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"Comparing Open versus In-Vessel Composting"

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1 ABSTRACT

The paper describes the most important differences between two common composting systems: Open type composting systems i.e. windrows or aerated static pile system and container type systems with air recirculation. The factors that are investigated are: Land requirements, possibilities of encapsulation, effectiveness and speed of decomposition, compost quality, odor and dust generation, independence to climatic situations, leachate and condensate problems, amount of exhaust air to be treated, skill of the staff needed, health and safety standards, composting in underdeveloped countries .

2 INTRODUCTION

Composting plays an important role in the waste management systems of many countries worldwide. As an example up to the year 1998 in Germany 520 composting-plants have been built and 6.3 million metric tons of biowaste are processed annually.

It is to be noted that although only 30% of the composting plants in operation have technical composting equipment, they process more than 50 % of the total biowaste stream. These figures emphasize the growing importance of technical systems for this type of waste management. In the following paper the advantages and disadvantages of uncontrolled windrow systems are compared to high tech in-vessel systems.

3 COMPOSTING SYSTEMS

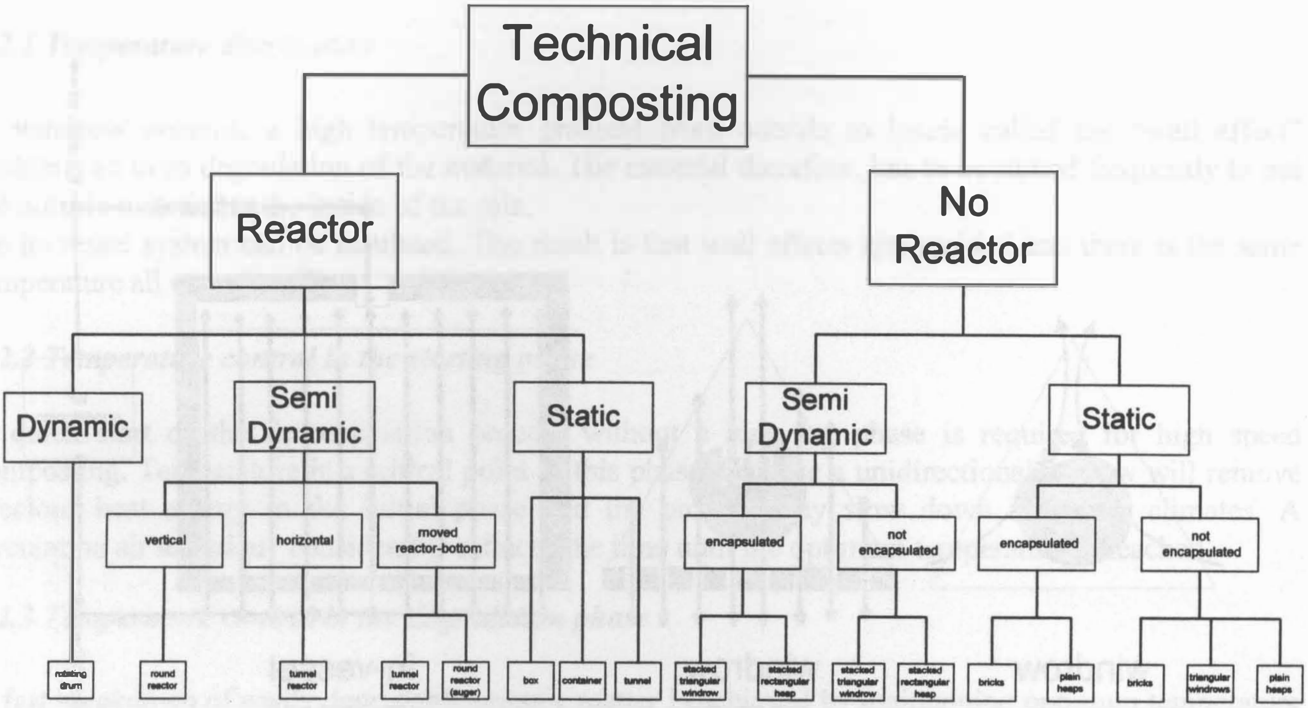

Figure 1: Composting systems

Figure 1 shows an organigram of the common composting systems. This paper discusses mainly the two above-mentioned types:

- no reactor - static - not encapsulated - triangular- windrows
- reactor - static – box

4 CONTROL OF AIR, TEMPERATURE AND MOISTURE

4.1 Air

4.1.1 Open systems

The air movement here only happens by convection (fig. 2). A more frequent air exchange in an open, unaerated windrow system is achieved by turning of the windrows. The disadvantages are:

- poor air supply in the center
- uneven air distribution which leads to uneven biodegradation of the compost heap
- inability to guarantee pathogen and weed seed kill.

- CO_2 is a gas heavier than air, so it sinks to the bottom of the windrow and negatively affects microbial growth there.
- The effective air consumption can only be guessed at and depends on the amount of degraded organic matter.

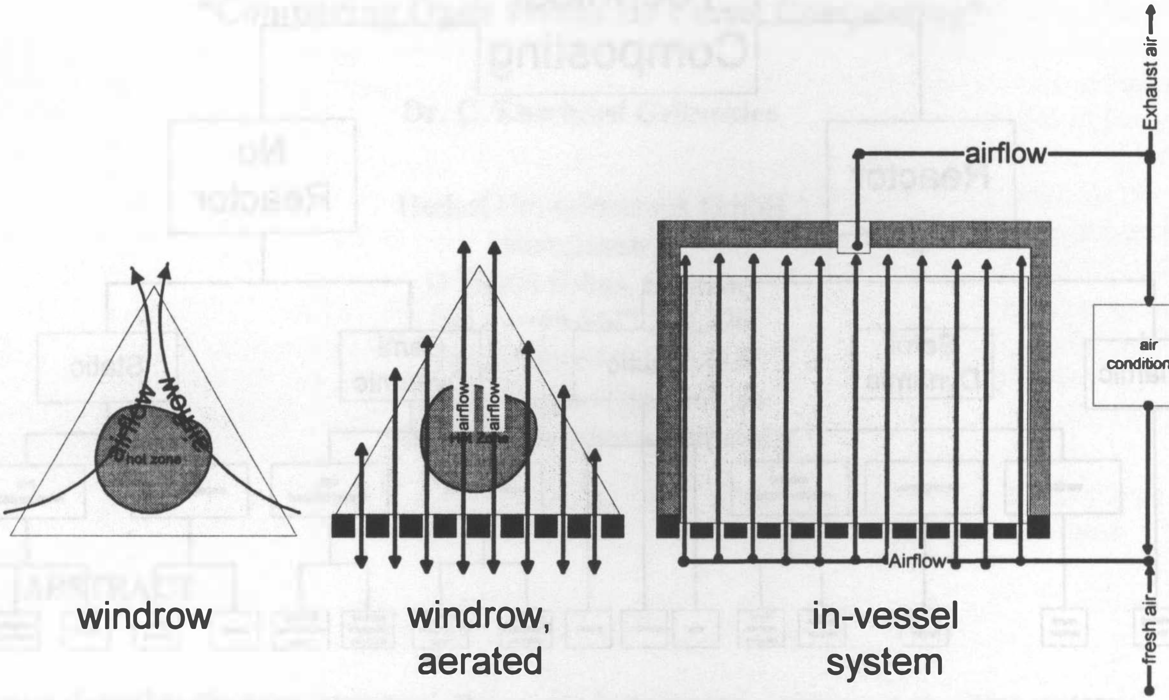

Figure 2:- Windrow systems and in-vessel system with air recirculation.

The more advanced windrows as indicated in figure 1, are equipped with a ventilation system underneath the windrow, which is either suction- or on pressure-based. Although measuring and control of temperature is possible, control of CO_2 or O_2 have to be performed by measurements in the material itself. In systems with suction ventilation this measurement is taken in the exhaust air. The disadvantage is high air consumption, because the temperature control has to be performed by the amount of fresh air delivered.

4..1.2 In-vessel systems

The most advanced technique, the in-vessel composting system can be operated with less air than the open system, due to the possibility of air recirculation and preconditioning of the supply air. This process has distinct advantages.

In general, the load of emissions (germs, odor) is dependent on the quantity of emitted air. The more air that is needed for the process (degradation, water transport, heat transfer), the larger the biofilter systems have to be in order to clean the resultant exhaust air.

In the case of closed systems with controlled aeration however, there is the possibility of extracting air from areas like the delivery bunker, shredder, and conveyor systems and to use this air as supply for the decomposition process. The in-vessel system reacts in this way as a pre-filter system. In these systems the air distribution is facilitated due to the even shape of the pile.

4.2 Temperature

4.2.1 Temperature distribution

In windrow systems, a high temperature gradient from outside to inside called the "wall effect" prohibits an even degradation of the material. The material therefore, has to be turned frequently to put the outside material to the inside of the pile.

An in-vessel system can be insulated. The result is that wall effects are avoided and there is the same temperature all over the pile.

4.2.2 Temperature control in the starting phase

A quick start of the decomposition process without a long lag phase is required for high speed composting. Temperature is a critical point in this phase, because a unidirectional airflow will remove precious heat energy in the initial phase and the process may slow down in colder climates. A circulation air technique considerably reduces the time until the optimum temperature is reached.

4.2.3 Temperature control in the degradation phase

A fast breakdown of easily degradable organic matter is achieved by maintaining optimum temperature conditions for the microbes. Uncontrolled systems develop the highest temperatures in first days of composting (fig. 3). Sterilization of the material in the beginning of the process due to the high temperatures means a long subsequent lag phase and therefore an extended decomposition time. Very frequent turnings are required to avoid overheating the pile.

In a controlled in-vessel system high temperatures in the beginning of the degradation can be avoided by the supply of cooled air and by maintaining temperatures in a range of the highest microbial activity as long as possible.

4.2.4 Temperature control during sterilization

Achieving a high temperature for inactivating microbes and weed seeds is necessary for a safe product. A temperature of 60 - 65 °C is considered sufficient for effective elimination of pathogens. Nevertheless, material temperatures over 65 °C should be avoided during the sterilization phase. Often systems, especially uncontrolled windrow system, are operated at temperatures higher than 70 °C (fig-3). These are not biological reactions, but chemical reactions which can result in formation of unwanted substances. Some of these substances can be toxic or can generate a pungent smell. In a closed system the temperature can be controlled in every phase of the process, even during the sterilization, and these problems do not occur.

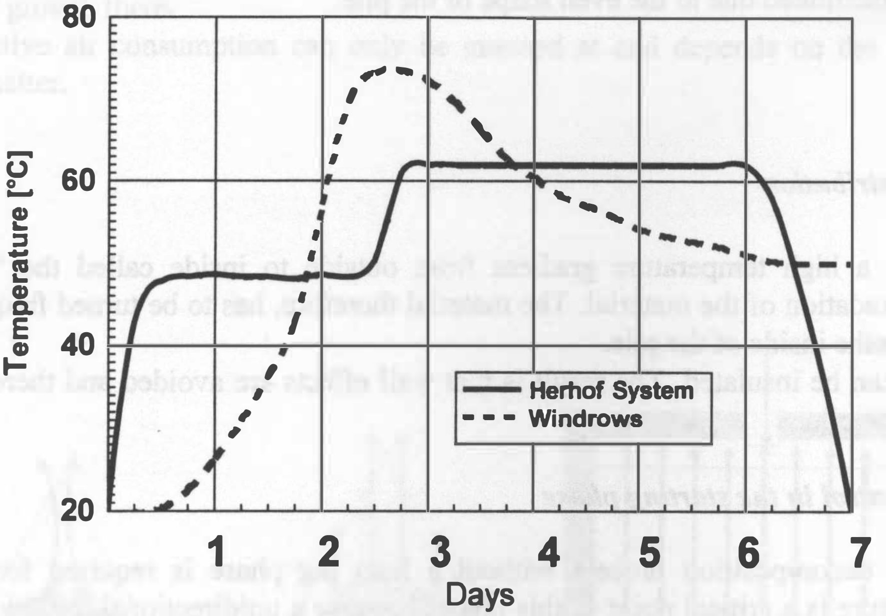

Figure 3: Temperature development in a uncontrolled windrow system and in the Herhof Composting System

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Compost can be sold both as fresh compost (as is frequently done in Germany) and as finished compost. For selling of a fresh compos.3 Water

4.3.1 Leachate

Leachate, usually 10 - 40 liters per metric ton of input can be collected and sprayed again over the material. However, this water is extremely highly loaded with organic matter and germs. Spraying it outdoors, is problematic because of health risks. A closed system therefore is best suited to handle it.

4.3.2 Water export

With the reduction of exhaust air a lot of problems can be minimized during composting - One of the most important is water loss. In an uncontrolled system with a unidirectional airflow without recirculation, one of the results is water loss. Every cubic meter of air, that is used to keep the process aerobic, exports water from the system. Irrigation of piles of composting material is problematic because the water is difficult to bring into the pile itself - -specially in the windrow approach. By using advanced ventilation technologies, water export is limited and the maximum amount of water saturated air can be recirculated into the system to keep the moisture inside until the end of the process.

4.3.3 Conditioning of the compost material

t material for use in agriculture the compost should have a moisture content of 30 - 40 % to avoid transportation of water and smell but it should not go less than 15 - 20 % to avoid dust emissions during handling. For further degradation and curing the moisture content should, be higher than 40 % to avoid the material becoming hydrophobic. Moisture control after such short of time of decomposition (7 - 14 days) can be done only in in-vessel systems with controlled aeration.

4.3.4 Possibility of collecting and cleaning the condensates

Condensates are formed during the condensation of the water saturated exhaust air. They contain 50 - 70 % of the odor forming substances, because most of these molecules are water -soluble. Also condensates are aggressive to metal constructions due to their content of dissolved carbon dioxide. If there is no possibility to collect them which is the case in a roofed windrow composting plant, that can lead to negative effects like corrosion, “raining” in the hall, bad workplace conditions, fog or ice.

If it is technically possible to collect condensates (e.g. in a heat exchanger) a lot of aforementioned problems disappear. In that case only 30-50% of the odors need to be cleaned afterwards. So the biofilters can be constructed very compact and effective. The condensate can either be cleaned or reused for instance in evaporating cooling towers, like it is done in the Herhof composting system.

5 CLIMATIC CONDITIONS

5.1 Warm countries

The climatic situation in most of the warm countries is not very suitable for effective “Low Tech” composting in windrows. In most of these areas, e.g. in South America, East Asia or Africa high temperatures predominate, either with low humidity as in the desert or high humidity and sometimes also high rainfalls in the rainy season. In desert like climates, a windrow system can dry out very quickly. In these areas water for irrigation is hard to find and often restricted for drinking water or for agricultural irrigation.

In hot and humid climates, effective moisture control in windrows is not possible, because water removal from a system can only work if there is a gradient in the water saturation of the air. The heavy rainfalls in these climates require at least a roofing of the plant or there is a risk that compost or biowaste is washed away. Storage of finished material is basically impossible because it gets saturated with water.

5.2 Cold countries

A lot of countries, where composting is done, have winter temperatures much below zero. Often it happens, that frozen biowaste is delivered to the composting plant. Even after crushing in a shredder and putting that material in a windrow, it sometimes takes days or weeks until the biological degradation process starts. In the compost business, however, it is necessary to have enough finished compost ready in spring, because this is the time when all farmers and gardeners need the compost most.

Technical in-vessel-systems do not produce these difficulties, because they operate independent from the outside climatic conditions. In some systems, like the modular Herhof Box Composting System it is even possible to take hot air from one module which is in full operation for preheating material in a system which is in the starting phase. The long lag phases of uncontrolled system is shortened to a controllable period of time and the calculated processing time can be completely used for decomposition and sterilization.

Guaranteed annual throughputs of the plants are not jeopardized as it can happen if the material stays too long in the system because of starting difficulties.

6 PATHOGENS, HEALTH AND SAFETY STANDARDS

6.1 Sterilization

6.1.1 General

All waste materials, including and specially the biowaste contain pathogens and weed seeds. One of the main targets of composting is an effective elimination of these species.

We can divide the pathogens into the following groups:
- human pathogens
- veterinary pathogens
- phytopathogens

The first two of the three above mentioned are eliminated very easily. For instance Salmonella needs to be heated to 50 °C for 2 h to be inactivated, like all these pathogens which are adapted to temperatures about 37 °C and living condition such as in human or animal bodies.

It is however, completely different with phytopathogens and weed seeds. These species have learned to survive under the worst conditions, such as high temperatures, no water, frost etc. A composting system must specially kill these pathogens, because the places of compost application are agricultural fields with crops. For example, spreading Plasmodiophora brassicae over a field by a compost application will make it unusable for brassica production (rape-seed-oil) for the next 5 -7 years or weed seeds in an ornamental flower production can ruin a professional gardener. Lawsuits can result from the damage incurred by using improperly treated compost.

Of the two examined composting systems, in-vessel-systems have clear advantages over the open-windrow system.

6.1.2 Temperature gradient

The outside areas of a windrow are usually cold while the inside is hot, so it is easily possible that pathogens survive in the cold areas, specially, when the windrows are not turned frequently. Also the actual residence time of the pathogen-loaded material in the hot areas is low in these systems

In a closed, heat insulated system there are no such "wall effects". An even temperature distribution inside the heap can additionally be provided by a circulation air technique.

From experience, in our own Herhof-Composting systems a maximum difference between air-inlet and -outlet of not more than 2 °C was measured. The same temperature at every place in the heap is ensured during the full time of composting.

6.1.3 Moisture

The heat energy needed for a perfect elimination of pathogens has to be transferred to the surface of the microbes or weed seeds somehow. Hot dry air alone is not effective. Only water-saturated hot air is the medium to do this task, but it has to be transported to every point in the waste heap. Open systems do not have the possibility to recirculate air. Only a controlled aeration system in a closed vessel and an advanced air circulation system will accomplish this.

6.1.4 Reinfection

Another problem often occurring with open systems is the reinfection of an already sterilized compost. Compost at a late stage of decomposition that is stored outside can easily be reinfected by flying weed seeds or by pathogens spread by birds. The energy in the semi-finished material is no longer sufficient for the delivery of enough heat so that seeds and pathogens stay alive in the compost. This problem can only be avoided by keeping the material inside of the closed system as long as possible.

6.2 Occupational health

6.2. 1 General

Working with waste and specially with biowaste has certain risks for the employees. Waste always contains bacteria, actinomycetes and fungi. Most of them are harmless and are necessary for the composting process itself, but there is always the possibility that infectious material is delivered to a composting plant with the domestic waste stream. Contact between workers and the waste must therefore be minimized or if possible altogether eliminated.

6.2.2 Need for encapsulation

The best solution is a fully automated plant, where the waste is dumped into a closed bunker, then automatically transported in closed conveyor systems to the shredder and afterwards brought into an in-vessel-system. If the transport has to be done with a front-end loader this has to be fitted with an appropriate filter system.

The best (but of course most expensive) solution is a full encapsulation of the process from the delivery up to the end-product compost. One of the reasons for closing the process is dust and aerosols emitted during decomposition and material handling. Swallowing or skin contact may cause sickness or allergic reactions. That does not only concern people working in the plant itself, but can also affect people in residential areas in the surrounding neighborhood.

6.2.3 The risk of emissions of pathogens to the environment

Recent studies in Germany prove that germs and fungal spores can be transported over long distances. A lot of bacteria and fungi are absolutely necessary for the decomposition process and usually not harmful to healthy people but, they can jeopardize people with an immune deficiency.

For that reason the smaller the source of emission is, the less risk remains for the workplace and for the environment.

A windrow-composting, plant has a very large surface from where the emissions arise. Every handling of the material sends emissions into the environment. On the other hand, an encapsulated system, if well designed, has as the only exhaust air outlet a chimney after a biofilter-system. This single source can be monitored very effectively for emissions, particles etc. If the biofilter or scrubber should not be sufficient, an additional treatment like ozonization etc. can easily be installed.

In order to avoid problems related to uncontrolled emissions, outdoor windrow plants must be constructed outside populated areas. Although this alleviates some of the concerns it does not alleviate the concerns related to worker health and costs related to transportation must be accounted for.

If the waste is transported for long distances, the ecological impact and the costs arise from the transportation.

If the plant is built near the city, encapsulation is necessary. The legal distance to residential areas in Germany is 300 m. The German waste legislation (TASI) tells us- that "... at least the intensive step of the composting process has to be done in a closed system".

7 ODOR PROBLEMS

Odor generation is a common problem in every composting plant; basically, a decomposition process always generates odors. The trick is only, how to handle the resulting emissions.

Odors can be transported by wind or air flow over long distances and are an irritant to people. Odor will occur even in places nobody would anticipate during planning of the treatment facility. Odors not only irritate people but can make them sick when constantly present over long periods of time. The result is the same in any place of the world: A composting plant producing too much odors is shut down by the authorities.

For that reason, the legal allowance for odors in Germany is not more than three so called "odor units" in three percent of the hours of a year.

An examination of plants which have been shut down, shows that the problems are mostly in the windrow types where uncontrolled composting was done (The other reasons were poor filter layouts, management problems or lack of maintenance).

Of course: A properly operated windrow plant can produce very low emissions. But, regardless, the emitting surface contributes decisively to the total odor emissions of the plant.

The situation is completely different for the in-vessel systems, where odor control is much easier. In these systems, the emitting surface is reduced to a minimum. The total emission therefore is low.

8 LAND REQUIREMENT

To shorten the transportation distances from the place where the waste is generated to the place where it is treated it is recommended to place the treatment facility close to the city. The disadvantage is that land is expensive in the direct neighborhood of industrial or residential areas.

So an important factor in the price calculation of a plant is the cost of land.

Open-windrow-systems have strict limitations for the height of the compost piles due to the required aeration. Additional space has to be planned for the moving of the front-end loaders, windrow turners and, depending on the used technique, for the windrow managing.

Here the closed systems have a clear advantage over the open-windrow systems. Due to the speed of composting by the advanced aeration systems and the accelerated initial mass loss the throughput is enhanced. A well-designed ventilation system allows higher heaps and in that way saves space. Boxes, container, tunnels and bays can be put close together, especially when they have automatic loading systems.

The following table gives data for a 60,000 t/a windrow composing plant versus a 60,000 t fully automatic box composting plant.

Table 1: Requested area for a windrow-composting plant and a box-composting plant (60,000 t/a)

Windrow		**In-Vessel**	
paved area	39,000 m²	**paved area**	2,850 m²
roofed area	2,000 m²	**hall**	11,850 m²
greens	6,000 m²	**greens**	2,500 m²
total	**47,000 m²**	**total**	**17,200 m²**

9 SKILL OF STAFF

There are varying degrees of skills of staff required for operating in-vessel systems, depending on the make, and operating simple windrow-systems. The skill required from the operators are:

- driving heavy machines like front-end loaders or windrow turners
- basic knowledge in biology of the decomposition process
- basic marketing and sales experience

For in-vessel, high-tech systems the above mentioned skills are also required and depending on the system the plant may require varying degrees of:

- computer knowledge
- knowledge in electrical / electronical control systems
- qualified mechanics for the maintenance of different technical installations and machines

Here, as expected, the open non-technical solution has advantages. A lot of work in these plants can be done by unskilled personal. The high-tech in-vessel-plants require at least a manager with some technical, electrical, computer knowledge. The salary for skilled workers naturally is higher than the salary of unskilled personnel, which adds further costs to the operation of the installation.

10 DESIGN OF THE PLANTS

Aesthetics of plant design can be very instrumental in terms of public support of the program. Windrow composting plants with a big covered or uncovered area never can be built in a stylish way because of their size and technical conditions. The modern in-vessel systems on the other hand offer all possibilities to realize a design which is satisfying from the aesthetic point.

11 COMPOSTING IN UNDERDEVELOPED COUNTRIES

"Why technical composting in underdeveloped countries?" is a frequently asked question. The solution for waste problems, including composting, in underdeveloped countries should usually be achieved with a technology for a sustainable development. Often "High-Tech" systems are not considered as a viable way for third world countries.

A basic proceeding often mentioned is that farmers or a farmer"s cooperative accept the kitchen and/or green waste of a catchment area, they compost the material in simple windrow composting plants with their own agricultural machinery and use the resulting compost to fertilize their fields. In addition to the benefit of saving mineral fertilizers they get some extra money for the handling. This sounds very simple, but on a closer look it is not that easy. There are some important facts, which are not in favor of simple solutions like the one mentioned above.

First of all there are the climatic conditions mentioned in section 5.

The next question is: Where is the waste produced in these countries and where does the waste problem occur?

Of course, waste is generated in the center of cities as well as in rural areas. In the latter ones waste is not a big problem. Food waste (if produced at all) is used as food for the animals, the rest (and in these poor regions there often is not much of that) is burned. Waste decomposes very fast under hot climatic conditions or due to the low density settlement it simply disappears in the landscape. Any waste treatment in these areas is very problematic because of logistics. In certain places, it is simply impossible.

The waste stream in these countries, which is a real problem, simply because of its volume, is generated in the big cities, where the majority of the population lives. In these cities, viable solutions for the waste problems have to be found first.

These places often have quantities of waste starting with hundreds up to even several thousand metric tons of waste a day. To avoid long transportation distances on roads or railways under the mostly problematic traffic infrastructure, the waste should be treated close to the city. But problems such as land-use, odor-problems or sanitary problems must be strictly avoided. Most often, non-technical solutions will fail here.

Many people will argue that in these countries there is a big pool of workers available to do the job instead of machines, but from our point of view this is cynical. Waste can be a harmful substance and working with waste can create working conditions harmful to the employees- This applies to the industrial nations and it is not different in under-developed countries.

So: High-Tech In-Vessel-System for industrial nations and
Low-Tech Open Windrow Composting for underdeveloped countries

is a formula which should not be acceptable.

13 COST

Cost has been deliberately omitted from this discussion because cost is specific to each geographical area. In certain areas, the bid process has revealed that in-vessel systems have been cost competitive with outdoor windrows. The cost of land, transportation, potential liabilities etc. must all be factored into the cost analysis.

14 SCOREBOARD

The following scoreboard collects points for the two systems.

Task	Windrow	In-Vessel
exhaust air control		✓
composting speed		✓
temperature control		✓
health standards		✓
climatic situation		✓
moisture control		✓
odour		✓
skill of staff	✓	
land requirement		✓
underdeveloped countries		✓
design		✓
price	✓	
score	2	10

The technical advantages of the in-vessel systems are clear.

IN-VESSEL MSW BIOCONVERSION SYSTEMS IN THE U.S.

THE EWESON PROCESS: AN ADAPTION OF MODERN FERMENTATION TECHNIQUE TO THE AGE OLD PROCESS OF COMPOSTING

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SUMMARY

The term "in-vessel composting" is used to describe many composting systems, some totally contained and some not. For the purpose of this paper, this term refers only to totally contained systems that are applied to mixed municipal solid waste composting.

This paper provides a review of in-vessel composting of municipal solid wastes in the U.S., with particular emphasis on the **EWESON PROCESS**. Provided is an in-depth view of the Eweson method of in vessel composting of municipal solid waste and sewage sludge to treat modern city wastes and produce enriched soil for land reclamation and fertilization.

IN-VESSEL MSW COMPOSTING IN THE U.S.
A BRIEF HISTORY

The U.S. history of in-vessel composting systems for municipal solid wastes (MSW) could be described as "sporadic". Its earliest beginnings are traced to the 1920 to 1930 era when one of the first in-vessel systems, Beccari, was used in 5 U.S. projects in Florida and New York[1]. Problems with this technology caused these projects to close and, for the most part, in-vessel composting was not again tried in the U.S. until the early 1950's.

Beginning with the early 1950's projects, and followed by subsequent projects through the 1970's, various in-vessel systems were attempted in the U.S., using technologies such as Thermax, Frazer-Eweson, Naturizer, Riker, Varro, Euramca, Danos and Eweson[1]. Each of these projects contributed to the common body of knowledge by its successes, its problems and, in most cases, its ultimate failure.

Only one project from this era continues to operate today. That facility was constructed in 1972 in Big Sandy, Texas and employs the Eweson Process. As such, it is the oldest, successfully operating facility of its kind still operating in the U.S.

The success of the Eweson digester in Big Sandy, Texas has paved the way for several subsequent projects using the Eweson Process. Today, the Eweson Process is used in more msw/biosolids co-composting projects in the U.S. than any other.

THE EWESON PROCESS: AN ADAPTION OF MODERN FERMENTATION TECHNIQUE TO THE AGE OLD PROCESS OF COMPOSTING

The Eweson Process is by far the most technologically advanced, yet elegantly simple, composting process available in the world today.

The effectiveness of the Eweson Process stems from the inventor's primary motivation which was to use the refuse from municipalities and farms alike to

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restore and maintain the agricultural productivity. This philosophy led Eric Eweson to a unique process that in every aspect was dedicated to the production of a usable and environmentally acceptable end product. He held that in nature there are no wastes, and furthermore, that nature has its own process to biologically convert its residues into useful end products. Starting in the 1940's, Eweson sought to harness the forces of nature and to mechanize and optimize these forces for the good of mankind.

Most composting processes, including Europe's most prominent technologies, were designed by engineers or machine designers. Microbiologists and fermentation technicians were not part of their technological development. The Eweson Process was an exception. Eweson's background as a fermentation technician, led him to make every effort to optimize the conditions for the microbiology in order to promote explosive microbial growth.

Eric Eweson, the inventor of the Eweson Digester was born in Sweden in 1897, and was the fifth generation heir-apparent to the family glass and crystal manufacturing business. He acquired a license from a friend to a bread yeast manufacturing process which used the waste sulfite liquor from paper mills as the primary source of raw materials. Eric raised several hundred thousand dollars from his associates in New York City during the depression and they proceeded to build two successful yeast manufacturing plants in Canada. After several years of successful yeast production they were bought out by another yeast manufacturing company and promptly shut down. Eric then retired at age forty and decided to apply what he knew about fermentation to other waste products.

The primary inspiration for Eric Eweson's work came from a British scientist named Sir Albert Howard. Howard was the first scientist to quantify and document the science of the composting process, which later became known as the Indore Process named after the agricultural research station located in Indore, India, where he did his work. He defined the composting process as having three stages 1) Thermophilic 2) Mesophilic 3) Cryophilic. Before his death, Howard issued a challenge for someone to apply modern industrial techniques to this now defined biological process.

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[1] Roger T. Haug, <u>The Practical Handbook of Compost Engineering</u>, Lewis Publishers, 1993, pp. 63-74.

Eric's first commercial attempt at this challenge was a five-story building constructed in Spain, known as the Frazier-Eweson Process. Eric also built a vertical silo reactor in a joint venture with the A.O. Smith Company. The real breakthrough came when he observed his fellow Swede, Mr. Peterson, using a Dano drum to grind solid waste preparatory to use in hotbed vegetable production. This he observed might be the ideal machine in which to conduct the industrial version of the Indore Process. He built the first unit in Egg City, California to adapt a drum to the process. He subsequently built Big Sandy, Texas and after his death, Pinetop-Lakeside, Arizona; Sevierville, Tennessee; Sumter County, Florida; and Cobb County, Georgia.

Biochemically, fermentation is the name given to the general class of chemical changes or decompositions produced in organic substrates through the activity of enzymes. These enzymes are produced by microorganisms such as bacteria and fungi to solublize organic matter to obtain the energy that they need for their own metabolic processes.

Louis Pasteur was the first scientist to show that fermentation was caused by microorganisms and not by spontaneous generation as was previously believed. Pasteur referred to both aerobic and anaerobic fermentations. In aerobic conditions, oxygen is consumed and growth and reproduction occur quite rapidly. The end products are carbon dioxide and water. In anaerobic conditions, limited cell growth occurs and the end products are carbon dioxide and alcohol.

Fundamentals Eric was trying to achieve:

A. Rotary Vessel (mass animated)

Rotation of the enclosed horizontally inclined vessel puts the mass into a semi-animated state, mixing, aerating and particulating in a relatively easily controlled environment.

B. Multi-compartmented

Eweson theorized that an infinite number of compartments would enclose the perfect process. His patent drawings show only four and, as a practical fact, he could afford only three. Process materials spend about 24 hours in each compartment.

C. Counter-current Air Flow

Enhances mass transfer and heat transfer.

PROCESS OBJECTIVES

A. Acclimation

The primary objective of the digester is to adequately prepare raw feed stocks for and initiate rapid biological degradation.

This includes, but is not limited to:

1. Bringing the moisture up into the 40-60% operating range.
2. Initiating explosive microbial growth.
3. Creating significant surface area of the organic fraction.
4. Bringing the material to thermophilic temperatures.

B. Inoculation

Inoculation is achieved by several distinct methods:

1. Auto-inoculation - Both municipal solid waste and wastewater biosolids are themselves very biologically active, but we enhance them by a return of inoculant from the process.

2. Culture Retention - The digester is constructed to retain inoculant in each of its successive chambers.

3. Cultural Contact - The walls of each chamber are designed in a way that is self-lining with an organic cake which also transfers bio-cultures by repeated and continuous contact. It also provides some insulation and corrosion protection.

4. Airborne Impregnation (Inoculation) - The counter-current air flow encourages airborne bio-cultures to be transferred to the upstream feed stocks.

C. Homogenization (Mixing)

When starting with feed stocks with such a wide diversity of particle size and composition, achieving some degree of homogeneity is important to process control and resultant product. The wastewater bio-solids and other nitrogenous wastes must be brought into intimate contact with the cellulose fibers in order to "jump-start" the composting process.

D. Particulation

Many composting processes achieve particulation and homogenization by use of high energy grinding. While this may be suitable in purely organic streams, this is inadvisable when dealing with MSW due to enhanced solubilization of metals. The partially filled rotating cylindrical vessel gently macerates the waste, causing the paper products to decline rapidly in particle size.

E. Putrescibles Conversion

Sugars, proteins, fats and carbohydrates all are susceptible to rapid decomposition and are leading causes of odor production and vector attraction. Being readily biodegradable, they can easily be converted in a three-day time frame.

F. Pathogen Reduction

The typical processing schedule does not allow achievement of a 72-hour/55 degree retention regime; nonetheless, tests have shown that the most probable number of fecal coliform colony forming units is reduced from the hundreds of thousands level to the less than one thousand in the nominal three day retention period.

G. Organics Separation

Last, but not least, the pulping of the organic fraction allows for a 90+% effective separation of the organics from the manmade inerts by means of a subsequent simple mechanical size separation.

Biochemical Relationships

Oxygen/CO2 Profile

Oxygen sampling is done by inserting a probe through the side of the vessel and drawing a sample from within the mass. Levels of oxygen in the mass can be adjusted both by the speed of rotation and by increasing or decreasing the amount of air introduced into the vessel by means of a fixed displacement blower.

Exhaust Gas Analysis

Analysis of the digester exhaust gases shows the normal by-products of aerobic thermophilic decomposition as well as the results of volatilizing some voc's found in the feed stock material.

pH Profile

The operating pH in the feed end compartment (#1) is in the 3.5 to 4.5 range. The pH rises slowly as it proceeds through the process. This low pH enhances nitrate formation and reduces losses of nitrogen in the exhaust gases. Solubilization of some compounds is also enhanced.

Thermodynamic Relationships

Heat Generation and Conservation

The heat generated in a 50 tpd digester is about 350,000 BTU└╤ per hour. The digester is insulated with urethane foam to conserve heat so it can be used to heat the incoming waste as it is introduced to the digester.

Transfer of Heat

Heat is transferred primarily in the water vapor contained in the air as it passes from one compartment to the other. Since the incoming waste is colder than the exhaust gases from compartment two, some of the water vapor condenses and imparts heat to the mass.

Heat Losses

Some of the heat is lost through the shell; the balance of the heat leaves the vessel in the water vapor that is exhausted from the first compartment and in the raw compost exiting the digester. In pile composting, air flows are determined primarily by cooling requirements. In the rotating vessel, air is adjusted primarily to satisfy the oxygen requirements and only secondarily to provide some cooling.

1. Use of Sludge Solids.

Eweson recognized that the microbes need the proper ratio of carbon and nitrogen in order to readily digest the waste products. The best way to get sufficient organic nitrogen is to use manure in the process, either animal or human.

2. Utilization of "Available" Carbon

Composting experts agree that sawdust and wood chips are a poor source of "available" carbon for the biological reaction. Eweson recognized that paper, which has already had the lignin (nature's preservative) removed from the cellulose, was an excellent source of "available" carbon for the biological reaction. Not only do paper fibers have vast quantities of surface area, but also, without lignin, is a source of carbon that is readily "available" for microbial consumption.

3. Reverse Process Air Flow.

Eweson recognized that the microbes, which accomplish the initial degradation and stabilization of waste, were thermophilic (heat loving). He further recognized that cold air was fatal or toxic to these organisms. Therefore, the reverse process air flow, provides pre-moisturized and preheated air for the microbes in the initial staged of decomposition.

4. Mass-Animated In-Vessel Processing

An insulated vessel is essential to protect the microbes from atmospheric air which is toxic to them. The animated mass addresses the fact that the microbes do not have wings, legs, or tails and cannot move to their food. The food must come to them. Static piles, vessels, or windrows do not address this essential factor of rapid decomposition.

5. Continuous, Staged, Microbial Inoculation

Other processes do not recognize that different populations of flora and fauna exist under distinct environmental conditions. The Eweson process provides for continuous yet environmentally specific microbial inoculation during each stage of the process.

6. Continuous, Geometric Expansion of Surface Area

Microbiologists agree that microbial populations are proportional to the exposed surface area (feeding surface) of the entrained mass. The Eweson process is unique, in that, the rotation and tumbling (mass animation) of the material causes continual internal abrasion of the material creating new surface areas in geometric proportions. These new surface areas foster proportional microbial populations.

7. Food Source Acclimation

Eweson recognized the lightning speed at which the microbial flora and fauna multiply and realized that as the feed stock changed, the micro flora could adapt in only a matter of minutes, even if the feed stock proved to contain small portions of hazardous material. This rapid-evolution or adaptation allows the process to quickly and readily adapt to variations in feed stock, even if these include hazardous or toxic materials. Hence, the inclusion of household hazardous wastes such as insecticide cans or paint cans, poses no appreciable problem.

THE COMPOSTING VESSEL

With these processing criteria firmly established, the inventor sought the ideal machine to contain this unique process. After several attempts with vertical silos and multi-leveled structure, Eweson settled on the very popular rotary vessel used in the lime and cement industries. This mechanical apparatus proved to be a near-perfect fit to this unique process.

A rotary vessel, 10 to 13 feet in diameter, divided into three distinct compartments, with reverse process air flow, proved to be the most effective blend of theory and practice.

The success of the process is due to three basic simultaneous factors:

1. Physical Grinding or Internal Abrasion

The continual rotation of the vessel causes continual tumbling and internal abrasion of the material, creating ever new surface areas for microbial activity, which leads to temperatures exceeding 140 degrees Fahrenheit.

2. Natural Chemical Degradation

These elevated temperatures and massive surface areas lead to the production of powerful natural organic acids which soften the wastes and prepare the material for consumption by the microbes.

3. Phenomenal Microbial Degradation

Though mentioned last, this activity is by far the most important function of the Eweson Digester. The phenomenal numbers of microbes, feeding on the ever increasing surface areas, cause the waste material to be consumed by the microbes at a prodigious rate. This leads to the "Bio-Conversion" of the once pollutive wastes into an entirely new substance which is microbial protein, otherwise known as humus or when mixed with other dirt, grit, minerals, etc. we call it compost. Hence, the entrained mass is no longer garbage and sludge, but a newly formed product, known as compost, natures answer to the solid waste crisis.

THE EWESON THREE-STAGE PROCESS_

While some competing technologies do use a rotary drum to mix and pulp the MSW, only the Eweson Process boasts a triple-staged, mass-animated, three day process designed to promote and achieve an advance level of the microbial process. In three days, the Eweson process accomplishes what most other technologies require two weeks to accomplish.

THE POST-DIGESTION CURING PHASE

After leaving the digester, the compost passes over a rotary screen which very effectively removes the oversize inorganic and non-degradable items that are found in the MSW. The compost which passes through the screen, then proceeds to a fully automated, dynamic channel, curing system. This portion of the process provides for regular agitation of the compost, either manually or by robotic turners, equipped with computer control for aeration, monitoring and process control reporting. The compost is carefully cured in this portion of the process for a two to four week period.

FINAL SCREENING AND MARKET PREPARATION_

Once again, citing the initial premise that the compost was made to be sold, the Eweson Process goes to great lengths at this point to remove glass shards and unsightly foreign matter. This unique, patented final process machinery plays an important role in producing a clean, environmentally acceptable compost, that can be distributed without regulations to market.

STATIC CURING_

Immediately following final screening, the compost is appropriate for use in some applications. Broader market applicability is achieved as the product is aged and becomes more stable.

Recognizing this fact, the compost may be stored, after final screening, for an additional period that is adequate to provide the level of maturity required by the targeted markets.