CORRELATION AMONG PLANT DESIGN, PROCESS CONTROL AND QUALITY OF COMPOST

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1. ABSTRACT

Composting is a microbial process that occurs inside plants or reactors; these reactors are designed and built by architects or engineers, which in their work are conditioned by the biological process that occurs in these plants. When discussing composting, a careful distinction must be made between questions regarding the plant and those concerning the process and its control. By plant it is meant the system of machinery, buildings and equipment for composting. By process we mean the correct application and control of the microbial transformation of organic matter, with the optimisation of all parameters and conditioning factors. Industrial microbiologists, who devise and perform the process, and architects or civil engineers who design and construct the plants have been working independently and separately. As a consequence, most of the existing plants have been built without taking into considerations the simplest requirements of microbial metabolism. Closer collaboration would certainly improve the practical results. A correct application of these principles will result in: (1) a better control of the process with high quality end-product; (2) lower retention times and consequently smaller reactors; (3) reduced building, operating and maintenance costs; and (4) reduced energy consumption.

The quality of compost is today the most important prerogative in order to recycle organic waste, to market and utilize the product in agriculture. Besides a good correlation between the process, the design and the building of a composting plant, the quality of the end-product is conditioned by the quality of the starting material, its conditioning (physical and chemical), the type of microbial process chosen (continuous or discontinuous), the composting system, the feed back control used, the biological stabilization and hygienization of compost. When quality is guaranteed, compost will have no problem to be used as an organic fertilizer in our soils. In modern agriculture, monoculture of cereals, absence of rotations and of green manure, extensive and intensive crop production, in particular in greenhouses, have depleted our soils. The availability of alternative sources of organic matter as compost, will be very important to maintain biological fertility of soils. In Europe, where agricultural soils have been depleted since 2000 years (see Mediterranean areas), the organic matter content in some cases is very low; when this value drops below 1%, the irreversible effect of desertification can occur.

2. INTRODUCTION

The quality of compost primarily depends on the starting material and its conditioning, the process, and the composting system. Most of the old composting plants failed to produce high quality compost for one of these reasons. Composting of mixed municipal solid waste has been abandoned because of the presence of high levels of heavy metals and inert materials (glass, plastic, metals) in the final product. The starting material should be physically and chemically conditioned and free from contaminants, in order to allow the performance of a proper composting process.

Composting is a spontaneous biological process that occurs in nature but heterogeneously and with unsteady rate. At the industrial level, the process must be constantly under control, optimising the main process parameters in order to obtain a highly stabilized product in a short time. Furthermore, a composting system should be adopted that guarantees the best results regarding environmental protection.

These problems will be discussed in the following sections.

3. THE PROCESS

The addition of fresh organic matter to the soil results in a change of the ecosystem in which the crop is developing (Kononova et al., 1966). Fresh organic matter when placed in the soil will be degraded by the microflora, resulting in a production of intermediate metabolites which are not compatible with normal plant growth (Zucconi et al., 1981a, 1981b). Other disadvantages are competition for nitrogen between microorganisms and roots, a high carbon to nitrogen ratio (C/N), and the production of ammonia in the soil (Golueke, 1977). Composting is therefore a system designed to overcome all of these problems and to produce an organic fertilizer not anymore phytotoxic but beneficial to plant growth (de Bertoldi et al., 1983).

The starting material for composting consists of solids, water and gas with a constant interchange among the three fractions. Solid matter consists of ash, inert material and biodegradable organic matter containing water. The individual relationships among these components are extremely important for the evolution of the process and the quality of the end product (Haug, 1982; Haug, 1993). These parameters can vary, as will be seen, within a limited range if the process is to proceed correctly. Microbial transformation of the organic fraction into compost is essentially an aerobic oxidative process. It means that the surface to volume ratio of the particles has a direct influence on the manner and the speed of degradation; air to water ratio in the particle interspace is equally important. Water and oxygen are indispensable for microbial activity and when the proportion is lower than the critical level, microbial metabolism and respiration slow down and stop. This means that composting also slows or stops.

In composting, only three basic means of intervention are available. As a practical matter two of these, water addition and agitation of the mass, can only be intermittent. The third means of intervention, the forced passage of air through the biologically active matrix, is applicable continuously. Irrespective of how it is effected, the functions of gas exchange are to supply oxygen and to remove heat, water vapour and CO_2. In theory, gas exchange can be managed through five basic stratagems: (1) Gas exchange through passive diffusion; (2) periodical mechanical agitation; (3) forced aeration with temperature feed back control; (4) forced aeration with O_2 feed back control; and (5) forced aeration with O_2 and temperature feed back control. All of these systems can be applied with variants all in conjunction giving many practical possibilities. It must be stressed that only temperature in conjunction with O_2 feed back control give the best results for the process performance and quality of the end-product. The management of these parameters can be carried out through a computer which continuously maintains the process at optimum or near optimum levels. It is important to remember that to control heat production and to maintain a constant temperature an amount of air is needed which is nearly 9 times higher than that to replenish O_2.

In all existing composting plants one of these configurations is applied to control the process, but in any case the process, from a microbiological point of view, is discontinuous (batch culture).

In open or closed systems, discontinuous microbial culture takes place Even in vertical reactors, continuously loaded and from which continuous removal of material can occur, the process is discontinuous because environmental conditions continuously change, specially temperature, causing a succession of different microbial populations (de Bertoldi et al., 1985).

In discontinuous composting processes the microbial growth has a sinusoidal pattern. A starting lag phase characterizes the process during which microorganisms adapt to the new environment, induce the production of new enzymes and start the multiplication process. The mesophilic microbial population, after this phase, starts to grow exponentially. The oxidative process produces a large amount of energy; only a part of this energy (40-50%) is utilized by microorganisms to synthesize ATP (adenosine triphosphate), the remaining is lost as heat, increasing the temperature of the mass. This increase in temperature determines an inhibition of mesophilic microorganisms, which quickly reduce their metabolic activity and then disappear. The thermophilic phase cannot be eliminated in a composting process because it is the most important event to reduce pathogenic agents present in the starting material. Experiments conducted with temperature feed back control with the set point at 45°C during the entire process, have clearly demonstrated the poor hygienization of the final products (de Bertoldi et al., 1988). Trials to relegate the thermophilic phase at the and of the process have also failed; it is difficult or impossible to raise the temperature at the end of the composting process because most of the easyly-degradable molecules have already been mineralised and therefore the energy production is rather low.

When thermophilic conditions start, mesophilic populations disappear and thermophilic microorganisms start the lag phase, adapting to the new environment, inducing enzymes and multiplying. When the easily degradable molecules are nearly transformed, energy production decreases together with temperature. When temperature reaches mesophilic values, thermophilic microorganisms tend to stop their metabolism. The few mesophilic microorganisms still alive start to multiply again passing through a lag phase and slowly reaching a stationary phase until the process slows down because the material is biologically stabilized and moisture becomes too low to support microbial activity.

The main consequences of this alternating growth are: (1) an increase of composting times; and (2) heterogeneous and incomplete biological stabilization.

This discontinuous microbial process characterized by a succession of different microbial populations needs longer times to reach a good biological stabilization, since the microorganisms nearly never reach the exponential growth phase. This will involve a longer retention time with bigger composting areas or reactors, more energy consumption and higher building, maintenance and operating costs.

Furthermore, if we consider that during the composting process there is a loss in volume of about 50% due to water loss and organic matter mineralization, this volume in static processes and also in periodically turned systems (bay) cannot be recovered. Therefore there is a reduction of 25% in working capacity with respect to the planned one (de Bertoldi, 2000).

Up to now, continuous reactors have been applied only to liquid culture in wastewater treatment plants and in many industrial microbial processes. Their application in solid state, strictly speaking, would be impossible in particular in a composting system where material of different age should not be mixed.

In a continuous culture a flow system of constant volume is continuously added to the medium and from which continuous removal of any overflow can occur. Cell numbers remain constant, the system is in steady state and the cells are always in the exponential phase.

The new concept in composting is to also apply in solid state the principles of continuous culture, or at least to go as near to continuous as possible. To maintain the main parameters that affect microbial growth (in particular temperature) constant, the composting process must be operated in two separate but adjacent reactors. In the first reactor, the thermophilic phase occurs, with a low retention time (3-5 days) in order to sanitize the material and to start degradation of short chain molecules. In the second reactor, the mesophilic phase occurs with a retention time of 14-20 days (with slight variations according the quality of the starting material).

A schematic design of a two-phase continuous reactor is shown in Figure 1. After a chemical and physical conditioning of the starting material, the primary reactor (thermophilic) is continuously fed from the top. The material is continuously extracted from the bottom and introduced in the second reactor (mesophilic). The feeding and extraction rate and the reactor volume are calculated in order to guarantee a retention time of about 4 days to reach total hygienization of the composting material. In this primary reactor a selection of thermophilic microorganisms occur, maintaining temperature around 70°C. Besides hygenization, in this first reactor the easyly degradable molecules start to be metabolized by thermophilic microorganisms which maintain their growth rate in the exponential phase. In this thermophilic phase, the most important factors affecting microbial growth are nearly constant. This reactor is ventilated from the top to the bottom with a downstream air flow. The intensity of the air flow is regulated by a computer in order to maintain oxygen and temperature at the desired levels.

The composting material automatically passes from the first reactor, to the second reactor and it is immediately cooled by an air flow, the same that is used to ventilate the second reactor. In addition, this reactor is fed and unloaded continuously. The volume of the reactor is proportional to the retention time, that is at most 14-20 days. The temperature is feed back controlled using probes connected to a computer which in turn control ventilators for air supply (de Bertoldi, 1999). The ventilation is by downstream flow from the top to the bottom. In this reactor temperature and oxigenation are maintained constant to allow the development and the maximal growth rate of a mesophilic microflora. The slight variation of other parameters like moisture, pH, and C/N will not affect drastically microbial growth rate inside the reactor.

By carrying out the two phases (termophilic and mesophilic) in separate reactors, alternation of microbial populations, typical of traditional systems, is avoided. This means that inside both reactors the two different microbial populations selected can reach the highest growth rate.

By operating the thermophilic and mesophilic phases separately it is possible to avoid the alternation of different microbial populations with relative negative influence on the rate of microbial degradation. That means that a good biological stabilization and hygienization can be reached with retention times nearly 40-50% shorter.

Consequently, the volume of the reactor will be proportionally reduced according to the retention time. Therefore, building, operating and maintenance costs will be reduced. With the new system, energy consumption is also lower due to reduced consumption of electricity and petrol.

In the first reactor, where all the mass stays at least 4 days at 70°C, a total hygienization of the mass is reached; pathogenic bacteria, viruses and parasites that normally are present in the starting material will be reduced to values below those which do not constitute a hygienic risk any longer (de Bertoldi et al., 1991; Strauch and de Bertoldi, 1985) .

This composting system provides total odour control. Molecules which produce odours during composting processes are originated mainly by anaerobic metabolism (anaerobic respiration and fermentation). This reactor guarantees constantly good oxidation of all the material promoting mainly aerobic respiration, without any emission of reduced molecules which produce odours. Furthermore, since this reactor is completely enclosed, only the ventilation air which passes throughout the two reactors needs to be cleaned by scrubbers or biofilters. The quantity of air to be cleaned in this system is therefore relatively small. In other closed composting systems the air inside the buildings must also be cleaned.

In this composting system complex turning equipment also is completely eliminated since the material is moved by gravity end extracted from the reactor with a simple rotating system. Flexibility is also an advantage of this system; it is possible to use only one primary (thermophilic) reactor which feeds many secondary (mesophilic) reactors (from three to five); this module can be repeated many times if the capacity of the plant needs to be increased.

Finally, in a shorter time than the other systems, it is possible to produce compost biologically stabilized, compatible with plant growth, not phytotoxic, totally hygienized and of high quality, specially concerning the humification of the organic matter.

4. COMPOST QUALITY AND UTILIZATION

A recent European Directive (Article 5) says that Member States shall set up a national strategy for implementation of the reduction of biodegradable waste going to landfill. By 2002, the total amount of organic waste to landfill must be reduced to 75% and by 2010, to 25% (C.E.C. 1997). This will result in a large increase of recycling plants in Europe. If we consider that every year the European Union produces 2000 million tons of organic waste, it is easy to deduce how many recycling and composting plant will be necessary to divert such a large amount of waste from landfill (OECD, 1991).

But we have learned from previous experience that only high quality compost will find a market. And this time there will be no room for failure, because the way out to landfill will no longer exist.

In the previous section, three main points to obtain a quality compost have been treated: (1) quality and conditioning of the starting material; (2) selection of the composting system; and (3) control of the process. These three points, if strictly observed, will guarantee the production of a good compost of standard quality.

Problems arise when the quality of the product must be checked in without any knowledge of the process. In this case, the only possibility to verify the quality is to analyse the material. A single analysis cannot give a definitive response about quality. Physical, chemical, biological and microbiological analyses must be carried out to have a complete picture of the composition of compost (Table 1). Furthermore, the Member States of the European Union have different regulations for compost with different requirements for compost quality and application (Fed. Ministry for Environment, Vienna, 1998). Even the limits of different parameters are not the same. This constitutes a seriuos difficulty for marketing and free circulation of compost in the Member States. In Table 1, the most important parameters used in compost characterization are reported. These parameters assume a different importance according to the use of compost. Those which generally are considered relevant are: quantity and quality of organic matter, N content, moisture content, concentrations of heavy metal, biological stabilization, hygienization and salinity

Once the quality of the product is checked, compost has a large variety of applications and utilizations (Table 2.). In an integrated waste management system, composting has to be considered a process which reduces and solves the problem of organic waste disposal, contributes to the reduction of waste going to landfill, reduces environmental pollution in particular concerning with the diffusion of agents pathogenic to human beings. Compost contributes to pollution control, public health benefit and resource recovery in economically developing countries.

PARAMETERS	UNITS
Organic matter	% fresh matter (fm)
Moisture	% fm
Total organic carbon (TOC)	% dry matter (dm)
Total Extractable carbon (TEC)	% dm
Humic carbon (HA + FA)	% dm
Non humic carbon (NH)	TEC — (HA + FA)
Humification degree (DH)	% humic carbon

Humification ratio (UR)	(HA + FA) / TOC
Humification index (HI)	NH / (HA + FA)
Total nitrogen	% dm
Organic nitrogen	% dm of total nitrogen
Nitric-N	% dm
Ammonium-N	% dm
C/N	organic carbon / organic nitrogen
Phosphorus (P_2O_5)	% dm
Potassium (K_2O)	% dm
Salinity	meq/100g dm
Electrical conductivity	$mS.cm^{-1}$
Bulk density	kg / l dm
Density	g / cm^3
Porosity	%
Particle size	mm (sieving)
pH	
Water capacity	g / 100g dm
Heavy metals	mg / kg dm
Inert (plastic, glass, metals)	% dm and size in mm
Phytotoxicity	germination index
Respiration rate	mg O_2 /Kg dm / h
Human pathogenic agents (bacteria, viruses, parasites)	must probable number (MPN)
Phytopathogens	MPN
Organic pollutants	mg / Kg dm

Table 1. Most important parameters in compost quality evaluation

A very large literature in this field confirms the beneficial use of compost in many agronomical and environmental aspects (Zucconi et al., 1983; de Bertoldi et al., 1987; de Bertoldi et al., 1996; Bidlingmaier et al., 1999).

Recently new emergent aspects on compost utilization are receiving a growing interest. Inefficient collection methods of waste, insufficient coverage of the collection systems, combined with improper disposal of municipal solid waste and contaminated sources of water

- Agronomic value
- Organic fertilizer
- Amendment
- Contribute to chemical fertilization
- Preparation of growing media
- Horticultural substrates
- Plant nurseries
- Control of plant diseases
- Beneficial effect on mycorrhiza and nitrogen-fixation
- Mushroom production

- Reclamation of sandy soils
- Viticulture, pomology
- Recovery of landfills
- Biofilters for air depuration and odour control
- Prevention of replant disease
- Improve soil organic matter
- Improve soil porosity and texture
- Increase biological fertility of soil
- Beneficial to microbial activity in soil
- Improve plant nutrient availability
- Prevent desertification
- Prevent soil erosion
- Increase water retention
- Reduce leaching of nutrients
- Enhance sustainability in agriculture
- Reduced costs in organic waste management
- Prevent pollution caused by improper waste disposal
- Bioremediation
- Degradation of toxic organic waste
- Waste processing and regenerative life-support medium in human extraterrestial exploration
- Pollution control, public health benefit and resource recovery in developing countries?

Table 2. Compost utilization and benefit

supply, are major threats to public health and environmental quality in developing countries. In many cases composting has given a positive response to pollution control, public health benefit and resource recovery in developing countries (Diaz et al., 1999). Composting is also finding an important role in supporting extraterrestrial life in interplanetary exploration both as a system of waste disposal and as a life-support medium to grow vegetables (Garland, 2000; Finstein et al., 1999a; Finstein et al., 1999b)

5. COMPOSTING PLANT DESIGN

In composting, the main factors that have influenced technology and around which system designs are developed are: availability of oxygen, temperature and moisture. With respect to design, the equipment to control and regulate these parameters range from the relatively simple to the very complex. This range leads to the generalized classification of compost technology described earlier as open (windrow, pile, bay), or closed (mechanical, reactor, in vessel or container) (Table 3).

When discussing composting, a careful distinction must be done between the plant and the process itself. By plant is meant the system of machinery, buildings and equipment for composting; by process is meant the biological transformation of organic substrates with the correct application and optimization of all conditioning parameters. Today, many sophisticated plants are available, more or less complicated, but most of them do not take care of the process control correctly.

OPEN SYSTEMS

- Turned pile
- Static pile: air suction
    - forced air
    - alternating ventilation
- Pile periodically turned and ventilated (bay)

CLOSED SYSTEMS

- Vertical reactors: batch process
- Vertical reactors: continuous process

- Horizontal static reactors
- Horizontal reactors with movement of material
- Bay inside a building (with ventilation and turning)

Table 3. Summary of composting systems

Civil engineers, who design and construct composting plants and industrial microbiologist who perform and devise composting processes up to now have been working independently or separately. A closer collaboration would certainly improve the practical results. These aspects will be treated in next sections.

6. CIVIL ENGINEERING & ARCHITECTURE

In order to build a composting plant the following services are necessary: access road, unloading/loading bay, vehicle scales and management office, delivery hall with pre-treatment facilities, process hall (composting-reactor or container or piles), subsequent composting area, storage and fine conditioning, and bio-filter.

6.1. Entrance design

Bio-waste/Bio-residue is delivered by collection vehicles. The delivery vehicles are controlled, weighed and registered on vehicle scales, before driving to the delivery point. Therefore, the management office should be situated between the three main points of the plant in order to control the composting process. The areas are : a) the scales, b) the pre-treatment area and c) the process area.

The architectural program of the management office has to consider the conditions of work in a composting plant. Dependent on the size and technical specification of the plant a staff of 2 or 4 people would be necessary. For these workers, a room with lockers for their change of clothes and sanitary facilities are necessary.

The operation of the plant and the visualization of the process take place by means of a personal computer and a printer. Therefore, it is necessary to include one room as an office and another room, which is used as a laboratory, to perform simple chemical and biological analyses.

6.2. Building design

6.2.1 Delivery area

The delivery vehicles drive into an enclosed unit. The gates can be quick closing gates to minimize the odour output. The delivery area for bio-waste and structure material has to be defined in its dimensions by a specialist, for example an industrial microbiologist, in regarding of an interim buffer capacity. Concerning the regulations, in Germany the material can be stored for two days in a bunker.

Depending on the consistency of the material, storage can take place in a flat bunker, as for green cuttings material rich in structure, or in a deep bunker, as for bio-refuse, which is poor in structure, or for sludges in a tank. When planning the bunker, the leachate has to be considered and the possibility of cleaning the bunker with a power wash.

6.2.2. Pre-treatment area

Separately collected bio-waste still contains several materials, which have a disturbing effect on the process. Therefore, a mechanical conditioning process has to be carried out with the following tasks: (1) pre-separation of disturbing constituents; (2), visual control of the delivered material.

The air exhausted from the bunker and the pre-treatment area is collected and treated in a biofilter.

In planning the construction of the receiving area, the architect has to consider the height of the delivery vehicles and the installations for artificial light and ventilation under the roof.

6.2.3. Process area

The bio-waste is transported from the closed delivery unit on a conveyor belt or with the help of an automatic grab-crane, to the process-hall or to a composting reactor or container.

Further, in planning the process area an engineer must take into consideration, that inside the building or the reactor a microbiological process occurs. This means, that all the construction materials and the machinery have to be selected taking into consideration the metabolism with respect to microorganism metabolism.
In the processing hall, water in the air condensates on the roof and on the walls. Condenstion drops to the floor and corrodes whatever material it comes into contact with since the pH of the condensate is 4,7 the normally used zinc-galvanization for steel doesn't help against corrosion. Even aluminium or stainless steel is not resistant to this atmosphere and wood starts to rot. Concrete with some type of surface protection is resistant. The concrete has to cover the steel about 2,5 cm. The joints between the construction elements have to be considered carefully.

6.2.4. Subsequent Composting area

The compost is transported from the closed process hall on a conveyor belt to an area, where the subsequent composting takes place. The material is kept in the composting area for about one month. The subsequent composting should consist of a covered area, equipped with sheltering walls on two sides.

6.2.5. Storage and Final Conditioning

After finishing the subsequent composting the compost is sifted and stored for a maximum of six months. The light materials can be removed from the compost with an air classifier. The architect has to provide space for a front-loader to mix the compost with other substrates and to plan flexible walls, to store the different substrates.

6.3. Urbanistic aspects

6.3.1. Site selection

The choice of the site for the composting plant depends on many factors. If the objective is to reduce the amount of rest-waste, a site close to the landfill can be selected. A correctly built composting plant shouldn't have any odour pollution, so a site close to a farm can be used. Agricultural areas are much better for the acceptance of compost . This acceptance is necessary, if the aim is the improvement of the soil. Early integration of agriculture and agro-industry as main investors, end users of substrate and of compost has to be a crucial element of the overall concept.

6.3.2. Centralized or decentralized concepts

Delivery costs in Europe are so low, that from an economical point of view the centralized solution is always cheaper. However, the economical point of view isn't the only one. Remember the experience in Europe, that big supermarkets have destroyed the landscape, the urban life of our old cities and finally the possibility of income for hundreds of families. Central composting plants over 15 to 20 thousand tonnes per year are out of scale in the landscape and too big for handling the input and output. Especially taking into account, that you need time to enter and build up a market for the compost and that, at the same time, you have to educate again and again the people to accept the collecting of biowaste and to use the compost. Experience has shown that in the long term view large centralised and in developing countries, highly mechanised composting plants have often failed to reach their target and were soon abandoned due to high operational, transport and maintenance costs. Small-scale decentralised communal composting plants are considered a suitable option to reduce transport costs and make use of low-cost technologies based mainly on manual labour. The government has to set up pilot projects aimed at encouraging low-income urban communities not only to manage their own waste collection, but also to integrate resource recovery and recycling of organic matter (Zurbrügg and Aristiani, 1999).

6.3.3. Logistics

The logistics of the roads and turning spaces for the delivery vehicles has to be carefully designed. It is not necessary to surround the building completely with asphalt, that the visitor gets the impression of a 'highway' around the building. Its better to find a reasonable hierarchy according to the frequency of the use adapting the bay design to the environmental conditions.

6.3.4. Configuration of the building

The configuration of all units of a composting plant have to be not only dictated by the necessity of the machinery, but as well by the need of an economical, technical and esthetical solution for the building. As clients often want to do an open tender to find the best economical and technical solution for the composting process. The client receives many technical configurations for the process, but no solution for the architectural problems. The conditions of the ground, site, size, shape of the building and the roof are all factors which determine the best and most economical solution for the plant

6.4. Aspects of civil engineering

6.4.1. Logic of sequence of machinery

Logic of sequence of machinery inside the building is often missed. The companies, that take part in a tender are often using schemes or tenders, they have done before for other clients. The result of this is that the client receives a tender not tailored to his own specific needs and requirements. Therefore a specialized consultant is required in order to design the optimum system for each site.

6.4.2. Dimensioning

The civil engineer is, in general, not a specialist in microbiological processes. The result is, that often the dimensioning of a composting plant fails. The space for the process is too small, the need of structure material is forgotten and the analysis of the input-material is non-existent. Here the industrial microbiologist can help to do the dimensioning according to the retention time and the loss during the process. According to the result of the analysis of the input-material he can recommend, whether a composting plant is the right choice, or a combination plant: digestion- and composting with energy production.

6.4.3. Control of odours

The exhausted air is collected and treated in a biofilter or in an air-purifier. If the site of the composting plant is in an area with good climatic conditions a biofilter can be built. If the composting plant is integrated in an urban space, like an airport, or close to residential areas it's better to choose a biofilter combined with a gas scrubber r, which allows to minimize the odours by 99%. When the site is situated in a valley or on a hill, the local winds carry the slight residual odour of the biofilter around. Therefore, the architect planning the configuration of the plant, has to choose its place very carefully according to the predominant wind direction, the environmental situation of the site and the length of the tubes for the exhausted air. The shortest way to the biofilter is the best, because it influences the dimensions of the ventilators. In a country with very long rainy seasons, the biofilter must be covered with a roof, otherwise it doesn't work. The engineer has to consider the space for a front-end-loader, because the material has to be changed 1 or 2 times a year. The filter material should be not higher than 2 m. The material is a mixture of wood bark, compost and calcium carbonate. It is also very important to remove the sulfur compounds from the exhausted air. This is achieved by the humidification of the air before it enters the biofilter. As a result, odour reduction of a biofilter reaches nearly 95,3 % (van Langenhove et al., 1999).

6.4.4. Leachate collection/Sewage

Process- and condensation water from the delivery area or the process area is carried in circulation and is stored in a process water buffer.
The sewage has to be passed through and treated mechanically-biologically according to the requirements before direct or indirect-introduction to the public sewage system. If treatment in a communal clarification plant is not possible, your own biological sewage treatment plant in form of a 3 units-sewage-plant in combination with a clarifying lake can be built. Here the constituents of the sewage are decomposed under anoxic, de-nitrification, and oxygen containing conditions, nitrification. In a biological sewage purification stage batteries are responsible for the CSB-,BOD- and nitrogen decomposition. The forming bio-mass is segregated off from the water and returns to the delivery area, where it's mixed with the bio-waste, rich in structure.

6.4.5. Precaution against fire

In case of fire there has to be a system to collect the used polluted water. The clarifying lake, the process water buffer or a rain water tank can be used to do both store the necessary water and collect the polluted water in case of fire. The delivery-area should be separated from the process-hall by non-burning materials.

6.5. Architectural aspects

6.5.1. Climate & regional aspects

Buildings have to adapt themselves to their environment, to live in harmony with the regional climatic conditions. Therefore, many different building configurations have been developed over the centuries for the different regions in the world. The architect has to consider the regional cultural and climatic specialities to plan not just a cover for machinery, but a building that fulfils the thermal, hygienic and visual needs of the society, otherwise you may produce 'visual waste', that's difficult to get rid of (Schnappinger 1995).
If you consider the four main climate zones: tropic, dry, moderate and cold on the earth, the analysis of the climate characteristics has influenced the traditional building —configuration and the used materials. Therefore, the architect has to consider the shadows, solar-heating as well as the winds and the vegetation on a building. Further, he or she has to obey the relative humidity, the quantity of rain on the site. In hot zones one has to consider the high evaporation. The necessity of shadow with architectural elements or plants, the shelter against wind with green fences and cooling with wind inside the building or solar cooling has to be considered. In a dry zone, where you have a low air-humidity you can use vaporization for cooling (Daniels 1995).

6.5.2. The shape of the roof

For extremely flat buildings like supermarkets or composting plants with a large delivery and process hall it's very difficult to find solutions, which are not monotonous and realize a natural ventilation. The ventilation system for the building can be the source for its shape. The roof might be formed like waves or slightly inclined or flat and covered with a compost-composition for dry climate. To get the effect of a chimney ventilation you have to let in the air at the bottom of the facades and design an outlet on the top of the roof.

6.5.3. The floor of the delivery hall

The flat or deep bunkers are built in concrete with a highly protected surface against mechanical damage. It has to be planned with high and low points to realize a simple possibility to clean the bunker dry and with water. The point of the dirty water collection has to be executed at a point not close to the storage-surface for the waste.

6.5.4. Floor of the Process-hall, bio-container or bioreactor

The floor of a process-hall is full of tubes for the ventilation system of the piles. As the hall and the walls are wet caused by the condensation you have to plan the way of the water carefully. The bio-container or the bioreactor put up on concrete. Here the run off of the rain-water has to be considered.

6.5.5. The facades

The facades of a composting plant are determined by the gates for the vehicles and the light needed in the delivery- and pre-treatment areas, the management office and the process area. However, it is not necessary to plan a composting plant facade with miles of steel panels without any design concept. The necessity of shadow and air entrances and the hierarchy of different quantities of light in the different units of a composting plant allows the architect to develop alternate and interesting façades. The use of regional material can also help the building to blend in more to its surroundings and retain affinity with local architectural styles.

6.6. Interdisciplinary Teamwork

Cooperation with the local authorities has to start before the beginning of the project. The integration of Agriculture, the agro-industry as main investors, end user and producers of bio-waste is desirable. There is a common joint interest necessary to realize the concept, thus helping to reduce the controlling activities to crucial and practically oriented issues.

A close relationship between local authorities, plant construction team, construction company and client is necessary to allow non-bureaucratic, fast decisions.

A well planned composting plant is the result of interdisciplinary teamwork, between the several sciences; the industrial microbiologist, the civil engineer, the electrical engineer, the mechanical engineer and the architect.

6.7. Architectural design

Design in planning a composting plant doesn't just mean a colourful final finish of facades. Such measures can improve previous bad decisions and reduce monotony on the landscape, however, with forward planning such blots on the landscape need never be built. Regarding a sustainable development and not repeating the failures done in Europe the aesthetics of a composting plant has to be considered as very important, because otherwise you go on to destroy the beauty of your landscape or your urbanistic structure. Tourism is extremely sensitive, to the problems of pollution whether in air, noise or water, as well as to 'visual damage' of urban spaces and landscape. Generally the machinery inside of a composting plant might change, but the plant once established stays for generations and these generations should not be subjected to our bad planning.

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