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PRINCIPLES OF WASTE TREATMENT AND MANAGEMENT

PROBLEMS IN PRACTICE

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Contents

CHAPTER I. INTRODUCTION

1.1. DEFINITION, SOURCES AND CHARACTERISTICS OF WASTE

Solid waste includes any garbage, sludge from a waste treatment plant, water supply treatment plant or air pollution control facility. Its characteristics depend on its composition. Waste can be a single substance with a specific name; it is more likely to be complex mixture with no name. In that case, a description of its physical type, e.g.. liquid, sludge, slag, semi-solid, solid, is given with a qualification which describes the process or part of the process from which it has been rejected, e.g., mineral, organic, oil, etc.
Other descriptions of waste rely on the type of matrix and the source from which it was derived, e.g. domestic, agricultural, industrial. The identification of waste relies, to a large extent, on a knowledge of it derivation and history. The precise chemical and/or physical analysis of waste can be extremely difficult, it being a complex of chemical substances.

The term **municipal solid waste** (MSW) is assumed to include all of the wastes generated in the community with the exception of waste generated from municipal services, treatment plants, industrial processes and agriculture. Important characteristics of municipal waste, next to composition, include quantities and specific weight.

The **quantity of municipal waste** collection varies in different countries**,** which was illustrated in figure 1.1, moreover, this factor is changing within the country, province or community. As it can be seen in figure 1.1. the mean amount of municipal wastes in Poland is located between 200 and 300 kg (per capita a year).

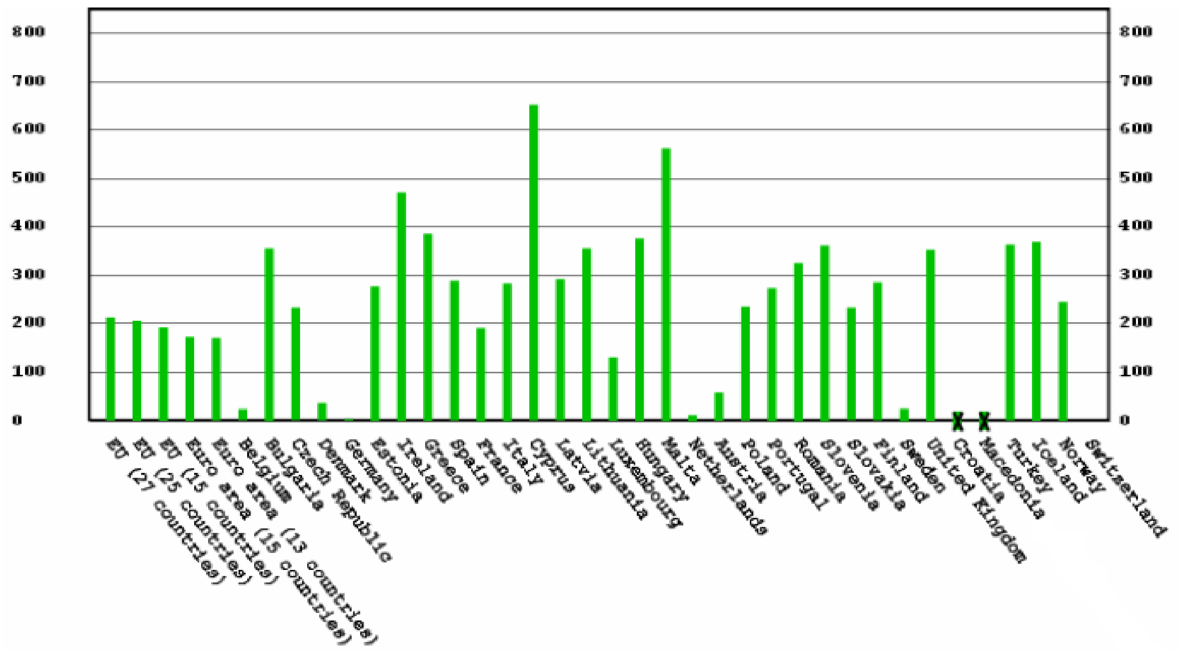

Fig.1.1. Landfilled kg of municipal waste per capita a year (2006)
Source: Eurostat database: http://epp.eurostat.ec.europa.eu/

Municipal waste consists of mostly organic food components, which are biodegradable. The examples of persistent organics in waste are those plastic products which exist every day in our house keeping activities. Other examples of persistent organics in waste are those containing PCBs/PCTs and chlorinated pesticides.

Industrial wastes assist all kinds of technological processes. Typically, industrial waste includes a significant amount of harmful substances. If there is no satisfactory alternative process yielding either re-usable waste or, preferably, no waste at all, then the first option is to examine where the waste can be reduced or recycled.
According to the EC Directive 75/442/EEC, which is called "frame –directive", waste is defined as any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force.
According to the EC Directive, 91/156/EEC waste is re-defined to mean: any substance in the categories set out in Annex I of the Directive which the holder discards or intends or is required to discard.
Types of waste may be divided into categories according to the part of the manufacturing process from which they have arisen. Process-derived waste can include unused starting materials which can be returned directly to the production process, whereas, product-derived waste has to be reprocessed before being turned into useful commodities.
From a practical point of view, waste may exist in the environment as: inert, hazardous, non-inert and non- hazardous.

Hazardous waste.

According to the EC Directive 91/689/EEC, as modified by the Directive 94/31, on hazardous waste, hazardous wastes are defined: as those featuring in a list to be drawn up in accordance with the procedure laid down in the framework Directive and based on Annexes I and II (including toxic and hazardous wastes) to the Directive, provided they possess one or more of the hazardous properties listed in Annex III.
Annex I, which is divided into A and B, lists the categories of generic types of hazardous waste according to their nature or the activity which generated them.
Properties which render a waste hazardous are listed in the Directive 91/689/EEC as:

explosive,	harmful,	teratogenic,
oxidising,	carcinogenic,	mutagenic
flammable,	corrosive,	ecotoxic
highly flammable,	infectious,	

The European Commission defines hazardous waste and such wastes are currently asterisked in the European Waste List (Commission Decision 2000/532/EC). The European Waste List is subject to periodic review by the European Commission.

1.2. WASTE TREATMENT AND DISPOSAL

Integrated Solid Waste Management means the practice of disposing of solid waste that utilizes several complementary components, such as source reduction, recycling, composting, waste-to-energy, and landfill. Industrial wastes need special technologies for treatment, characterized with peculiarities suited to the definite rest product. They are very differentiated and depend on the industry which the waste is relayed and the state and composition of the waste. For several industrial wastes, containing organics, the same treatment methods can be used as those which are applied for municipal solid waste. Municipal solid wastes containing food waste have certain peculiarities and require at least a two-stage technology for its recycling. A peculiarity is that the substrate preparation facility requires several pre-treatment activities, like disintegration, inorganics separation and pasteurisation. Traditionally, municipal waste treatment includes the biological and thermal methods. The biological methods can be divided into: mechanical-biological treatment and biological destruction. The biological methods are represented by aerobic - realised in the composting plant or anaerobic methods - realised in the digestion installations.

Composting.

Composting is a process based on the decomposition of organic matter by microorganisms in the presence of oxygen. The result is a stable organic product - compost, which is both hygienic and rich in humus. This process, which normally takes several months, can be accelerated and controlled using various techniques. The quality of the compost depends on the feedstock to be processed. Feedstock purity can be obtained by the enforcement of contaminant standards and/or manual or mechanical sorting of the feedstock prior to and after the treatment.

Anaerobic digestion.

If the system is not aerated it will become anaerobic. Anaerobic digestion breaks down the biodegradable component of the waste to produce biogas and solid material, which can be transformed into compost after the aerobic processing. A variety of engineered anaerobic reactors to treat food waste are in full scale use, depending on the solids content of the feed, the number of stages, the operating temperature, and the methods of introducing the feed into the reactor.

In the anaerobic reactor, the conditions necessary for biological degradation are created, which allows the production of methane. Because anaerobic decomposition does not reach the temperature necessary to kill pathogens, an additional pasteurising stage is necessary. The main target of anaerobic digestion is the high calorific biogas production, which can be used to produce electricity and heat, as a natural gas substitute and also a transportation fuel. The process in anaerobic digestion plants is similar to that which occurs naturally in landfills.

Thermal treatment.

Thermal methods are led in highly specialized incinerators.

In the incineration of municipal and typical commercial waste, the main objective is to reduce the volume and so considerably to save on the transport costs associated with landfill and extending the life of the landfill. In the incineration of industrial waste, the objectives are to destroy any hazardous or infectious organic materials present and also to reduce the volume. The level of development of the thermal method treatment was illustrated in figure 1.2. Because of the high investment and exploitation costs, the thermal method is highly developed in rich countries, like Switzerland, Germany, Sweden and Japan.

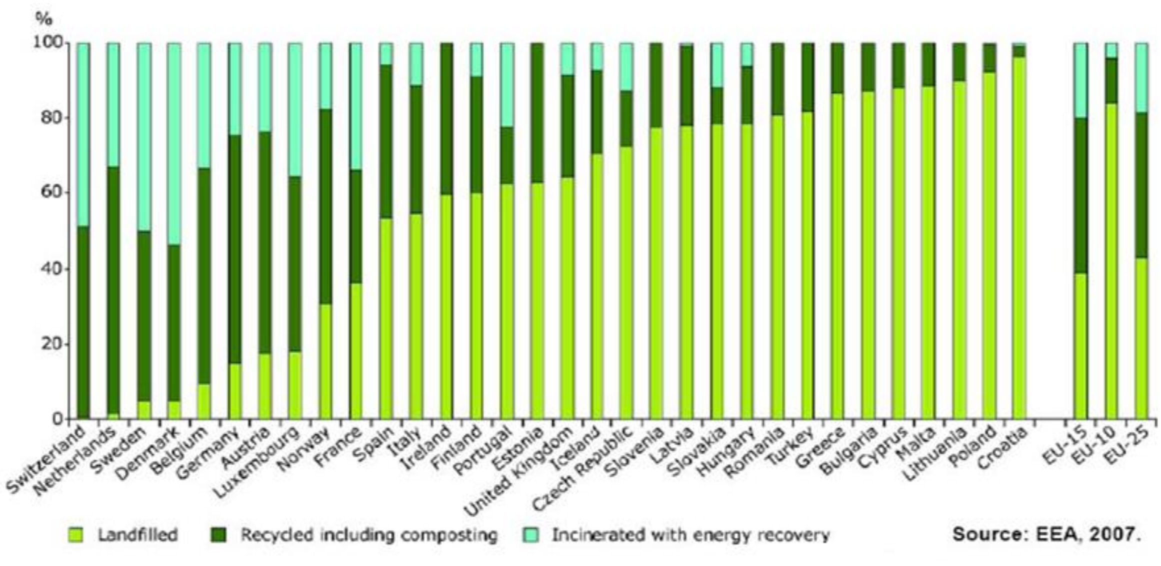

Fig.1.2. The level of waste treatment in Europe

Source: EEA, 2007

Landfilling – is the oldest method of waste neutralization and now, according to European legislation, the method is regarded as complementary to the above mentioned methods. This method is mainly preferred by developing countries as other methods of waste treatment are more costly. Unfortunately, in Poland more than 80% of municipal solid waste generated is landfilled. But it is surprising that in the United States, 54% of municipal waste is buried in landfills according to the US EPA and, in another statistic, even 64% of the total MSW generation was landfilled.
Landfill gas production and leachate emission result from the chemical reactions and the microbes acting upon the waste as the putrescible materials begin to break down in the landfill.

One alternative for the diversion of waste from landfills is to increase the quantity of food waste that is treated biologically, either by aerobic composting or anaerobic digestion.

1.3. LANDFILLS IN THE ENVIRONMENT

Disposal is defined as the placement of the waste so that it no longer impacts society or the environment. There are some important distinctions between landfills and illegal unregulated dumps. The dumping creates health and safety hazards for humans and animals. Dumps are any place where people commonly throw trash that is not regulated. There may be dumps in fields or wooded areas or in aqua- reservoirs. Dumping trash can be dangerous because there is nothing to protect the groundwater or the animals in the area. Such places usually result in risks for the environment, mainly as bio-gas and leachate emission. Bio-gas includes methane, volatile organic compounds and many toxic substances harmful to humans and animals.
A sanitary landfill is a controlled method of solid waste disposal. The site must be geologically, hydrologically and environmentally suitable. Modern landfills must be equipped with environmental protection installations (biogas, leachate).

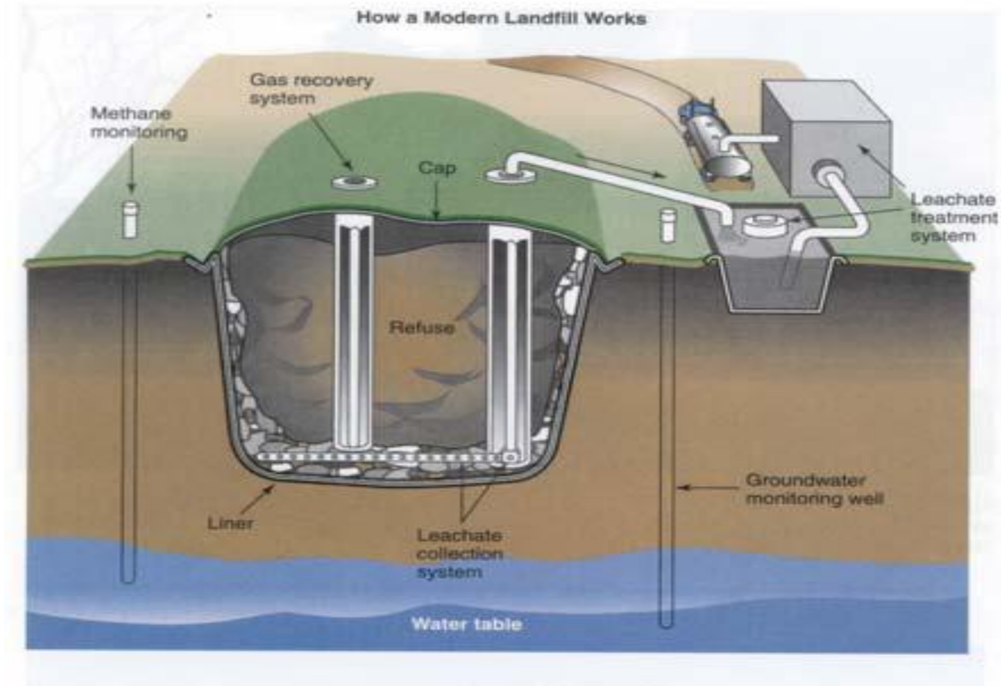

Fig. 1.3. A sanitary landfill schematic
Spurce; http://people.hws.edu/halfman/Data/PublicInterestArticles/Landfills.pdf

This method of disposing solid waste on land does not create nuisances or hazards to public health or safety. Careful preparation of the fill area, including the use of clay and/or synthetic liners and the control of water drainage, is required to ensure proper landfilling.

Emissions.

The decaying of organic substances and the elution of toxic substances from wastes result in the pollution of the local environment such as: the contamination of groundwater and/or aquifers by leakage and residual soil contamination during the landfill usage, as well as after the landfill closure. Such liquid emissions, resulting mainly from water percolation through the solid waste is called leachate.

Leachate are the fluid metabolic products from decomposition which contain various types of toxins and dissolved metallic ions. If the leachate escapes into the groundwaters, which are drinking water reservoirs, it can cause health problems.

Also, gaseous emissions appear in the final stage as the waste is decomposed and biodegraded. Although the biogas may be collected and used as a fuel, its presence within the voids and channels of a landfill presents a risk to humans and the environment. Methane gas is a strong greenhouse gas, it means that methane absorbs terrestrial infrared radiation that would otherwise escape to space. This greenhouse gas characteristic is 27 times more potent than carbon dioxide. Methane can itself be a danger to the inhabitants of an area, and can build up inside the landfill leading to an explosion.

Apart from disadvantages described above, there are some advantages of landfilling as a waste disposal option:

- It costs less than the other disposal options
- A wide variety of wastes are suitable for landfill
- It frequently offers the only final disposal route for the residues arising from end-of-pipe treatment technologies and other waste management options, such as incineration

- Landfill gas can be collected and utilized for heat and as a low-polluting fuel for energy generation.

1.4. BIOLOGICAL TREATMENT

Biological treatment refers to either:

- Composting
- Anaerobic digestion
- Mechanical - biological treatment (MBT)

Among the above mentioned processes, composting is the most simple and it is practiced by individuals in their homes, farmers on their land, and industrially by industries and cities. Composting needs the oxidizing atmosphere, which can be fulfilled by the throwing of compost piles or by mechanical ventilation.

Composting plants.
At the composting plant, the arriving waste is sorted, broken up, screened in a trommel and cleaned from ferric impurities and ballast materials and then disposed in a vessel or in piles in the appropriate conditions for the process to take place. Composting involves human intervention to accelerate the decay process by the addition of various materials (for example sludge from a sewage treatment plant) and manipulating the conditions. In that process, much water will be released as vapour and the oxygen will be quickly depleted, explaining the need to actively manage the composting mass in a chamber or in piles.
A simplified chemical equation for the overall composting processes, illustrated in the glucose molecule example, is as follows:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H2O$$

The use of compost is an excellent way of regenerating soils impoverished by intensive farming because a compost is rich in nutrients. It is used in gardens, landscaping, horticulture, and agriculture.

Anaerobic digestion (AD) plants.
Anaerobic digestion is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen, used for industrial or domestic purposes to manage waste and/or to release energy. The decomposition is caused by the natural bacterial action in various stages. The biological process of the consecutive conversion of organic compounds can take place in an anaerobic environment i.e. in an oxygen-free tank called a biological reactor. The process is the same as that which exists in a landfill body: there are several steps of biological and chemical stages of anaerobic digestion: hydrolysis, acidogenesis, acetogenesis and methanogenesis.
The remaining, non-digestible material which the microbes cannot feed upon, together with any dead bacterial remains, constitutes the digestate solid by-product.
A simplified generic chemical equation for the overall processes outlined above, illustrated in the glucose molecule example, is as follows:

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$$

In industrial practices, two-stage anaerobic digestion technology assumes the splitting of the main digestion steps. In different digesters with different temperature modes and retention

times. Organic waste accumulation is designed for 1-2 days of storage capacity and takes place in the receiving tank.
In the first stage of fermentation, substrate hydrolysis takes place under an acidogenic bacteria influence. In the second stage, elementary organic compounds come through hydrolysis oxidation by means of heteroacidogenic bacteria with the production of acetate, carbon dioxide and free hydrogen. The other part of the organic compounds, including the acetate, forms elementary organic acids. The produced substances are the feedstock for the methanogenic bacteria of the third type. This stage distributes in the two processes, the character of which depends on the different bacteria types. These two types of bacteria convert the compound obtained during the first and second stages into methane CH4, water H2O and carbon dioxide CO2.

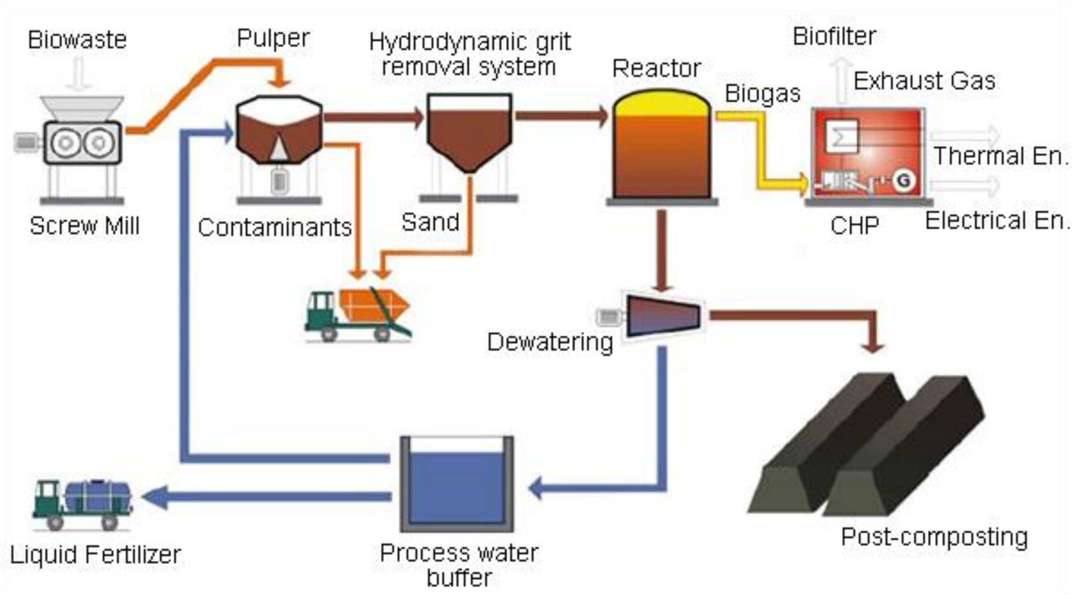

Fig. 1.4. Process scheme of the BTA® Single-stage wet fermentation
(Image: BTA International GmbH);Source: http://www.wtert.eu/default.asp?Menue=13&ShowDok=17

In the industrial plant (Fig.1.4.), the feedstock in first step is milled and sent to the pulper where the mechanical separation of the heavy and light ballast material can be removed. In the next step, hydrocyclones separate the small particles of solids as sand and then the clean homogenous pulp undergoes digestion in the digester tank, where hydrolysis, acidogenesis, acetogenesis and methanogenesis take place.
Typically, the obtained biogas in the digester is burned in a cogeneration installation to produce thermal and electrical energy. The digestate – the residual solid post–fermentation material is mechanically dewatered and sent for aerobic treatment (composting).

In some AD installations the anaerobic digestion phase can be prefaced by hot water that is percolated through the raw waste, dissolving the readily available organic substance. The obtained solution, being a mixture rich in organics, is treated in the digestion facility.
A variety of engineered anaerobic reactors to treat food waste are in full- scale use:

- mesophilic (25-45°C) or thermophilic (50-60°C)
- wet (5-15% dry matter in the digester) or dry (over 15% dry matter in the digester)
- continuous flow or batch,
- single, double or multiple digesters,

- vertical tank or horizontal plug flow

Thermophilic AD (the digester is heated to 55oC and held for a period of 12 to 14 days) shows several advantages over mesophilic, such as an increased degradation rate for organic solids, a high gas production rate and an increased disinfection of pathogenic organisms. However, the capital costs of thermophilic systems are far higher, more energy is needed to heat them and they are more sensitive to environmental changes than the mesophilic processes. This explains why thermophilic digestion is less common and not as mature a technology as mesophilic digestion. As was observed, conventional anaerobic digestion is carried out at mesophilic temperatures.

1.5. Thermal methods

Incineration may utilize the energy content of the organic waste and the volume of waste in the incineration process is reduced to about 10-15%. The high combustion temperature makes it possible to recover energy from the waste and use it for heating, industrial applications and electricity production. However, incineration has some disadvantages such as the energy requirement, the emission of toxic gases and the particulate matters released into the atmosphere and the generation of fly and bottom ashes, containing heavy metals. Gaseous emissions usually contain toxic substances, like heavy metals, chlorinate organic compounds and others.

Among the gases emitted, the most interesting is focused on the **chlorinated dioxins** and **furans**, a very toxic by-product of every incinerator process. Although the hazardous organic materials should be destroyed in the process, the emissions and residues containing the pollutants need special attention.

However, the EPA requires controls to be in place at all waste-to-energy facilities to capture these gases and minimize the contained impurities to ensure they are safe for the environment.

Currently, the thermal treatment method is widely used in highly developed countries. The statistics (in 2008) show that municipal solid waste incineration facilities worldwide, in the frame EU-27 are as follows:

- Number of installations: about 420
- Total capacity: 200 Mt/y
- Average capacity MSW incinerator: 200,000 t/y

Municipal and typical commercial waste is incinerated at temperatures of up to 1000°C in the presence of air; most industrial waste incineration is carried out at higher temperatures, i.e. 1200-1250°C, to ensure the complete destruction of the hazardous organic materials. Special facilities, based on **pyrolysis** processing, **gasification** and plasma reactors have been used in the last decades for hazardous waste treatment.

For efficient incineration, not only the temperature in the furnace but also the "residence time" of the waste gases and the effective processing of the effluent gases are important.

Fot.1.5. The AEB Waste–to-Energy Plant, Amsterdam, the Netherlands
Source: http://www.martingmbh.de/pdf/broschueren/Amsterdam_07_10.pdf

A good example of a modern installation is the AEB Waste-to-Energy Plant, Amsterdam, the Netherlands (Fig. 1.5.). It has the highest throughput rate in the world. Approximately 1,4 mln tonnes of domestic and industrial waste can be treated each year in the six combustion lines. The AEB plant generates 1 million MWh of electricity which is sufficient to supply 285,000 households. The AEB plant generates 500,000 gigajoules of energy for district heating and hot water. A household connected to the district heating uses an average of 25 gigajoules per year.

CHAPTER II. PROBLEMS IN PRACTICE

Task 1.

WASTE CHARACTERISTICS IN A GIVEN COMMUNITY.
CALCULATING THE NECESSARY AREA FOR LANDFILLING

1.1. **Collect the necessary data for "your" chosen community (find the pattern on the next page): A, B, C, D,...etc. concerning:**
- population,
- community characteristics (urban, rural or urban - rural),
- waste collection factors, per capita
- waste characteristics.

1.2. **Describe the following features of "your" community:**
- collecting systems,
- contribution of recycled waste
- treatment methods realised
- ability for other treatment methods (your suggestion basing on waste structure),
- the negative behaviours of habitants resulting in high collection index,
- suggest how to improve a collecting system and what activity is necessary to minimize the stream of waste directed onto landfills.

1.3. **See format sheet given below, which should be filled in by every student with the basic parameters. The introduced data are to be used for further determination of:**
- Individual and total waste stream generated in the community (in volume denomination and mass denomination); [m^3/ inhabitant d], [kg/ inhabitant d]; [m^3/yr], [Mg/yr]
- Waste stream of putrescible materials, [kg/ inhabitant d]; [m^3/ inhabitant d]
- The necessary area of landfill, [ha]

Calculate the landfill area applying the following formula:

$$A = \frac{V \quad \tau \, K_c}{H \quad K_z \quad 10^4}$$

where:
A – landfill area [ha]
V –volume of waste stream in medium year of exploitation time **[m^3/ a]**
T – duration time of landfill exploitation [y]
K_c – extending factor due to technological area around the landfill [-], assume value 1,2
H – height of landfill body [m]
K_z – compacting factor [-], assume value 3

Pattern to be completed by the student

Name and surname ....

Community ....

Community characteristics ....

....

....

....

Population ....

Waste stream parameters:

- Accumulation per capita .... m^3/ yr
- Accumulation per capita .... kg/yr
- Density .... kg/m^3
- Total amount of waste generated in the community .... Mg/yr;
- Total amount of waste generated in the community .... m^3/yr
- Time of landfill operation .... yrs
- The height of landfill body .... m
- Calculated landfill area .... ha

Waste structure characteristics [%]:

- organics ....
- metals ....
- glass ....
- papers ....
- rest ....

Task 2.

MUNICIPAL WASTE MORPHOLOGY.
WASTE COLLECTION AND TREATMENT
EUROPEAN WASTE LIST.

2.1. Basing on the circular diagrams enclosed in the figures 2.1.- 2.3 presenting the morphology of solid municipal waste in different countries: The US, The UK and Poland, describe the ability of each kind of waste to be treated by the method:

a. Composting, RDF (refuse derived fuel) technology, Thermal Treatment.
b. Compare the number of waste generation *per capita* in The US, The UK and Poland (look at Fig. 2.4. and 2.5.). Plot your results for each country for the selected year.
c. Calculate the particular streams of organic matters going in that year into the potential treatment plant in those countries on the examples of a town with 200,000 citizens .

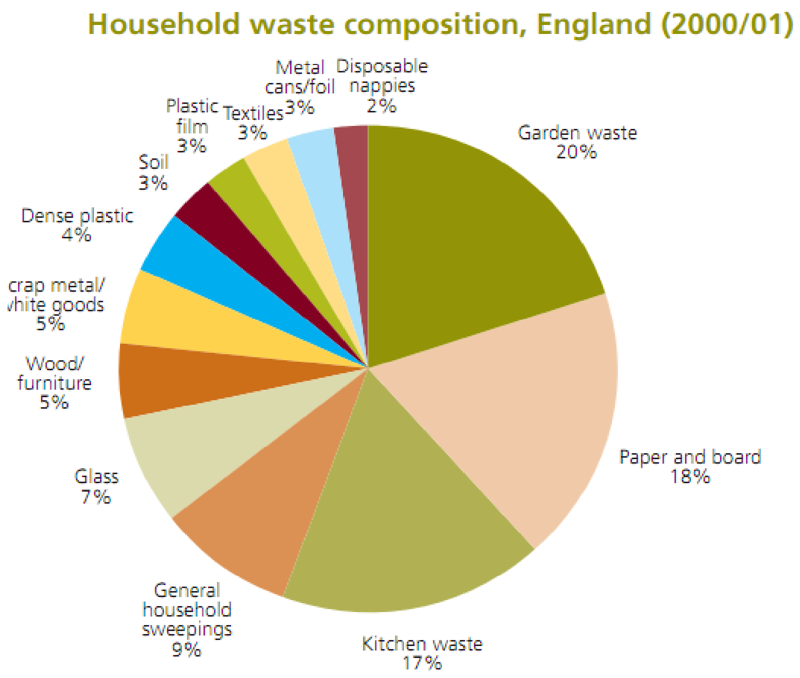

Fig.2. 1. Waste composition in England

Source: Dr Julian Parfitt. WRAP

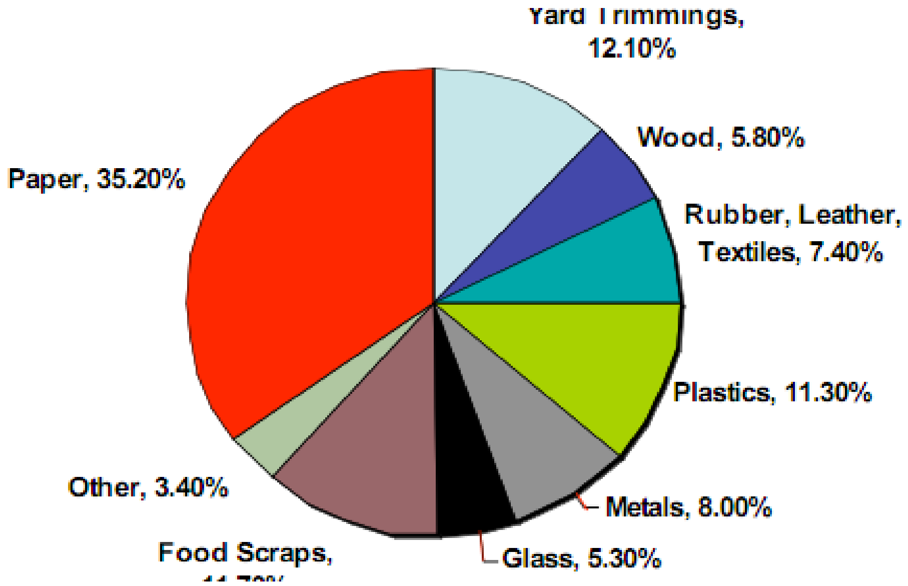

Fig.2.2. Waste composition in the USA

Source: US EPA

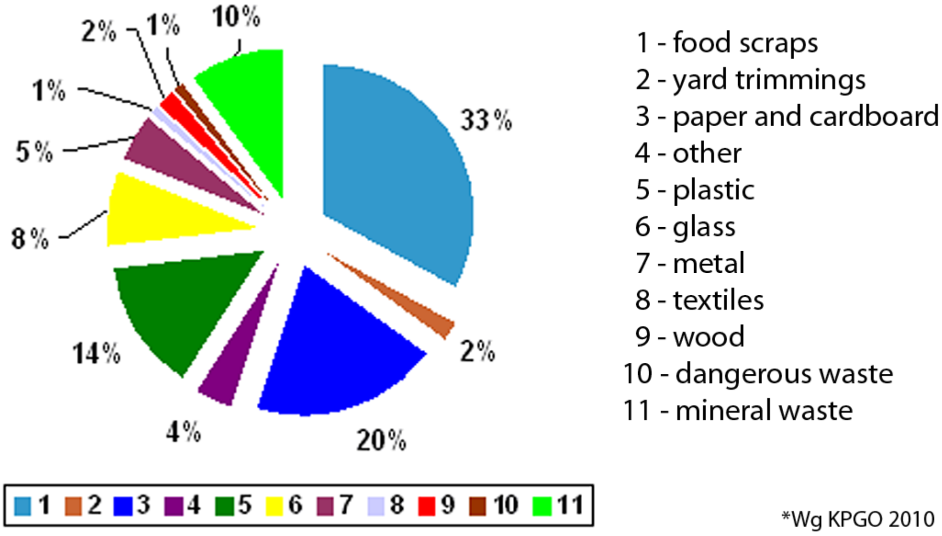

Fig. 2.3. Waste composition in Poland (urban areas)

Source: KPGO 2010

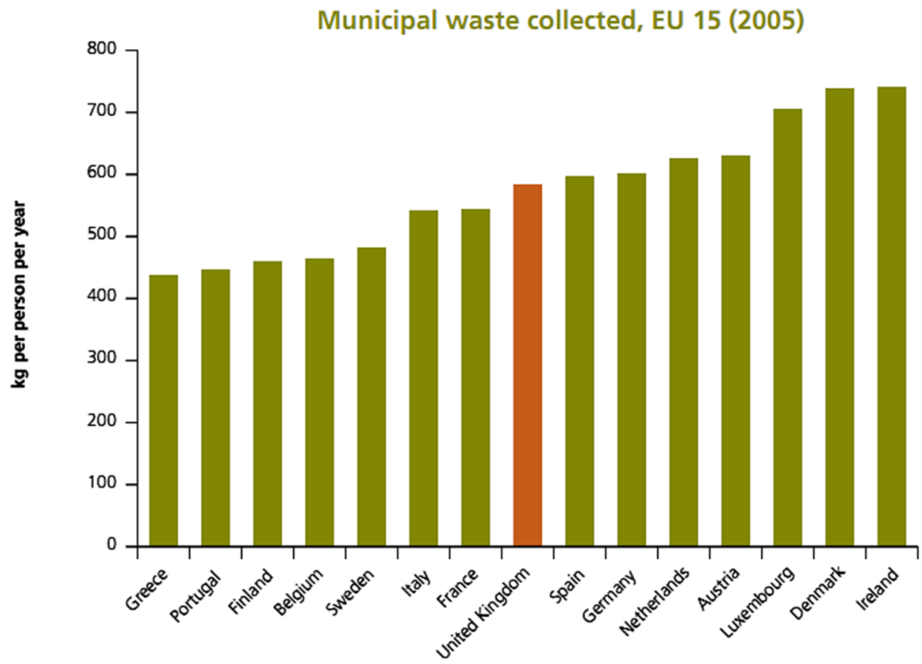

Fig. 2.4. Municipal waste collected in the EU (2005)

Source: Eurostat

Fig.2.5.MSW Generation Rates in the USA, 1960 to2010
Source: http://www.netl.doe.gov/technologies/coalpower/gasification/gasifipedia/waste.html

2.2. Looking at the diagram in figure 2.6 describe the ways of reducing municipal waste before landfilling. What method of treatment is the most efficient and why?

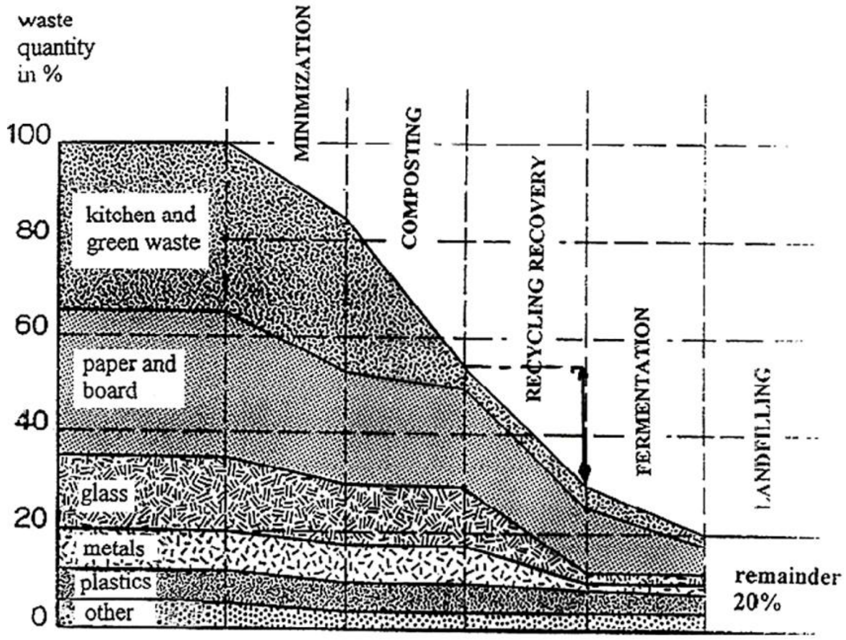

Fig.2.6. The ways of reducing the streams of municipal waste before landfilling

2.3. An example: Mr Black is the owner of a construction business and Mr Brown is the owner of a photographic company. Both firms employ more than 50 staff, and they are well managed. Mr Black and Mr Brown strive to protect the environment. Thus the wastes collected in both firms are collected according to the law in force.

Solve the practice problem described below and present your opinion in table form allowing the comparison of the required data.

a. Search on the Internet the **European Waste List** and find the appropriate name group of the waste generated in a particular firm
b. Present the possible kinds of waste in a construction company and in a photographic company using the name of the wastes and the six-numbered code
c. Evaluate in which company (it can be expected) the more dangerous wastes can be generated;
d. Assess from an environmental point of view:
- whose company can influence the environment more;
- which kinds of wastes are the most dangerous and why;
- which kinds of wastes can be recycled.

2.4. Looking at the diagram in figure 1.2 in Chapter I, concerning the level of waste treatment in different countries, please show the country which fulfills the directive of European Waste Hierarchy (fig. 2.6.) in the best way. Support your opinion.

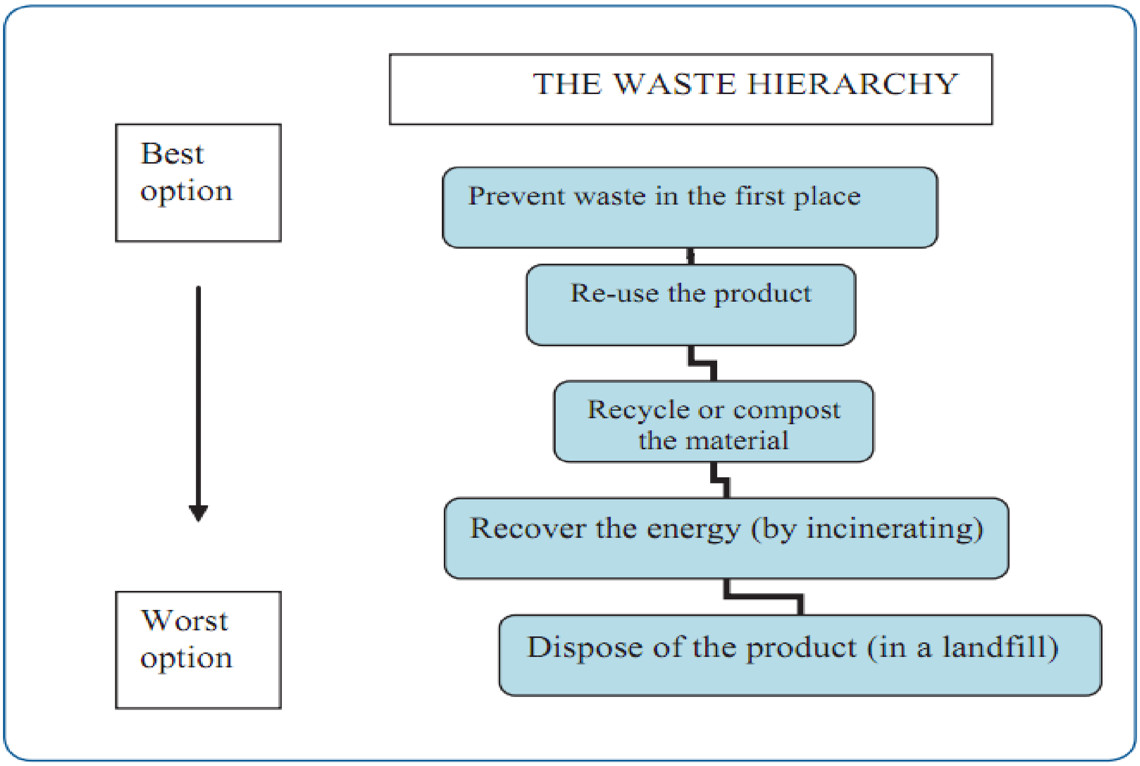

Fig.2.6. European Waste Hierarchy

2.5. **Looking at the diagram in figure 2.7. answer the next questions:**

a) What type of waste is predestined for energy recovery
b) What is your opinion on energy recovery using MSW in the home furnace
c) Why the disposal in landfill is the worst option

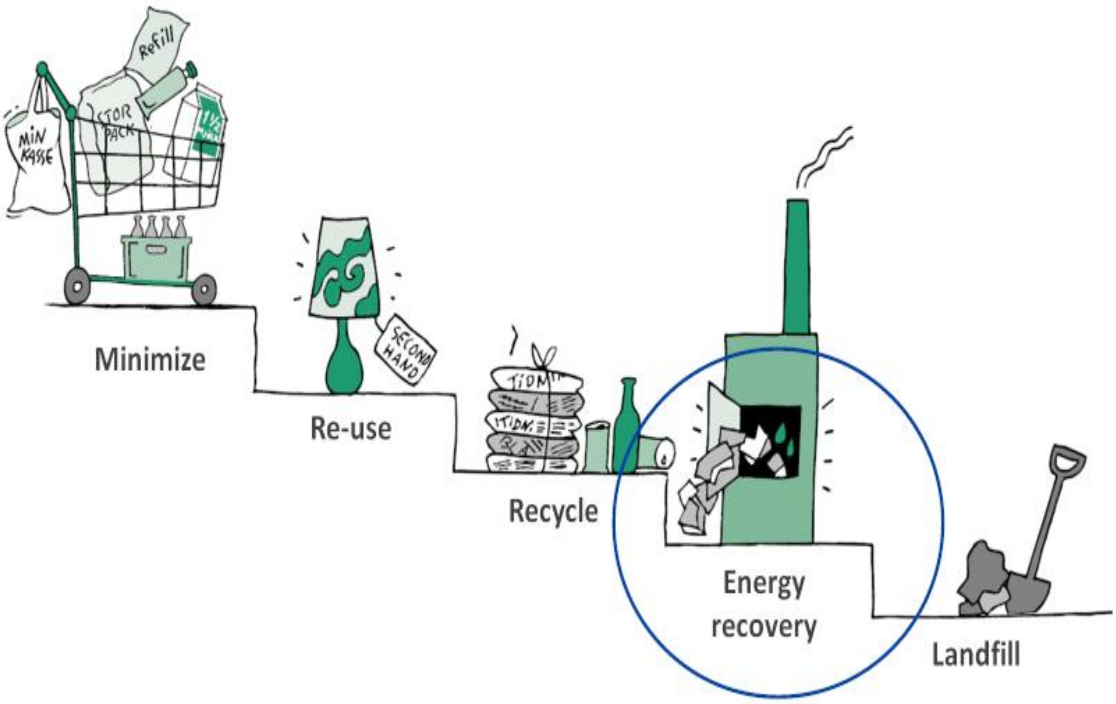

Fig. 2.7. Waste management hierarchy in a pictorial presentation

Source: http://www.ieabioenergytask36.org/vbulletin/showthread.php?24-End-of-Triennium-Conference-November-2012&p=24#post24

2.6. According *to* the block scheme (fig.2.8.) presenting the FRAMEWORK LEGISLATION, please show the adequate directive concerning the regulation of the reduction of organic waste deposited on landfills.

Find in the "Krajowy Plan Gospodarki Odpadami" the proper regulations and answer the questions:

a). what is a "basic year" referenced in that directive?

b). what targets are to be achieved according to this directive up to the year 2020?

c). give the numbers of the planned results of organic waste reduction in landfills during the next few years (until 2020) and present them on a diagram.

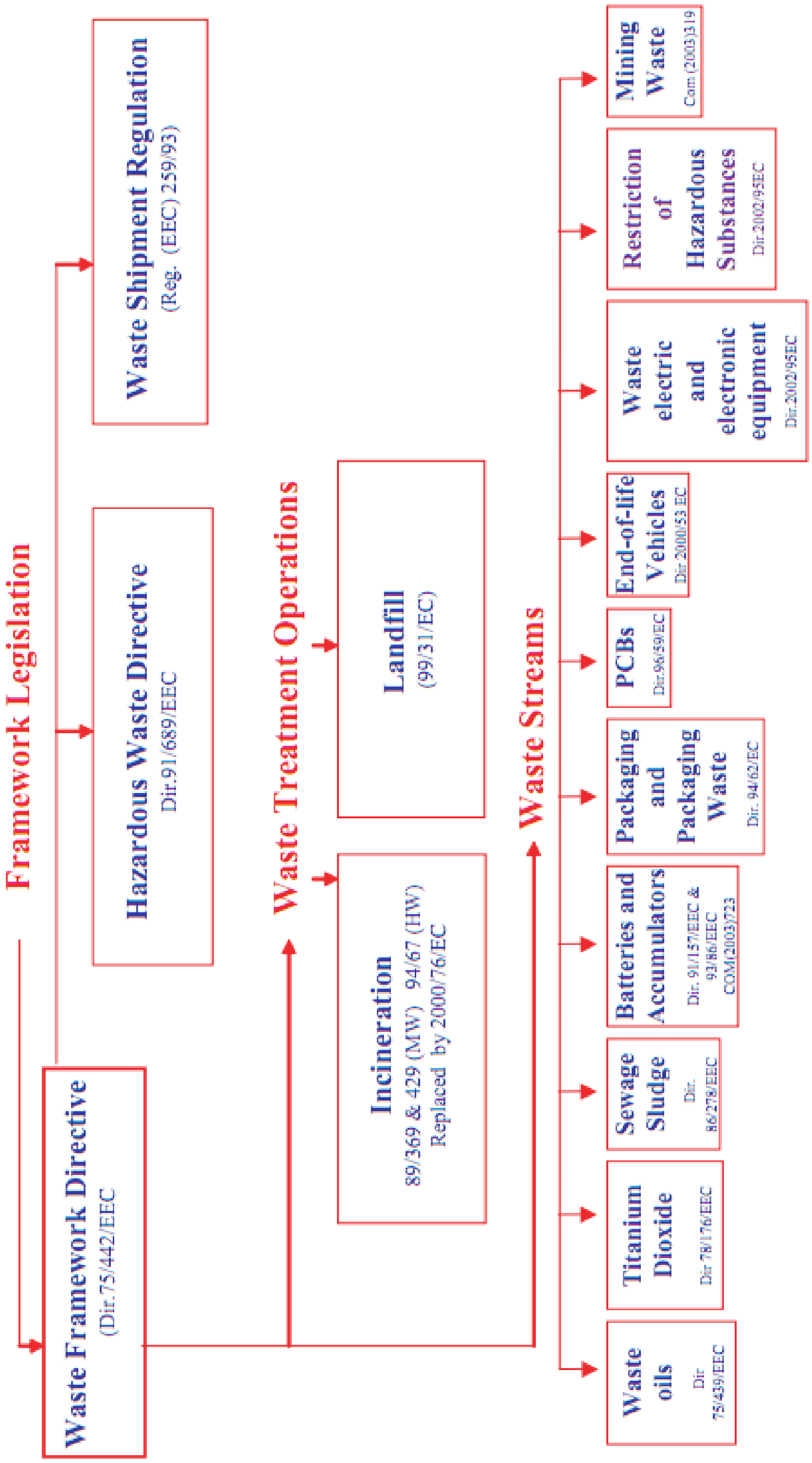

Fig. 2.8. Framework Legislation

Task 3.
MODERN LANDFILLS.
BIO-GAS EMISSION AND CALCULATION

3.1. Assess the methane generation potential per unit mass for typical municipal solid waste in our country.

Potential Methane Generation Capacity (L_o), can be determined according to the formula given by Tabasaran:

$$L_o = 1{,}87 \cdot C\ (0{,}014T + 0{,}28)\ [m^3/kg],$$

The above formula allows to assess how much landfill gas containing 50% CH_4 and 50% CO_2 results with units of mass,

Where:
C – carbon content in organic material, it can be assessed at 200 kg/Mg
T –temperature in landfill body, in ^{o} C; assume 20^o C
Coefficient **1,87** was the ratio:
22,4 dm^3/mol: 12 g

Where:
22,4 - molar volume ($2.24x10^{-2} m^3 mol^{-1}$)
12 - relative molar mass of carbon

3.2. Determine the amount of landfill gas emission using the LandGEM model ; it is available at:

- **landfill AER/PRTR Guidance**
- **http://www.epa.gov/ttn/catc/dir1/landgem-v302-guide.pdf**

For this purpose use the data given in task 1 for a chosen community. Therefore, calculation should be realized in the sequent steps (see tab on the webside):

1) In **USER INPUT** (point 1): provide the waste characteristics: the landfill's open and closure year; put the annual refuse rate for the landfill; enter the waste acceptance rates (point 4)
2) Go to **INPUT REVIEW**; calculate the total amount of refuse in place in the landfill; see and fill the cell **WASTE DESING CAPACITY**
3) Go to **REPORT**, print the summary results and add them to this overall project report.

For the determination of biogas emission, the First Order Decomposition Rate Equation is applied:

$$Q_T = \sum_{i=1}^{n} 2kL_o M_i e^{-kt_i}$$

Where:

Q_T = total gas emission rate from a landfill, mass/time, [m3/yr]
k = landfill gas emission constant, time^{-1}, [1/yr]; assume: k = 0.05 yr^{-1}
L_o = potential methane generation capacity, volume/mass of waste, [m^3/Mg]
t_I = age of the ith section of waste, time [yr]
M_I = mass of wet waste, placed at time i [Mg]
n = total time periods of waste placement [yr]

3.3. Graphs shown in figure 3.1. present the different models for methane generation on a landfill site. Which graph is the most congruent with the LandGEM model ?

a) Answer the questions: which model is the most realistic and should be recommended in practical use - in your opinion.
b) Give reasons for your opinion on the basis of knowledge about the processes running on the site: what is the scheme of organic matter decomposition during the time?
c) Draw a picture showing the proper production of methane during the time.

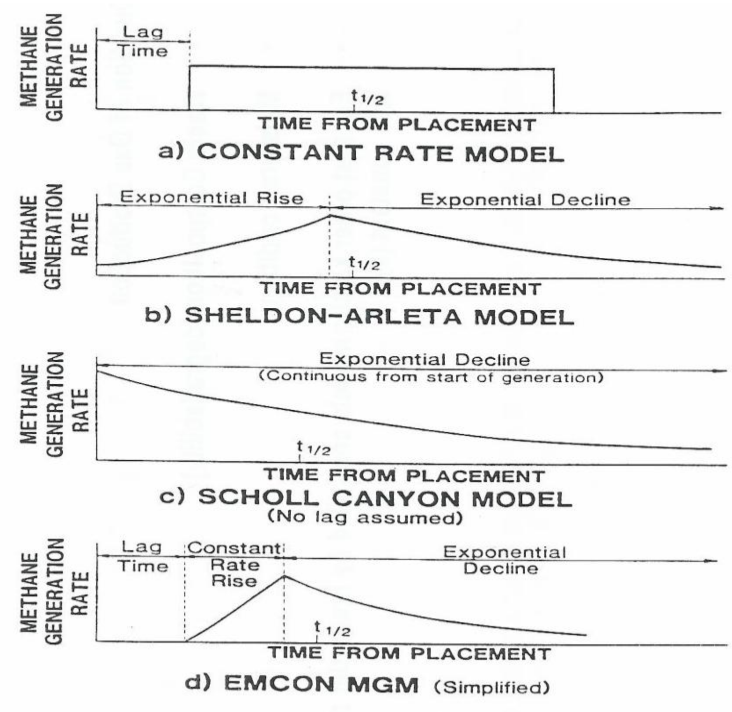

Fig. 3.1. Different models for the methane generation rate on a landfill site
Source: Stephen L.Rice, Landfill Gas Quality and Quantity, 2010; www.msw.cecs.ucf.edu/Gas.ppt

3.4. Figure 3.2. shows a scheme of minimizing the waste stream directed for landfill. Try to name the type of installation, where the presented operations are running.

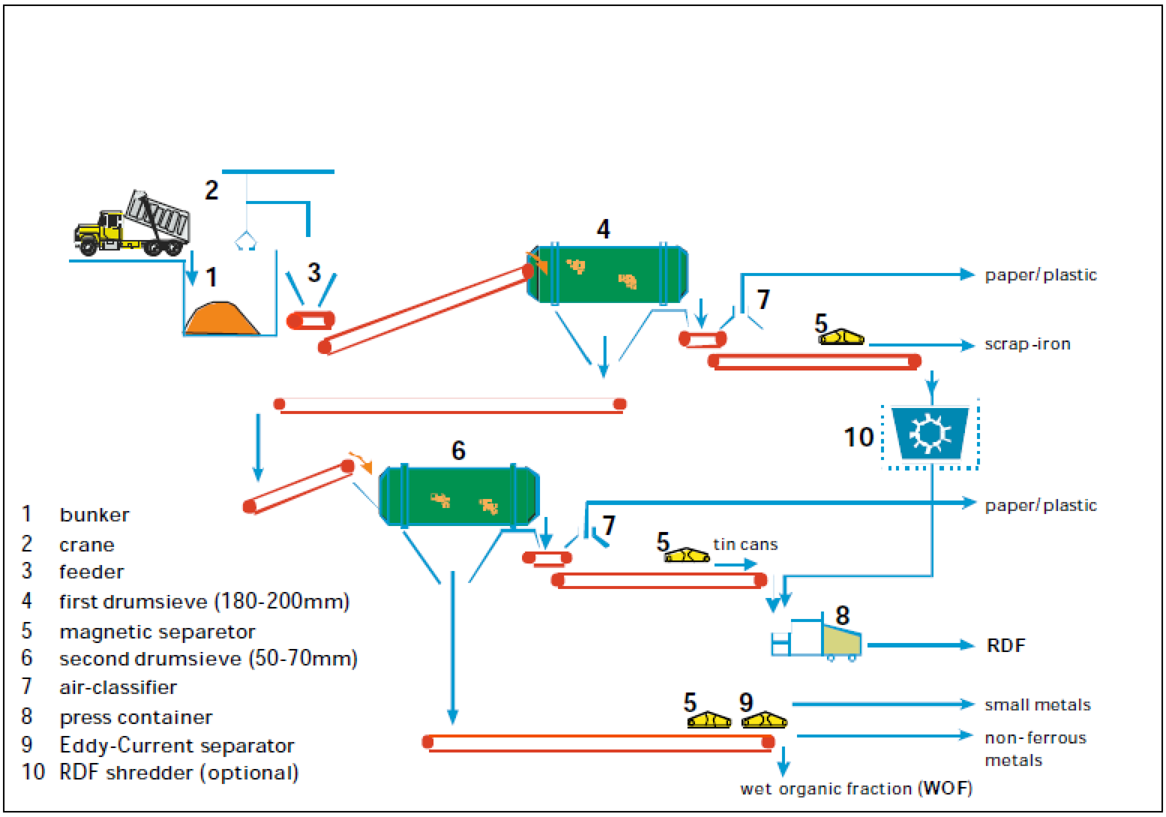

Fig.3.2. Separation technology before landfilling

Answer the questions:

a). What kind of waste is separated in the particular step of operation in the plant: from step 4 to 7?
b). What is the final fraction of waste for recovery?
c). In which device the organic matter will be mostly separated; support your opinion?
d). What is the difference between the first and second drum sieve?
e). What is the function of the eddy-current separator?
f). Explain the abbreviation "RDF".

Task 4.

BIOLOGICAL METHOD TREATMENT
COMPOSTING. MECHANICAL –BIOLOGICAL TREATMENT.

4.1. Basing on figure 4.1. describe the layout of the plant. And do the following tasks:

a). Draw a box diagram of the technology
b). Calculate the stream balance during the process, basing on the parameters: the starting amount of waste should be counted for the municipality, according to TASK 1.1.
c). The assumed Collecting number per capita according to TASK 1.1.
d). The separation efficiency of the ballast waste in the various stages of the process assuming a level of 50-60%.
e). Calculate the daily production of compost, taking the losses of organic mass: 30% in the first step of composting (the tunnel system), 10% in the second step (the curing stage)

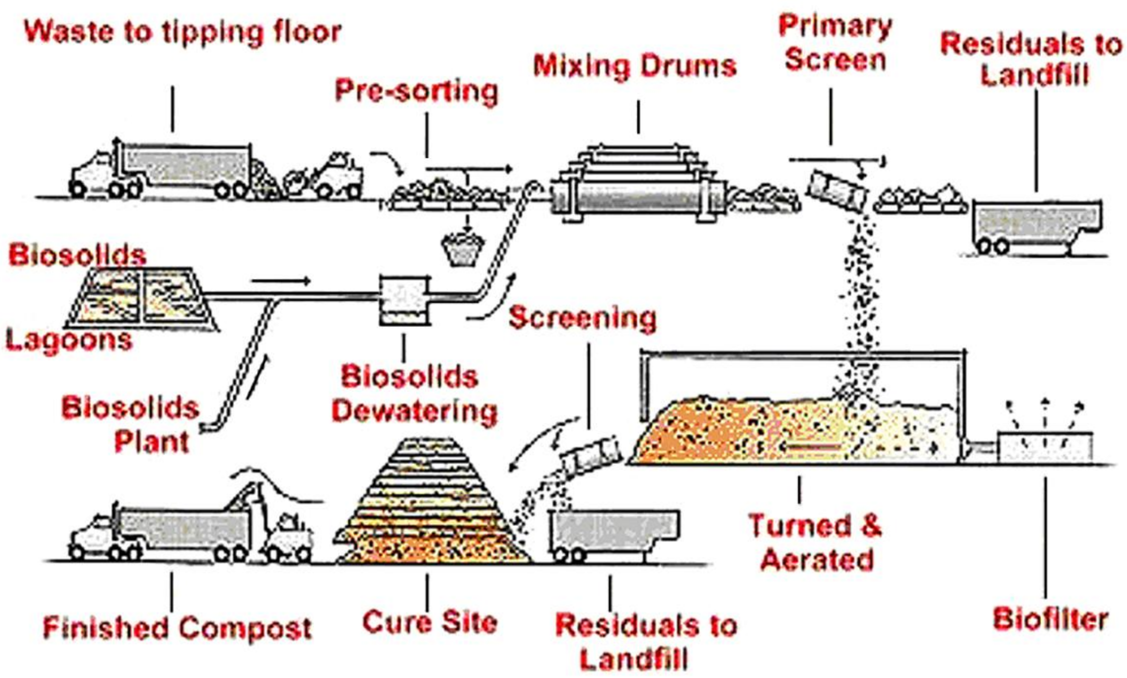

Fig. 4.1. Technology scheme


Fig. 4.2. Cure site. Reintroducing oxygen to the pile (left); screening of the finished compost (right)

Source: http://www.harvest-quest.com/MSAP_process.ht

4.2. For the layout in task 4.1., calculate the substrate incoming the compost plant per day, applying the formula:

$$Q_d = \frac{Q_{bio}}{250} \cdot k_1$$

Where:

Q_d = $Q_{bio\ dob}$ – waste incoming into compost plant per day[m^3/d]
Q_{bio} – annual amount of bio-waste collection[m^3/a]
k_1 – factor of irregularity [-]; assume 1,25
250 – number of working days in the year

4.3. Using the data obtained in the tasks 4.1. and 4.2., calculate the summary length of the composting heaps in the cure site (fig. 4.2), according to the formula:

$$\sum L = \frac{2G_K \cdot t_p}{(a+b) \cdot h}[m]$$

Where:

$G_{k\ I(U)}$ - amount of raw compost (after first step) directed on pile-curing area [m^3/d]
t_p – time of compost curing [d]
h – compost pile height [m]
a – compost pile footing width [m]
b – compost pile upper base width [m]

Parameters of pile gauge: a,b,h values assume to make possible the use of the typical equipment for a pile turning
The loss of mass in the first step of composting is assumed at 30%.
Note that the value in the numerator should be introduced in volume units. The density of the raw compost is assumed as 700 kg/m^3.

4.4. According to the stream balance, calculate the area of the curing site (see fig. 4.2) (in the second step of composting).

For calculation use the formula as follows:

$$A_P = \left(\frac{2 \cdot G_K \cdot t_P}{h} - a \sum L \right) \cdot K$$

where:
A –area
K – enlarging factor including technologically necessary area for turned piles; K=3,0

TASK 5
ANAEROBIC FERMENTATION. MASS BALANCE.
BIOGAS POTENTIAL ENERGY ASSESSMENT

5.1. Look at the scheme presented in figure 5.1.

a) Draw the adequate block diagram for the presented technology

b) Answer the next questions:

- What kind of feedstock is used in the process?
- Does it present dry or wet fermentation?
- What kind of sources does the feedstock originate from?
- What options are expected concerning the biogas?
- What is the fate of digestate?
- Describe the scheme step by step.

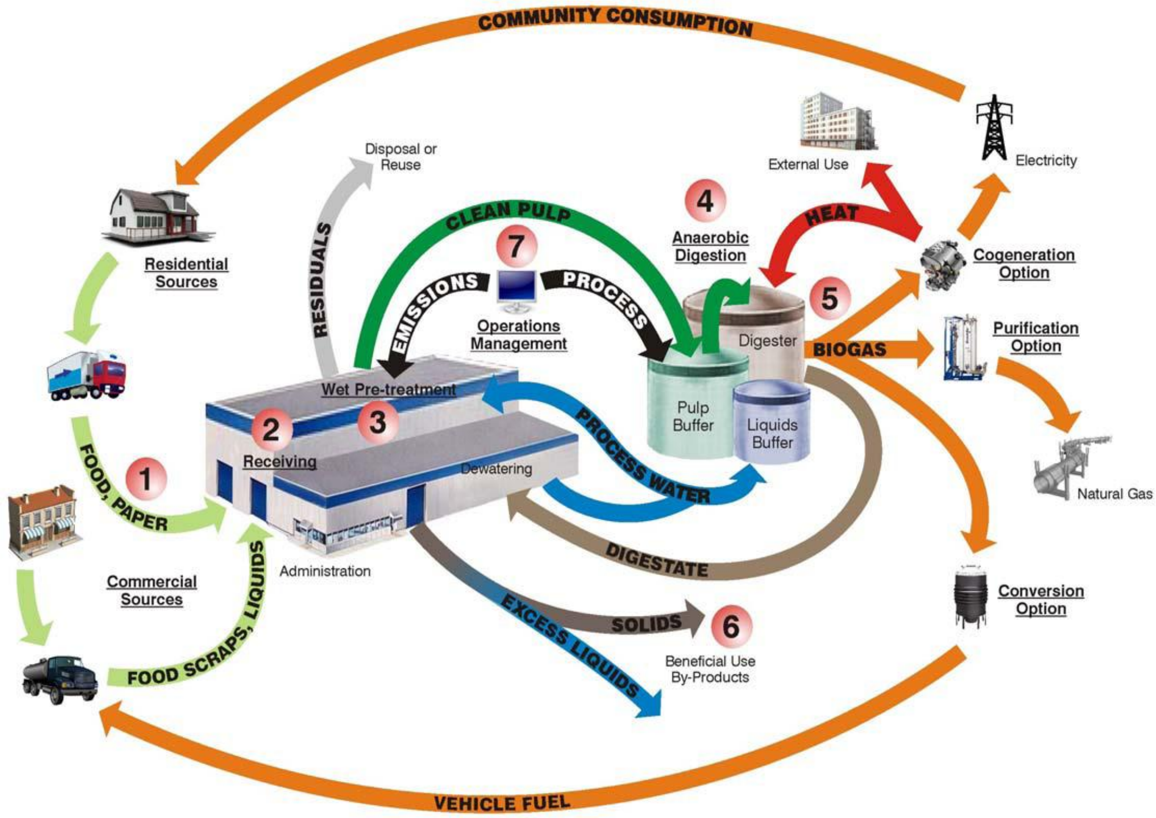

Fig. 5.1. BTA principles (source: http://www.ccibioenergy.com/userfiles/html_file/ccibrochure.pdf)

5.2. Looking at the draft in figure 5.2.

a) Describe this case study giving an explanation for the role of the particular equipment in the layout.
b) Answer the questions:

- Is it the wet or dry technology ?
- Is it one or two step technology ?
- What kind of process is performed in the encircled area ?
- Where is the excess of liquids directed?

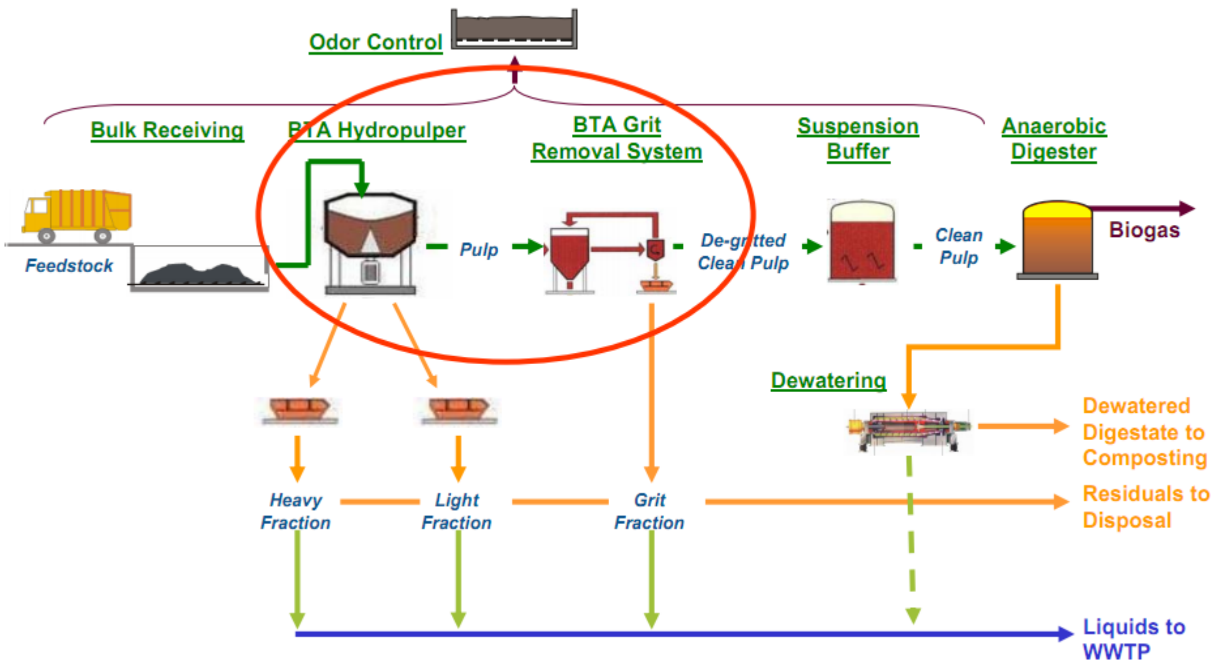

Fig. 5.2. BTA technology layout

source: Blischke J., Anaerobic Digestion of Organic Solid Waste, AECOM Workshop, PORS 22-24 September 2009

5.3. According to the data given in the tables 5.1 and 5.2. for the DRANCO technology do the following tasks:

a) compare the AD plants in different countries and evaluate which technology is the most efficient,
b) draw a diagram presenting the dependency of the total and individual (per unit of mass) biogas production versus the amount of feedstock in the Brecht plant ,
c) calculate the amount of total production of biogas in the Brecht plant when the feedstock will be doubled (between 2002-2006),
d) calculate the amount of electricity potential in Brecht between 2002 and 2006 and for the assessed doubled amount of feedstock.

Table 5.1. DRANCO efficiency in different towns/countries

INSTALLATION	SALZBURG AUSTRIA	BRECHT BELGIUM	BASSUM GERMANY
CAPACITY (TON PER YEAR)	20.000	50.000	13.500
KITCHEN WASTE GARDEN WASTE PAPER WASTE	80 % 20 % -	15 % 75 % 10 %	MUNICIPAL WASTE
TOTAL SOLIDS VOLATILE SOLIDS	31 % 70 %	40 % 55 %	57 % 51 %
TOTAL SOLIDS IN THE DIGESTER	22 % (17 - 27 %)	31 % (25 - 37 %)	40 % (35 - 45 %)
NM³ BIOGAS/TON	135	120	137

Source: De Baere L., Organic waste systems: true all-rounder in anaerobic digestion of solid, and semi-solid organics, IMPLEMENTING ANAEROBIC DIGESTION IN WALES, CARDIFF, 11 NOVEMBER 2008

Table 5.2. DRANCO efficiency in Brecht between 2002 and 2006

	2002	2003	2004	2005	2006
FEEDSTOCK (T/Y) - BIOWASTE - OTHER TOTAL	 45 394 966 46 360	 45 691 1 776 47 467	 51 229 2 525 53 754	 52 946 2 126 55 072	 52 943 2 030 54 973
PRODUCTION OF BIOGAS - M³ BIOGAS (IN MILLIONS) - M³ BIOGAS/TON INCOMING - M³ BIOGAS/TON/DAY	 5.8 125 6.8	 6.0 127 7.2	 6.9 128 7.4	 6.9 125 7.2	 7.0 128 7.6

Source: De Baere L., Organic waste systems: true all-rounder in anaerobic digestion of solid, and semi-solid organics, IMPLEMENTING ANAEROBIC DIGESTION IN WALES, CARDIFF, 11 NOVEMBER 2008)

5.4. Look at the figure 5.3 presenting the DRANCO mass balance:

a) Make a block diagram for the mass balance assuming the stream of feedstock from the community according to TASK 1.1.

b) Convert the end amount of biogas in mass to volume. The biogas density varies depending on the proportion of CO_2 (1,98 kg/m^3) and CH_4 (0,71 kg/m^3) between 1.04 and 1.22 kg/m^3.

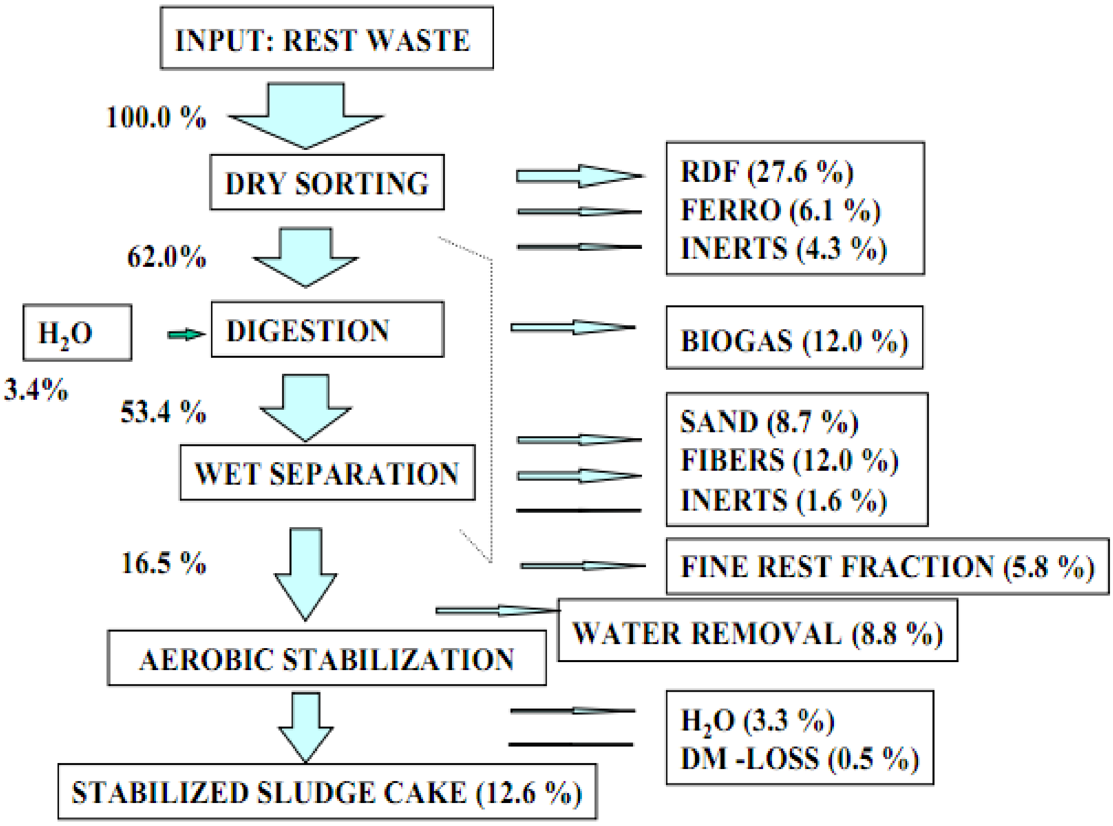

Fig.5.3. DRANCO technology: mass balance

Source: De Baere L., Organic waste systems: true all-rounder in anaerobic digestion of solid, and semi-solid organics, IMPLEMENTING ANAEROBIC DIGESTION IN WALES, CARDIFF, 11 NOVEMBER 2008

5.5. Look at figure 5.4. presenting a simple block scheme of some technologies and do the following tasks:

a) Describe the particular steps 1-5; what equipment should be used in steps 2 and 3?
b) Discuss what kind of wastes are preferred for this technology, support the answer.
c) Explain, is this an example of aerobic or anaerobic technology ?
d) What about odours? You can be helped by fig. 5.5.
e) What does the biofilter consist of?

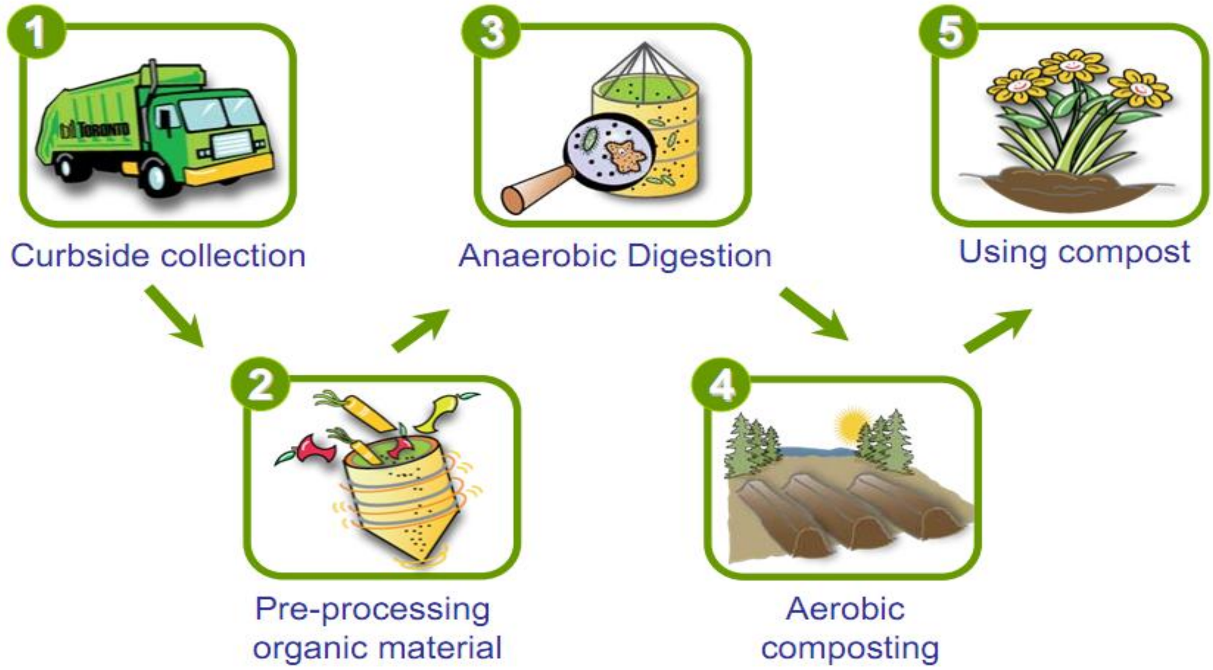

Fig.5.4. A sequential presentation of some technologies

source: http://www.toronto.ca/greenbin/organics_processing/processing_css_intro.htm

Fig.5.5. Exhaust air from the receiving and processing buildings' ventilation system is passed through a biofilter to remove odour and dust.

source: http://www.toronto.ca/greenbin/organics_processing/processing_css_intro.htm

TASK 6
THERMAL METHODS.
CAPITAL AND TREATMENT COST COMPARISON

6.1. Look at figure 6.1., presenting the incineration scheme and describe the scheme. Answer the following questions:

a) What kind of furnace is used in the presented plant?,
b) Label the relevant parts of the installation distinguished by numbers using the given names (assign a name to those numbers): rotary kiln, preliminary air supply, tipping hall, secondary air supply, container feed system, waste pit, flue gas purification system, ash removal system, start-up and auxiliary burners, wet deslagger, steam generator, economizer, feed hopper, overhead crane, skip hoist for solids.
c) Through what equipment are the solid wastes put into the furnace?
d) What equipment follows the furnace?
e) What happens to the slag from the furnace?
f) What kind of waste is this furnace suitable and preferred for?

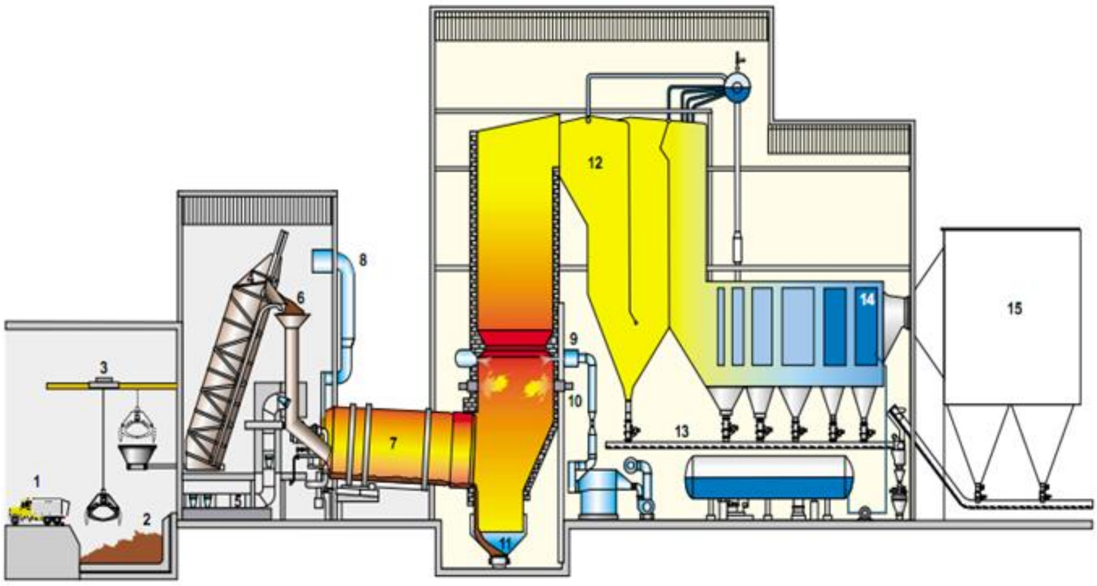

Fig.6.1. A scheme of some incineration technology

source: Von Roll INOVA, AVG Hamburg, hazardous waste, incineration plant – offering material

6.2. Look at figure 6.2. presenting the scheme of the Spittelau incinerator in Vienna and answer the following questions:

- What kind of waste is treated in the plant?
- Is it this an example of a dry or wet by-processing gas cleaning system, and support the chosen option?

6.3. What kind of chemicals are used in the gas cleaning processes?; for a better presentation of the processing scheme of the Spittelau WTE facility use : http://www.wtert.gr/downloads/Spittelau.pdf .

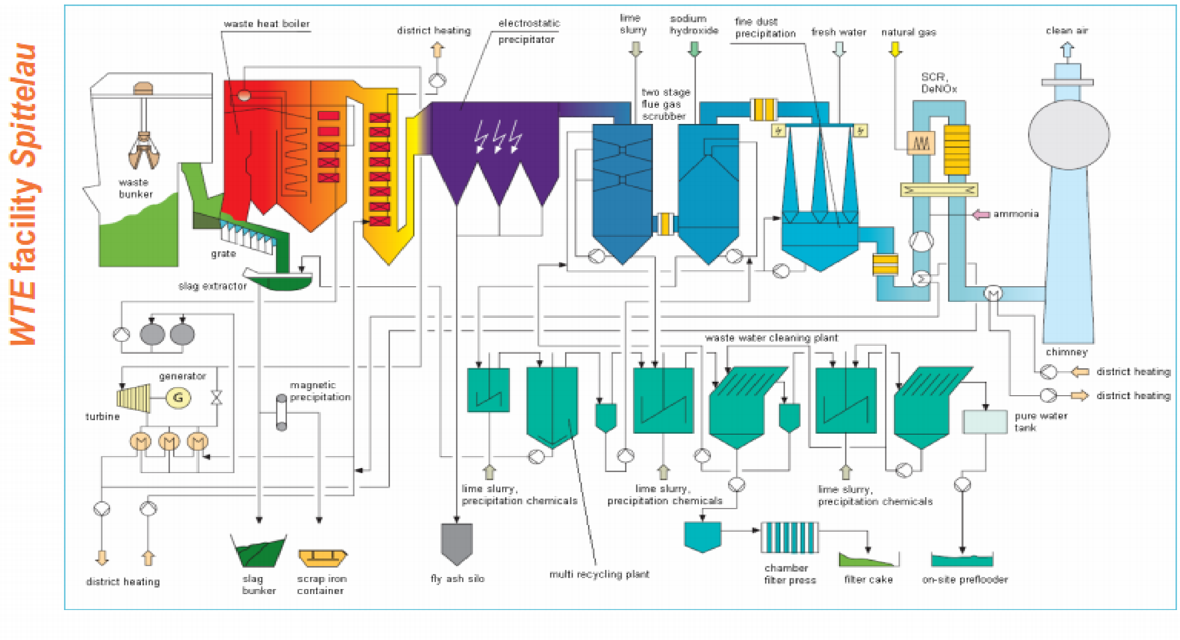

Fig. 6.2. A scheme of the Vienna incineration plant

Source: http://www.seas.columbia.edu/earth/wtert/sofos/Sunk_Fieldtrip%20to%20Spittelau%20final%20version.pdf

6.4. Describe the methods used for NO_x removal in incinerators. Illustrate them with proper chemical formulae. Looking at figure 6.2, discuss the method used in the presented plant.

6.5. Looking at figure 6.3., complete the following tasks:

a) Describe the processes occuring in the secondary chamber,
b) In what technology shall be applied this type of furnace?

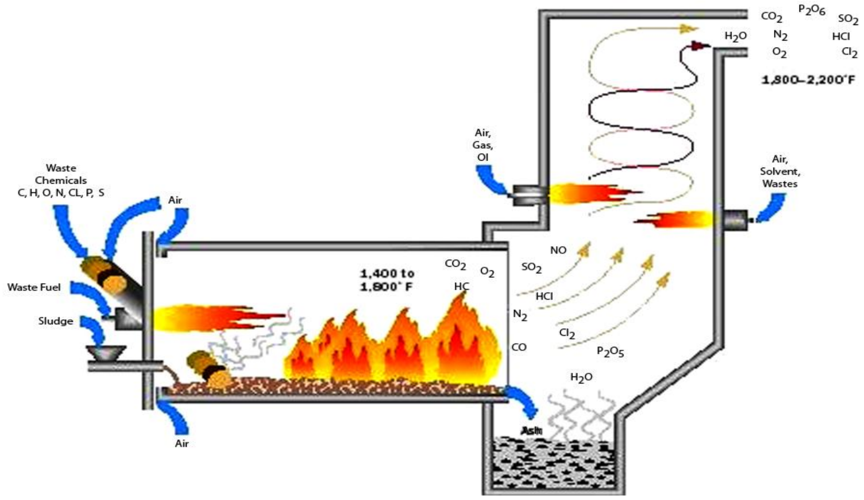

Fig.6.3. Waste incineration technology
source: Oppelt, E.T. (1987). "Incineration of Hazardous Waste—A Critical Review." Journal of the Air Pollution Control Association 37(5) 558–586;http://www.pollutionissues.com/Ho-Li/Incineration.html

6.6. Certain thermal treatment technology limits the airflow in the process to one third of that which an open fire would consume.

The burning process itself is starved of oxygen. An oxygen starved burning process generates marginal (combustible) gases like methane (CH_4), ethane (C_2H_6) and carbon monoxide (CO), instead of (CO_2) and (H_2O) as would happen in an open airflow burn. These gases are then burned in an afterburner chamber later in the process.

Answer the following questions:

a). What is the name of the described technology? Support your opinion.
b). In what circumstances is the mentioned technology used?

6.7. According to the data presented in table 2.3., compare the particular costs of the installation assuming that the plant is designed for the community described in TASK 1.1.

Table 2.3. *The capital investments and treatment costs of various waste treatment technologies (excluding VAT)*

Waste treatment technology	Specific capital investment (†/tonne annual capacity)	Treatment costs (2) (†/tonne treated)
Incineration	450 - 550 (1)	approx. 100
Indoor composting	135 - 185	approx. 45
Fermentation	200 - 290	approx. 65
Open air composting	50 - 100	approx. 30

(1) 40% is due to cleaning of flue gas
(2) depreciation plus operation and maintenance (O&M) costs

Source: Oorthuys F., Brinkmann A, Benefits of separation of municipal solid waste, GRONTMIJ; Water & Waste Management, Expoambient 99

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