types of GCLs are illustrated in Figure 1. Although the overall configuration of the GCL affects its performance characteristics, the primary performance factors are clay quality, amount of clay used per unit area, and uniformity.

Costs as of 1994, the cost of an installed GCL ranged from $0.42 to $0.60 per square foot. In general, GCL barrier systems are especially cost-effective in areas where clay is not readily available for use as a liner material.
EPA, 2001

During a solid waste management project in the philippines, a landfill was constructed, that migth show us a way to construct a good composting site.

- The base of the landfill (former rice field area) was graded as a V-shaped trough with a diagonal slope of at least 3%.
- Ạ perforated collection pipe, consisting of 150 millimeter (mm) diameter PVC pipe, was installed at a slope of at least 2% used to convey leachate under gravity flow
- A 30 cm thick drainage layer consisting of 50 mm diameter cobbles covering the perforated collection pipe and graded base of the disposal area was applied.

Mair, D. A, 2003

This construction might be used for a composting site. The water collected can be reused for watering the piles. The type of soil and level of groundwater on the location will determine the construction of the floor. A waterresistant floor might proof a good choice when a thick clay layer is absent on the location.

Collection and finances

Collection and diverting of solid waste

Since our feestock is solid waste, the organic waste must be divided from other solid waste. Separation at the source, that means in peoples homes, results in the less poluted compost. Separation after mixing solid waste first contains the risk of contamination of organic waste with heavy metals, paints and other toxics.

Composting is profitable as a manufacturing activity only under certain circumstances. Usually, the involvement of the public sector, either in regulating or paying for waste management, is necessary for a composting operation to be economically sustainable.

Organical waste is the largest fraction of the solid waste, while reusing organic waste, landfills can be smaller. Composting decreases the volume of organic waste with 20 to 60%.
Composting can manage the seasonal fluctuations in waste volume or composition,combining different waste streams such as leaves, kitchen waste, crop residues.
Health hazards of disposal of rotting organics are diminished. The temperature rise during the composting process reduces the amount of pathogens, deactivates weed seeds and fungal spores.

Finances

It is as a waste management activity or integrated waste system component that composting has the most potential to be sustainable. Even where operations are privatised, in the end waste management remains a public responsibility, which is paid for from public means. Composting provides an alternative to disposal, so the cost of producing compost, including labour and depreciation of equipment or infrastructure, should in fact be considered as cost for elimination. The justification for costs also includes positive environmental externalities, sometimes called hidden or ‘shadow’ benefits, such as preserving organic materials and avoiding energy-intensive transportation. And of course the avoided cost of landfilling or other disposal of the organic and inert materials is the main benefit to the public sector.
Dulac N. 2001

8. Recycling

8.1 Heavy metals

Contamination of waste with heavy metals decreases the chance of using solid waste for agricultural purposes. The situation on heavy metals in Garla Mare seems to be good.The concentrations of heavy metals in the groundwater from the main spring in Garla Mare, Sipot, are noted in table 5.

Metal	Concentration in Sipot	EU max. concentration
Lead	0,005 Mg/L	0,01 mg/L
Cadmium	<0,001 Mg/L	0,005 mg/L
Chronium	0,02 Mg/L	0,05 mg/L

Table 5 *Heavy metal in water samples from Sipot*

These results suggest that there is not an enormous pollution with heavy metals in the water of Sipot. This might be caused by the deep clean sand layer it passes, by the absence of heavy metal on the landfills on top of Sipot or by the adhesive effect of organic material of the landfills for heavy metals. The absence of heavy metals in groundwater does not neccesarily mean that they are absent, but these data can be used as an indication.
Wolters A, 2004

To show the effects of heavy metals in human health, the most common heavy metals and their health effects are noted in table 6. Mostly the paints and additives in plastics contain heavy metals.

Heavy metal	Health effect	Source
Lead	Lead is causing concern in particular due to the possible impacts on children. Lead influences the nervous system, slowing down nerval response. This influences learning abilities and behaviour. Children are exposed to lead right from their birth, as children in the embryonic stage receive lead from their mothers through the blood. Children are, furthermore, exposed to lead via dust and soil contaminated by deposition from air and other sources. In the environment lead is known to be toxic to plants, animals and microorganisms. Effects are generally limited to specially contaminated areas.	Important sources include: Plastics, fishing tools, lead crystal glass inclusive cathode ray tubes, ceramics, solders, pieces of lead flashing and many other minor products. To these waste types must be added residues from metal shredding, steel reclamation and cable reclamation.
Mercury	Concerning mercury the primary focus is on methyl mercury originating from the diet in particular though the consumption of fish and fish products. In humans methyl mercury affects among other organs also the brain, and it is documented that (as for lead) children in the embryonic stage receive mercury via the placenta causing persistent	Important sources for mercury to waste include: dental amalgam, measurement and control devices inclusive thermometers, batteries, tubes and lamps etc. It is interesting to note the significant differences between countries, which

	effects on childrens mental development. Notable effects on microorganisms are believed to take place in large parts of Europe in forest soils dominated by organic material.	may be explained by differences in regulation as well as tradition.
Cadmium	Cadmium accumulates especially in the kidneys leading to dysfunction of the kidney with increased secretion of e.g. proteins in urine (proteinuri) and other effects. Intake of cadmium is generally based on the diet, in particular vegetables and corn products. The concern of this pathway is based on the knowledge that an increase in the content of cadmium in agricultural soil will result in an increased uptake of cadmium by plants. However, for smokers also the use of tobacco is of concern. Concerning microorganisms cadmium is known to significantly influence leaf litter decomposition.	For cadmium the picture is somewhat simpler, as the use of cadmium has been restricted for some years and NiCad batteries today is the all-dominating product. However, to understand the picture of sources to incineration plants, it is necessary to remember uses as pigments and stabilisers in plastic as well as plating on steel, which have been significant uses 1-2 decades ago. Many of the relevant cadmium products were quality goods with an expected lifetime of 10-20 years or even more (e.g. PVC-window frames). Such goods are only slowly released to waste. Concerning landfills, manufacturing waste is a source of the same magnitude as industrial products in municipal waste.
Chromium	Chromium differs from the 3 other heavy metals discussed here by being essential in form of Cr(III) to humans and animals. The most widespread human effect is chromium allergy caused by exposure to chromium (especially Cr(VI) compounds) in the working environment. Chromium compounds are also assumed to cause cancer. Environmentally Cr(VI)-compounds are generally considered the most toxic. Hexavalent chromium is toxic to microorganisms; a property utilised in chromium-based biocides. In general, toxicity for most microorganisms occurs in the range of 0.05 - 5 mg chromium/kg of medium. Trivalent chromium is less toxic than hexavalent. The main features are inhibition of growth and inhibition of various metabolic processes	The environmental concerns related to chromium are focused on applications like tanning, wood preservation and pigments and dyes for plastics, paint and textiles. Chromium alloys and in particular stainless steel are by far the dominating field of application for chromium, but normally not regarded as a serious waste problem due to the high value of chromium alloys, which motivates collection for recycling. One may, however, pay attention to that many types of stainless steel are not magnetic and cannot be separated from waste streams by magnetic separation.

	such as photosynthesis or protein synthesis. The toxicity of low levels of hexavalent chromium (1 mg/kg) indicates that soil microbial transformations, such as nitrification, may be affected.	

Table 6 *Health effects and sources of heavy metals.*

The mobility of heavy metals inside landfills is low, and a complete wash-out of a specific metals may require a time of hundreds to thousands of years and in special cases even more. However there is no evidence existing that landfills can be regarded as a permanent containment for heavy metals.

Dedicated recycling of heavy metals may be carried out rather efficiently with very small losses to the environment and residues, assuming that proper technology is applied. The main problem here is to ensure an effective collection of items made of heavy metals. The fact is that effective collection only will work for items present in such a quantity and condition that collection is feasible.

Continued recycling of plastics only exists for few products like boxes for beer ad soft water bottles. This will typically only delay the disposal of the heavy metals in question for a single product generation. Systems are being developed for recycling of cathode ray tubes. Apart from this lead crystal glass will mainly be source for lead contamination of ordinary secondary glass and may be a source for lead emission from glass manufacturing as well as from landfills at the time of final degradation of the glass matrix. Recycling of organic materials to be utilised as soil improvement media will lead to dispersal of heavy metals present in other waste types, e.g. plastics, contaminating the organic material.

Substitution is the option left, when recycling cannot solve the problem. By substituting products containing heavy metals with products that are heavy metal free, pollution is prevented at the source, as it is avoided that heavy metals are taken into the manmade circulation.
Alternatives have been developed for many of the applications of lead and nearly all applications of mercury and cadmium, while the development regarding chromium so far has focused in particular on tanning and wood preservation.
EC. 2002

8.2 Plastics

Characteristics of plastic waste

Plastics consist of large molecules (macromolecules), the building blocks of all materials. Plastics can be regarded as long chains of beads in which the so-called monomers such as ethylene, propylene, styrene and vinyl chloride (the beads) are linked together to form a chain, called a polymer. Polymers such as polyethylene, polypropylene, polystyrene and polyvinyl chloride are the end products of the process of polymerization, in which the monomers are joined together. In many cases only one type of monomer is used to make the material, sometimes two or more. A wide range of products can be made by melting the basic plastic material in the form of pellets or powder. The properties of plastics can be modified by a number of substances known as additives.

The four types of plastics that are most commonly reprocessed are polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyvinyl chloride (PVC). Most polymers (macromolecules) are considered nontoxic (PVC is an important exception). Polyethylene (PE) and polypropylene (PP), for example, are inert materials, but it should be realized that polymers are not completely stable. Under the influence of light, heat or mechanical pressure they can decompose and release hazardous substances. For example, the monomers from which polymers are made may be released and may affect human health. Both styrene (which is used to make polystyrene, PS) and vinyl chloride (used to make PVC) are known to be toxic, and ethylene and propylene may also cause problems.

The environmental effects of plastics also differ according to the type and quantity of additives that have been used:

- Some flame retardants may pollute the environment (e.g. bromine emissions).

- Pigments or colorants may contain heavy metals that are highly toxic to humans, such as chromium (Cr), copper (Cu), cobalt (Co), selenium (Se), lead (Pb) and cadmium (Cd) are often used to produce brightly coloured plastics. Cadmium is used in red, yellow and orange pigments. In most industrialized countries these pigments have been banned by law.
- The additives used as heat stabilizers (i.e. chemical compounds that raise the temperature at which decomposition occurs), frequently contain heavy metals such as barium (Ba), tin (Sn), lead and cadmium, sometimes in combination.

Because plastic degrades slowly under the effects of wind, sun and rain, plastic waste is one of the most objectionable kinds of litter. It lies around streets and open spaces for weeks or months after it has been dropped. It may become coated with other, objectionable wastes, provide a harbour for vermin and insects and it can block up drainage systems.
Vogler J, 1986

The environment benifits from collecting plastic waste and recycling it. Not only the litter is cleaned up; the use of reprocessed pellets in the production of plastic bags saves around 70% in energy use and 90% in water use, compared to the use of pellets made of virgin material. Likewise, a reduction in emissions of CO2, SO2, NOx (NO and NO2) can be achieved varying from around 60% to 80%
Klundert, 1995

Large plastics factories usually do not reprocess municipal plastic waste because of the sensitivity of their machinery to the impurities that are normally present in recycled materials, the irregular shapes of plastic pellets, and the generally low quality of the final products made from waste materials.
Vogler J, 1986
This is why the process of selling recycled material to producers of plastic is not taken into account in this chapter. This chapter is written for reuse of plastics in small scale projects.

Taking into consideration the process of plastic recycling, the most important environmental problem caused by the (afore mentioned) polluting substances is air pollution, either within the reprocessing units or in the open air. During the extrusion process several substances such as additives, may be released. Since PE and PP do not contain large amounts of additives, potential problems with PE and PP are far less than with PVC. While extruding PVC additives may be released, but also vinyl chloride and HCl
Klundert A, 1995

This is why landfilling PVC might be the safest option of disposing of it. The common statement throughout the literature is that PVC products are probably not environmentally significant sources of vinyl chloride (VC) monomer which can be found in landfill leachate. PVC does not depolymerize to VC and/or other degradation products unless placed under extreme thermal, chemical or photolytic conditions. The PVC polymer is therefore regarded as resistant under landfill conditions. More likely primary sources of VC are chlorinated solvents, VC aerosol propellants and PVC sludge waste (Mersiowski HW_DO, 1999; Hagan HW_DO, 1995).

The general view expressed in studies investigating the release of stabilisers from PVC products is that as the stabilisers are encapsulated in the PVC matrix, the migration rate is expected to be extremely low and would only affect the surface of the PVC but not the bulk of the material. The mobility of organotin stabilisers in flexible PVC is higher than in rigid PVC due to the plasticiser, the release of organotin in landfills can be expected, however available data is insufficient.

The PVC polymer is regarded as being resistant under soil-buried and landfill conditions.
Bro, 2000

8.3 Plastic recylcing techniques

Collection

This project wants to contribute to a cleaner environment. This means that probably all plastic waste has to be collected. Also the material that cannot be used for recycling. Materials that cannot be used for recycling are:

- o plastics that are attached to other materials, such as metals or cloth.
- o Thermosets (they do not melt at higher temperatures)
- o Plastics that are unhygienic, such as articles for babies, animals or hospitals.
- o Foamed or extended materials, except when used in the extended form for isolation. Transportcosts are high relative to the weight.
- o Flimscrap, unless the right equipment to manage that material is available. It is difficult to clean it properly.

Vogler J, 1986

The key to establishing a successful recycling operation is emphasizing collection over processing. It is important to ensure that sufficient material is collected before large capital investments are put into processing. Developing a business plan for a recycling facility can be difficult without an established program for collecting waste. This predicament also makes it difficult to get investors given the speculative nature of the facility without a collection program in place. With a plastic waste collection system in place, however, investors are very interested in supporting a recycling facility.
Carmis, 2000.

The costs of collection may be calculated on a daily, weekly or monthly basis, for each collector individually or
for the whole team together. The following should be included:
- Cost of labour (wages)
- Labour overheads (clothing, insurance, pension, supervision, etc.)
- Transport (bus fares, lorry fuel, animal fodder etc.)
- Publicity (advertising, leaflet printing and distribution etc.)
- Depreciation of equipment (cart, lorry, etc.)
- Interest on loans to buy equipment.

Vogler J, 1986

Sorting

Plastic waste normally consists of a mix of all kinds of plastic. In annex 7 most kinds, characteristics and the products that are commonly made of them are described. Different kinds op plastic can be recognised by scratching, burning and floating tests. How this is done is described in annex 8. In household waste there will be little material other than PVC, HDPE, LDPE, PS and ABS. Sorting is easier if objects have not been chopped up, as this destroys the familiar appearance. Built up experience of what different products and different brands of the same product look like. After working for a few days in this way tha staff will be able to distinguish 90% of all polymers by appearance. The remainder need testing. The rule is "If in doubt test. If still in doubt, throw it out".
Be aware that PVC has different environmental effects then other kinds op plastics because of its chlorus content. Recycling this material by reheating can cause healthproblems, the process causes chlorine to enter the gases that result from the process. This can cause respiratory problems.
Because it is impossible to know how they have been contaminated, reclaimed materials from an unknown source should NEVER BE USED FOR food packaging, toys for children, kitchen utensils, drinking water piping and tanks, or clothing.

By sorting plastic scrap into separate colours it is possible to produce a coloured reclaim whose use can save the moulder substantial colouring costs. Products that are black, dark grey or dull green or brown are very likely to have been made from reclaim of mixed colours. Refuse sacks, garbage cans, buckets and jerry cans are common examples.

Not all colours need be sorted; perhaps five groups will be sufficient such as:
- Clear
- White
- Red, yellow and orange
- Brown, black and green
- Blue

Cleaning and drying

The plastic material that will be recycled, has to be cleaned. Impurities influence the strength and toughness, resistance to chemicals, leak resistance and, especially, visual appearance. Apart from the product quality, impurities also obstruct the production process.

The main problem is obstruction of nozzles and screens (fine wire mesh strainers) by non thermo plastic impurities such as grit, sand, paper, adhesive tape and paper labels. Although such blockages can be removed they play havoc with the economics of the production process.

Plastics machinery is designed to handle soft solids and fluids under high pressures and moderately high temperatures. In these conditions hard grit or metal can score or wear moving parts and have serious long term effects on the efficiency of the machine.

Cleaning can be done by brushing, brushing with water and detergentand washing in hot caustic soda solution. This should be avoided if possible but may be necessary to remove oil or grease or heavy dirt. It is essential that stout, elbow length, rubber gloves, free from holes are worn.
Waar gaat het afvalwater naartoe? Met welk water wordt er schoongemaakt? Gaan mensen dat in de rivier doen?

To save time (that means cost) and water do not rinse after washing unless unavoidable. Place objects to drain on a sheet of polythene film, taking care that no sand or dust can blow onto them. When dry, store in a drum or carton.

Some polymers are "hygroscopic" they absorb moisture slowly, and need to be dried before they can be successfully extruded and pelletized. Drying these playtics normally requires between 2 and 3 hours at between 70~C and 90 C but lower temperatures and a longer time can be used for sun drying, especially if there is a slight wind.

Size reduction

One reason why siye reduction is important, is that transport costs normally dominate recycling economics. If the value is high compared with the transport cost then a profitable operation is frequently possible and vice versa. Transport coats depend not only upon weight but also on volume. It is no use having a high value if the volume is so high that transport costs are excessive, even though the ratio of value to weight may be advantageous. This is why much attention must be paid to volume reduction Size reduction during collecting reduces transportation volume but may make sorting difficult. Size reduction at the depot helps transportation to the customer and feeding of material to the granulator.

The easiest method for size reduction is with a circular saw, such as is used in a woodwork shop - special blades for cutting plastics are available. Protection measures for the staf must be taken: Operators should be trained, should have hair in a cap and loose clothing such as scarves or sleeves tucked in. Goggles should be worn to protect the eyes.

Preparation for moulding

Before scrap can be fed into an injection moulder or extruder it must be converted into a "homogeneous", free flowing grain, powder, pellets or crumbs.

The granulator choppes solid material into regular sized, irregular shaped pieces. This is done with a granulator, there are different types, one is shown in fig. 27.

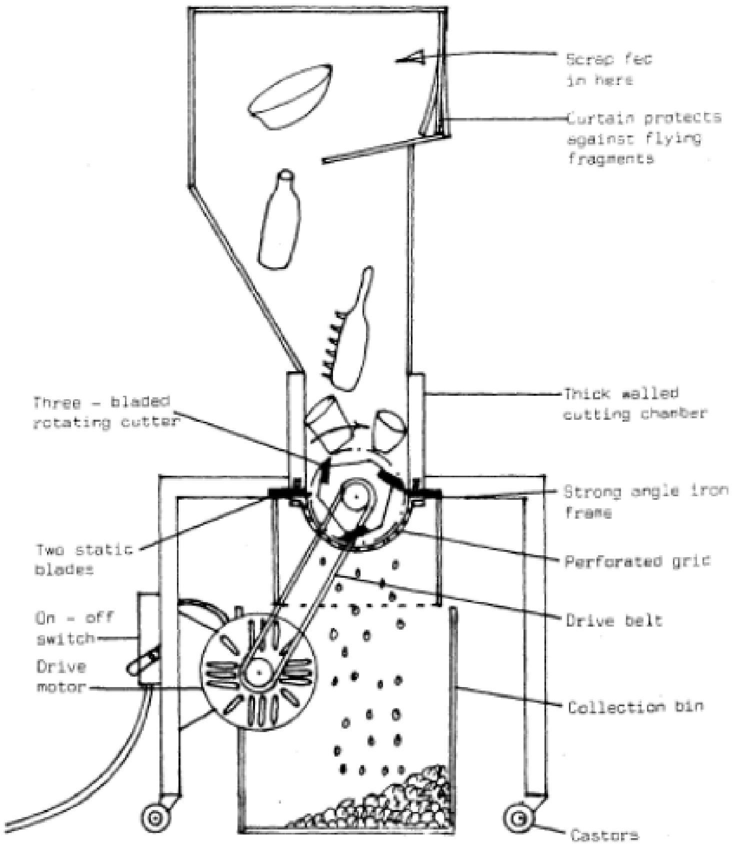


Fig. 27 *Horizonzal axis granulator.*

It is neither uncommon nor difficult to make your own granulator, if you are a competent mechanic.

Granulated film is too light and bulky to feed to an extruder or injection moulder. It does not feed freely in the hopper or down the screw. It can be converted to freeflowing material in a machine called a crumber . This is like a vertical axis granulator but there is no perforated grid; the material stays in the path of the rotating knives and, while being chopped, is heated to it's melting point. The volume of the material decreases and, at the right moment, water is admitted to the cutting chamber. The molten plastic explodes into a hard, dense, beady crumb, irregular in shape and size but suitable for feeding down the barrel of an extruder. Large amounts of water vapour are produced and sucked out by a fan.

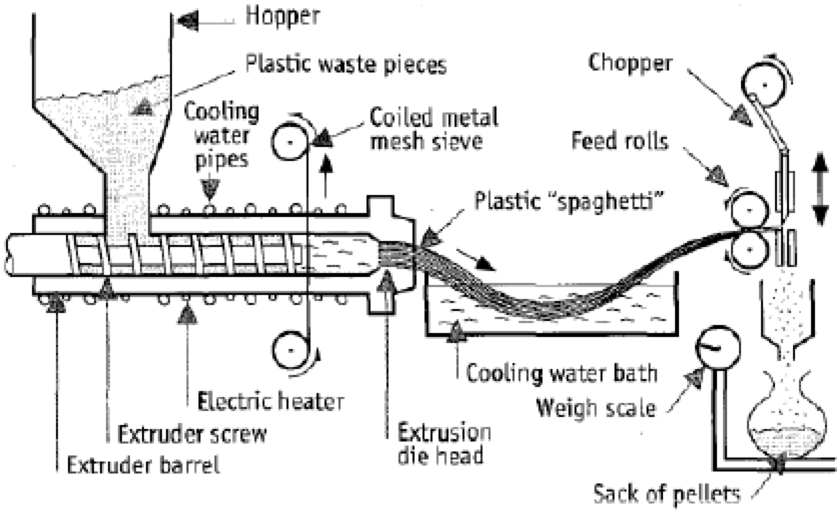
Extruding and Pelletising

Virgin polymer is normally sold either as pellets or as powder. The pellets are of uniform size and shape, about the size of maize grain. The powder is of consistent grain size. Consistency is important because it decides the density of the material in the moulding machine, which in turn determines the density and strength of the product. Particles of different sizes and shapes result in air spaces, gas bubbles or areas of incomplete fusion (due to unmelted material) in the product. Solid plastics scrap that has been passed through a granulator with a grid size of 4mm or 6mm will be equivalent to virgin pellet and will mix with it, even though the granules may be irregular in shape.

Another argument to reduce plastics to smaller granules is that small particle sizes are economical to pack. Large particle materials occupy more space and are expensive to transport and store.

The pellets or granules are used to feed an extruder (see fig. 28) An extruder is a machine normally used for producing plastic material in long, continuous rods, sheets, shaped sections or pipes, but it can also produce pellets. For the production of small articles from reclaimed material, a small injection moulder can be used.

Figure 6-2: Extruder with a pelletizer.



Source: Vogler,[45] 1984.

Fig 28 *Extruder used for production of pellets.*

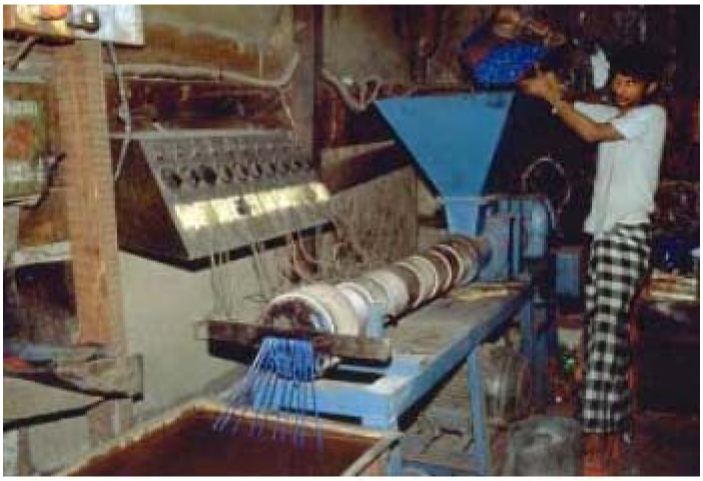


Fig 29 *Extruder used in Bombay, India*

Most plactics change during heating and extrusion. The changes depend on the kind of plastic that is used. The color and viscosity can change, some materials aren't stable during recycling.
Klundert, 1995

Investements

Finally, a vigorous plastics recycling industry can provide unique opportunities for the poorest to earn a small income by collecting waste materials for sale to a recycling plant. No capital is needed, skills may be passed from one to another with little difficulty, so this can provide a catchnet against the consequences of extreme poverty. The initial stages: collection, sorting and cleaning of material are all labour intensive and require little capital equipment.

The later stages do require investment in equipment, which may be bought using the profits of the earlier stages if outside finance is not available. This prevents complex developments before early stages have been learned and consolidated. For those lacking previous industrial experience, this may be essential to ultimate success. However this is a slow process and to have capital ready from the start may be more attractive to those who are impatient or ambitious, although it does increase the risk and scale of failure.

Vogler, 1986

9. Burning household waste

In Garla Mare people use open burning of solid waste as a management technique. There are some kinds of air pollution caused by open burning of household waste. In the United States, in many rural areas there is no facility for garbage disposal. People burn their garbage in oil-drums, which is almost the same technique as used in Garla Mare. This causes air pollution, especially if PVC is burned with organic waste. The burning of PVC generates polychlorodibenzodioxins and furans (PCDD/F) in soot and ash. These substances can cause cancer and are mutagenic.
Carrol F. C., 2003

Emissions from burning only leaves without plastics, are dependent upon the moisture content, density, and ignition location of the leaf piles. Increasing the moisture content of the leaves generally increases the amount of carbon monoxide, hydrocarbon, and particulate emissions. Carbon monoxide emissions decrease if moisture content is high but increase if moisture content is low. Increasing the density of the piles increases the amount of hydrocarbon and particulate emissions, but has a variable effect on carbon
monoxide emissions.
EPA, 2003

Dioxine

Burning waste in barrels was found to be a significant source of dioxin air emissions (7 - 23 grams TEQ/year) in the USA. The high dioxin content of burn barrel ash also raises environmental health concerns. Air dispersion modeling showed that fifteen minutes of open burning resulted in dioxin impacts two times the health based guideline for subchronic (24-hour) exposure at a downwind distance of 500 meters. PVC plastic is the major chlorine donor for dioxin sources that account for 79% of quantified dioxin releases to air, water and land. PVC is also the major chlorine donor for dioxin releases from car and building fires, open burning at construction sites and landfill fires.
Belliveau M,E, 2003

Much of the dioxins created and released into the air through backyard burning settle on plants. These plants are, in turn, eaten by meat and dairy animals, which store the dioxins in their fatty tissue. People are exposed to dioxins primarily by eating meat, fish, and dairy products, especially those high in fat. Backyard burning occurs most commonly in rural farming areas where dioxin emissions can more easily be deposited on animal feed crops and grazing lands. These dioxins then accumulate in the fats of dairy cows, beef, poultry, and swine, making human consumption of these harmful chemicals difficult to avoid.

Dioxins are classified as persistent, bioaccumulative, and toxic pollutants (PBTs). PBTs are highly toxic, long-lasting substances that can build up in the food chain to levels that are harmful to human and ecosystem health. Persistent means they remain in the environment for extended periods of time. Bioaccumulative means their concentration levels increase as they move up the food chain. As a consequence, animals at the top of the food chain (such as humans) tend to have the highest dioxin concentrations in their bodies.

Dioxins are potent toxicants with the potential to produce a broad spectrum of adverse effects in humans. Dioxins can alter the fundamental growth and development of cells in ways that have the potential to lead to many kinds of impacts. These include adverse effects upon reproduction and development, suppression of the immune system, disruption of hormonal systems, and cancer. For more detailed information on dioxin health effects, safety issues, and risk,
EPA, 2003

Experimental studies show that under open burning conditions, PVC content positively correlates with dioxin emissions. PCDD/F emissions increase with higher amounts of CL, whether organic or inorganic , and with higher amounts of copper catalyst.
Gulleth B,K, 2000.
A proposed solution is the seperate collection of PVC and diverting it away from incineration.
Belliveau M,E, 2003

PAH
Polycyclic aromatic hydrocarbons, or PAHs, are a group of chemicals commonly found in particulate matter (or smoke and soot) released from backyard burning. The are formed from the incomplete combustion of certain materials. Some PAHs are carcinogenic, or cancer-causing.

VOC
People in the immediate vicinity of a burn barrel are also exposed to high levels of volatile organic compounds (VOCs) produced by open burning. Many VOCs are harmful to humans. They also contribute to ground-level ozone pollution, also known as smog, which can worsen respiratory, heart, and other existing health problems. Inhaling certain VOCs can lead to eye, nose, and throat irritation; headache; loss of coordination; nausea; and damage to liver, kidney, and central nervous system.

Hexachlorobenzene, or HCB, is a highly persistent environmental toxin that degrades slowly in air and, consequently, undergoes long-range atmospheric transport. HCB bioaccumulates in fish, marine animals, birds, lichens, and animals that feed on fish or lichens. Based on studies conducted on animals, long-term low-level exposures may damage a developing fetus, cause cancer, lead to kidney and liver damage, and cause fatigue and skin irritation. HCB is considered a probable human carcinogen and is toxic by all routes of exposure.

Nitrogen oxides
Nitrogen oxides, or NOx, is a group of nitrogen compounds that are partially responsible for acid rain and contribute to global warming, ozone depletion and the formation of smog.

Carbon monoxides
Carbon monoxide or CO, chemically reacts with sunlight to create harmful ozone. CO production can significantly impact ambient air quality and a region's ability to meet Clean Air Act regulatory air quality standards. Burning garbage in a barrel or pile produces more CO than decomposition in a landfill. CO is also a significant greenhouse gas.

Particulate matter
Particle pollution, also referred to as particulate matter, or PM, refers to microscopic particles released by open burning. Particles that are small enough to get into the lungs (those less than or equal to 10 um in diameter) can cause numerous health problems. Particles can aggravate respiratory conditions such as asthma and bronchitis, and have been associated with cardiac arrhythmia (heartbeat irregularities) and heart attacks. People with heart or lung disease, the elderly, and children are at highest risk from exposure to particles. Coarse particles come from sources such as wind blown dust and unpaved roads. Coarse particles can accumulate in the respiratory system and aggravate health problems such as asthma.

Particles can be carried over long distances by wind and then settle on ground or water. The effects of this settling include:

- making lakes and streams acidic
- changing the nutrient balance in coastal waters and large river basins
- depleting the nutrients in soil
- damaging sensitive forests and farm crops
- affecting the diversity of ecosystems

Many scientific studies have linked breathing particle matter to a series of significant health problems, including:

- aggravated asthma
- increases in respiratory symptoms like coughing and difficult or painful breathing
- chronic bronchitis
- decreased lung function
- premature death

EPA, 2003

Dus de combi van slechte wegen, stof van velden en verbranden van vuil is echt een accumulatie van mongproblemen...

PE burning

The articles reviewed provide no evidence that burning the PE plastic sheeting along with the slash pile would cause a significant impact to air quality, however, the limited amount of information regarding the pyrolysis/combustion of PE in conjunction with woody biomass precludes an ironclad statement. Based on the available data, it can be assumed that the volatilization of the PE will commence at a relatively low temperature. In the early stage of the pile burn, temperatures will quickly rise from ambient to around 350 to 400 °C. This is high enough to thermally degrade the PE, but not high enough to allow combustion. The pyrolysates will melt and drip into the hotter region of the fire and volatilize into the atmosphere. Since up to 41 percent of the PE is lost prior to ignition at temperatures lower than 750 °C, little PE will remain by the time the pile temperature becomes high enough to favor the formation of PAHs. This means the emissions of PAHs from the PE are likely to be low.

Wrobel, C. 2003

Ash residue

Backyard burning also produces ash residue, which can contain toxic metals such as mercury, lead, chromium, and arsenic. These metals can be toxic when ingested. When a person ingests hazardous amounts of lead, for example, he or she may experience high blood pressure, cardiovascular problems, kidney damage, and brain damage. Unaware of the potential danger, some people scatter the ash in their gardens or bury it on their property. Garden vegetables can absorb and accumulate these metals, which can make them dangerous to eat. Children playing in the yard or garden can incidentally ingest soil containing these metals. Also, rain can wash the ash into groundwater and surface water, contaminating drinking water and food.

More details about the substances that form during household waste burning are found in annex 9.

Preventing burning waste

When surveyed, local fire wardens offered three broad categories of opinion as to why rural people burned their trash in backyard barrels: economic incentives (e.g. avoiding pay-as-you-throw disposal fees), cultural habits and the inconvenience of proper disposal.

A curbside or door-to-door collection service is a very convenient disposal option for residents. Many burn barrel users, when asked, stated they would stop backyard burning if collection service were available. Local governments or tribes frequently contract with a hauling company and use tax dollars or designated collection service fees to pay the hauler. Another option is for residents to contract directly with a waste hauler.

EPA, 2003

10 Wastespreading

The principle

It is expected that landspreading will increase, following the implementation of Community and National regulations which restrict disposal of organic-rich materials in landfills and which require treatment of organic-rich industrial effluent from different branches of the food and drink and other sectors. The key tenet in support of landspreading of wastes is that it recycles nutrients and organic matter to the land which would otherwise be lost in disposal to landfill or thermal destruction. Provided that benefit to agriculture (or ecological improvement) can be demonstrated, landspreading of wastes is considered preferable to thermal destruction or landfilling in the ranking of options in the Waste Framework Directive.

Waste producers using the landspreading outlet must recognise that it is waste recovery not waste disposal. They should be prepared to improve the management of wastes for landspreading by investment as appropriate in storage at the point of production, dewatering and other treatment, monitoring and analysis, and field trials to quantify the agricultural benefit of their wastes.

Two of the benefits of landspreading of waste are that it is often an economic route for the waste producer compared with the other options available, and for the farmer it usually represents a free or competitively-priced source of nutrients and/or soil conditioner.

Public acceptance

The development of landspreading depends partly on public acceptance of the concept and of landspreading operations at the local level.Landspreading depends on the willingness of farmers to accept waste for recycling on their land and this willingness may be influenced by various outside influences. An important factor is the attitude of the buyers of farm produce to the fact that waste has been recycled on the land. Any suggestion of a public acceptance problem with food made from crops grown on waste-treated land might cause the buyer to compel the farmer to stop the practice.

Public acceptance at the local level is important. Neighbourhood concerns can be triggered by odour, visual and traffic nuisance all of which must be avoided both at the plants where the waste is produced and treated, and at the farms where it is spread. This will require making sure the waste is treated as far as possible to remove odour, planning lorry routes to the farm to avoid nuisance, and ploughing in waste soon after spreading on the land or else applying the waste by subsurface soil injection.

Regulations

There are currently no specific regulatory controls at the Community level on wastes applied to land with the exception of sewage sludge. However, in Annex IIB of the Waste Framework Directive 75/442/EEC as amended by Directive 91/156/EEC (CEC 1991), landspreading operations of wastes other than animal carcasses and animal manures are considered as recovery operations as long as they are carried in accordance with Article 4, i.e. without endangering human health and the environment.

More specific controls for landspreading of wastes could be compiled from the European Waste Catalogue (classification) and from Directives 86/278/EEC on landspreading of sewage sludge, Directive 91/676/EEC on protection of waters against pollution caused by nitrates from agricultural sources and the EC initiative on biodegradable waste. The two Directives, and extended guidance for their implementation which is available in most Member States, contain much of relevance to the landspreading of wastes.

A permitting system may be justifiable to ensure a high level of environmental protection. There is no reason why the permit should be confined to a single operation. It might cover several wastes and farms and a number or spreading operations provided that the competent authority is satisfied that the following criteria are met:

- The waste(s) have been designated as suitable for landspreading
- Article 4 of the Waste Framework Directive 75/442/EC as amended
- Directive 91/676/ EEC on nitrates
- Directive 86/278/EEC on sewage sludge used on land for Class 3 wastes
- The operation will be compatible with the farm waste/fertiliser plan
- The activity will be undertaken by competent operator(s)

- A site risk assessment has been carried out by properly qualified personnel and necessary precautions to ensure a high level of environmental protection will be acted upon
- A record of each spreading operation will be kept (type of waste, quantity of waste applied, location of farm and field, date of spreading) including the results of monitoring and analysis, and supplied to the competent authority

The competent authority would make the necessary site visits and spotchecks to confirm that landspreading operations were in compliance with the permit conditions and the records would indicate where any pollution incident could be linked with a landspreading operation.

In some countries there is increasing public concern about the volumes of untreated animal waste being landspread. This has led to the development of various schemes, which either still lead finally to reuse on farmland, or remove this option entirely. These schemes are most developed in Sweden where a proportion of animal manure produced is anaerobically digested or composted with other industrial wastes before being recycled to land.

Environmental effects

Animal wastes are responsible for a large number of diffuse pollution of both surface and groundwaters. Following manure application to land, ammonium-N (plus uric acid N for poultry manure) will be converted to nitrate-N which is susceptible to leaching.

Most animal excreta such as slurries have a high biochemical oxygen demand (BOD) ranging from 10,000 to 30,000 mg l which, if entering a watercourse after application to land, can deplete the available oxygen content in water and result in ammonia levels which are toxic to many aquatic animals. High BOD waste added to wet soils can give rise to anaerobic conditions in soil due to soil oxygen depletion and result in poor plant growth. Manures and slurries also contain suspended solids which can increase turbidity in water and smother benthic fauna and flora.

Manures and slurries can contain high levels of potential toxic elements (PTEs), particularly zinc and copper due to the use of mineral supplements and veterinary products (hormones and antibiotics). This is more problematic for pig slurry which can contain up to 600 mg/kg ds of copper and up to 900 mg/kg ds of zinc, compared to the current EC recommended limit value for sewage sludge used in agriculture of 2500 mg kg ds for zinc and 1000 mg kg ds for copper.

Waste spreading can cause odour problems, mainly with pig and poultry waste. The sources of ammonia from livestock production are from animal housing, waste handling, storage and landspreading. It has been reported that more than half of the emissions arose from spreading slurry on land. Soil incorporation can be very effective in reducing odour but it must be done rapidly, i.e. within hours or via injection if a significant reduction in losses is to be achieved. The dry matter content has a large influence on ammonia losses from surface application of slurries and other liquid manures. The emissions from landspreading of the two greenhouse gases nitrous oxide (N2O) and methane (CH4) are relatively small compared with emissions from manure stores, fertilised land, housing and outdoor livestock.

Effects on human health

Animal manures contain pathogenic elements in variable quantities depending on the animal health. Manures are applied without treatment and restrictions on the application to land of agricultural wastes are less stringent than other wastes. They potentially represent a greater risk because of the large volumes compared with other wastes for possible contamination of meat, dairy products, vegetables and water resources. In many cases, manures and slurries are applied on the same farm that they originated from. While this practice does not reduce the risk to humans or wild animals, the resident animal population is likely to become reinfected. There have been reports on cases of drinking water supplies contaminated by cattle slurry resulting in outbreaks of disease in people

Wood and plant materials are mostly not dangerous for health and environment. Application to land of wood products with a high C/N ratio can temporarily remove plantavailable nitrogen from the soil. Additional inorganic nitrogen should be applied to the soil to compensate for this and avoid crop yield and quality loss.

The nature and origin of waste plant matter needs to be considered in case diseased material is present that could act as a source of infection for succeeding crops e.g. haulms of potatoes infected

with the potato blight fungus Phytophthora infestans. Rotten wood may harbour the honey fungus, Armilleria, which can destroy trees and shrubs. If these materials are to be used as soil conditioners then a rate of application to the land of about 20 tonne ha-1 yr-1 would be suitable and is not critical; more or less could be applied according to local circumstances. A mulch of bark or wood chips would be applied over the soil to a depth of about 3 – 8cm according to the size of the chips. Site or field storage without containment should be feasible except perhaps in the case of putrescible vegetable waste, which should be stabilised by turning occasionally until it no longer smells (a simple form of composting).
Gendebien, A.H. , 2001

Spreading of human waste; sewage sludge.

During the summer for most of Europe, and for the whole year in southern Europe, a 3-week period of 'no-grazing' or prohibition of working of bare soil should be adequate to reduce pathogen numbers by 2 log10 after spreading sludge.
Where crops are consumed directly by humans, particularly where they may be eaten raw, a longer period between application and harvesting should be applied. A prohibition of application during the growing season would seem appropriate. This would allow application when vegetation is minimal or non-existent and maximises the deleterious effect (to pathogens) of the climate. The original literature reviews for the UK Code of practice for agricultural use of sewage sludge land (unpublished) identified a 10-month period before harvest during which at least a 2 log10 reduction in numbers should occur. Similar constraints were made in German and

Ploughing down has the advantages that it is more aesthetically pleasing than surface application, minimises the loss of ammonia, and places the fertilising effect immediately in intimate contact with the soil. It also minimises potential runoff of residues into surface waters. However, it does reduce the effects of environmental factors on the survival of pathogens. There is information on the survival of pathogens in soil, but little information on the die-off rates.
Injection and ploughing down minimises the risks to wildlife and non-agricultural users of land. However, because of the risks of splashing and spillage during injection and the unknown factors relating to survival in soil, it would seem appropriate that similar grazing and harvesting constraints are used, particularly for crops eaten raw, whether conventionally treated sludges are incorporated into the soil or applied to land surfaces.

There is a much higher risk where fruit and vegetables are eaten raw, as with salads, than from processed cereals from arable land. As a precautionary measure, a 30 month no-harvest period is recommended between an application of sludge to the land and the subsequent harvesting of any fruit and vegetable crops in ground contact and to be eaten raw. In reality, sludge would not be used on land growing salad crops and this guidance would apply in situations where a farmer growing, for instance, arable crops fertilised with sludge plans to change the land use to salad crops without sludge. Evidence to justify the 10-month no-harvest recommendation for vegetables in ground contact was presented by Carrington et al. (1998)
Carrington, E G, 2001

Advantages of waste spreading

- Recovery of waste which might otherwise be dumped or destroyed;
- Replacement of chemical fertilisers
- a potentially more sustainable approach than reliance on continuous supplies of nitrogenous fertiliser from energy-intensive processes, and phosphate fertiliser and peat soil conditioners from finite sources; and
- Improvement of soil structure.

Gendebien, A.H. , 2001

- The organic matter content is higher than in mature compost.
- Being untreated, the costs of acquiring such wastes are relatively low.
- On arid soil, the improvement of the soil is more evident in soils treated with fresh waste then those treated with compost due to a higher fraction of mineralised carbon.

Dulac N., 2001

Disadvantages of waste spreading:

- Hazard to human and animal health due to pathogens;
- soil contamination from potentially toxic and persistent elements or organic compounds, and associated implications including long-term effects on soil fertility.
- pollution of water (surface and groundwater);
- nuisance (odour, visual);
- damage to soil structure from spreading operations.
- Other aspects to consider are the net energy use, acid gas emission, greenhouse gas emission.
- Many factors influence the costs of waste spreading, but mostly it is a cheap solution. Factors that can influence the ecnomics of waste spreading are: distance from the site to the farm, the cost f finding suitable land and contact with the farmers, Cost of pretreatment of waste, recovery of value of the waste, costs of storage of the waste, costs of compliance with regulations,

Gendebien, A.H. , 2001

- Untreated waste products contain pathogens.
- Untreated material has a larger volume that has to be transported to the fields.
- There is a great variation in the nutrient content of the untreated waste, which might include uncomposted material that might damage plants.
- Land application of non stable organic material can extract micro-nutrients from the soil that are necessary for plant growth.

Dulac N., 2001

11. Landfill reclamation

Landfill reclamation is a relatively new approach used to expand municipal solid waste (MSW) landfill capacity and avoid the high cost of acquiring additional land. The material in the landfill is filtered in a way that valuable material can be recycled and earth from the landfill can be reused.

Reclamation costs are often offset by the sale or use of recovered materials, such as recyclables, soil, and waste, which can be burned as fuel. Other important benefits may include avoided liability through site remediation, reductions in closure costs, and reclamation of land for other uses.

Some potential drawbacks exist to landfill reclamation: This technology may release methane and other gases, for example, that result from decomposing wastes. It may also unearth hazardous materials, which can be costly to manage. In addition, the excavation work involved in reclamation may cause adjacent landfill areas to sink or collapse. Finally, the dense, abrasive nature of reclaimed waste may shorten the life of excavation equipment. To identify potential problems, landfill operators considering reclamation activities should conduct a site characterization study. There is a risk of workers to come into contact with hazardous waste, a health protection program must be developed for the workers.

The equipment used for reclamation projects is adapted primarily from technologies already in use in the mining industry, as well as in construction and other solid waste management operations.

In general, landfill reclamation follows these steps:

Excavation: An excavator removes the contents of the landfill cell. A front-end loader then organizes the excavated materials into manageable stockpiles and separates out bulky material, such as appliances and lengths of steel cable

Soil Separation: A trommel (i.e., a revolving cylindrical sieve) or vibrating screens separate soil (including the cover material) from solid waste in the excavated material. The size and type of screen used depends on the end use of the recovered material. For example, if the reclaimed soil typically is used as landfill cover, a 2.5-inch screen is used for separation. If, however, the reclaimed soil is sold as construction fill, or for another end use requiring fill material with a high fraction of soil content, a smaller mesh screen is used to remove small pieces of metal, plastic, glass, and paper. Trommel screens are more effective than vibrating screens for basic landfill reclamation. Vibrating screens, however, are smaller, easier to set up, and more mobile.

Along with the expenses incurred in project planning, project costs may also include the following:

Capital costs:
- Site preparation.
- Rental or purchase of reclamation equipment.
- Rental or purchase of personnel safety equipment.
- Construction or expansion of materials handling facilities.
- Rental or purchase of hauling equipment.

Operational costs:
- Labor (e.g., equipment operation and materials handling).
- Transport, equipment, fuel and maintenance.
- Landfilling nonreclaimed waste or noncombustible fly and bottom ash if waste material is sent off site for final disposal.
- Administrative and regulatory compliance expenses (e.g., recordkeeping)
- Worker training in safety procedures.
- Hauling costs.

United States Environmental Protection Agency, 1997 .