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Proposed design of a composting facility for the treatment of municipal waste with built-in deodorization system (in Western Macedonia, Greece)

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Abstract

Composting is a complex, aerobic microbiological process capable of converting the organic fraction of municipal solid waste, and many other organic wastes, into beneficial compost products. Odor is a serious issue in the management of a composting facility and, more so, it is often the issue in public acceptance of composting facilities. Offensive odors from composting are one of the greatest environmental problems associated with the industry. In this paper, an innovative modular semi-open composting system is designed and proposed for municipal waste treatment using a built-in deodorization system which finally incorporates the means to better manage waste, producing optimal final product (compost) in a shorter time and eliminating odor release.

Keywords: composting, odor, municipal solid waste, windrow composting

Abbreviations:
AD - Anaerobic Digestion
BC – Before Christ
EU - European Union
MBT - Mechanical Biological Treatment
MSW - Municipal Solid Waste
UK – United Kingdom
US – United States

1. Introduction

Composting is a complex, aerobic microbiological process capable of converting the organic fraction of municipal solid waste, and many other organic wastes, into beneficial compost products. The composting process can be optimized by controlling the quality of the feedstock and a number of operational parameters.

The biological degradation of complex organic matter into simpler forms and ultimately to its inorganic components, essentially occurs in nature by the consolidation of life on our planet. Human activities, and especially the development of modern culture, have adversely affected nature, since they have caused great disturbances in climate change and natural phenomena.

Municipal waste is a term, the definition of which exhibiting variations across the European countries. However, for most countries, where there is a formal definition, municipal waste includes household waste (of all different types, including bulky materials) as well as commercial waste collected by the local authorities/municipalities concerned, wastes generated from maintenance of parks and street cleaning activities.

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Six are the municipal solid wastes treatment methods which are used by the European countries in a lesser or greater extent, namely landfilling, mechanical biological treatment, incineration, pyrolysis, anaerobic digestion and composting. Landfilling of waste has occurred for many years. Actually, all Member States and Accession States landfill some waste though several of them are implementing, either have implemented restrictions or bans on the landfilling of municipal waste. In Greece, Ireland, Italy, Portugal, Spain, United Kingdom, Cyprus, Estonia, Hungary and Slovenia, the majority of municipal waste is landfilled. The EU Landfill Directive binds Greece to the reduction of biodegradable waste sent to landfill to 35% of 1995 levels by 2020.

MBT is a process designed to optimize the use of resources remaining in residual waste. Usually, it is designed to recover materials for one or more purpose, and to stabilize the organic fraction of residual waste. In Greece, Athens has only one MBT plant, which handles approximately 20% of the entire waste produced in the Greater Athens area, producing low quality compost.

Mass-burn incineration is a technology also applied in many countries in EU. Incineration can, depending upon waste composition (which may exhibit seasonal variation), handle unsorted municipal wastes as well as wastes from which materials have already been separated. One of the principal constraints on the use of incinerators is public opposition since the residents do not want to live near these plants owing to problems of disamenity and the emissions of NOx, SOx, HCl, particulates, heavy metals and dioxins associated with the plant.

Pyrolysis and gasification are relatively new methods for treatment of municipal solid waste and remain relatively unproven in European usage compared with classical moving grate methods. Although the technology is widely used and well-established as an industrial process for energy recovery from hydrocarbons feedstock, their use as processes for dealing with heterogeneous, mixed municipal waste streams is at an early stage of development.

AD is the bacterial decomposition of organic material in the (relative) absence of oxygen (Sánchez-Monedero et al. 2003). AD of MSW has been commercially available for approximately 15 years. However, this treatment method is relatively rare at present (it is only part of waste management strategies in Germany, Austria, Belgium and Denmark, with some application on mixed or residual waste in France, Spain and Italy, though a small-scale plant is in operation in the UK). The principal advantage of the process is the biogas production from controlled anaerobic digestion (comprising principally carbon dioxide and methane, which is capable of combustion to generate energy) (Dounavis et al. 2015; Dounavis et al. 2016). Another by-product of this process is a semi-solid residue, referred to as a digestate which could be used for agricultural / horticultural purposes after further treatment (normally through composting). Over the recent years there has been a resurgence of interest in composting of MSW. A large amount of source segregated wastes are now composted across Europe, and the compost is used routinely by many users, from domestic to commercial ones.

Composting is the actively managed process of decomposition of organic residuals in the municipal solid waste stream. A range of composting systems is designed to manage this decomposition process to yield a high quality compost product without creating a public nuisance or negative environmental impact. In fact, when processing household organics, it is of critical importance to have the right starting mix of feedstocks, and to manage moisture, oxygen and temperatures closely in order to minimize the risk of nuisance factors and environmental impacts. It should be mentioned that there is no single method of composting which is correct or optimal under all circumstances. The composting technology chosen will always depend upon a number of local parameters, such as a) the cost of competing organic waste disposal processes, b) the gate fee that can be obtained for receiving the feedstock, c) the availability of particular wastes, d) the location of the composting facility, e) the type of compost required by available markets and f) environmental legislation. The efficiency with which organic waste, from whatever source, can be collected in a form suitable for composting, has a major effect upon the financial viability of the composting option.

Composting is one of the oldest agricultural techniques and its history dates back to the long past, many centuries ago, where agricultural processes such as the manure of manure have their roots. The first attempts to intervene in the biological process took place in China 5,000 years ago. Composting as a recognized practice dates to at least the early Roman Empire, and was mentioned as early as Cato the Elder's 160 BC piece De Agri Cultura (Cato, 160 BC).

Until the early 20th century, the process remained essentially primitive, without any control or influence on the degradation of organic materials. The first improvement in the traditional process of composting occurs in the third decade of the 20th century in India, by Sir Albert Howard and his colleagues (Howard et al 1929). Essentially, this is a simple systematization of the process in the open space. At the same time the composting begins to accrue interest and hygiene tool, particularly in densely populated areas, for healthier handling the waste of the human body and reduce disease transmission. First, Waksman and his colleagues systematically dealt with the scientific study of composting and in particular the microbiology of the biological degradation of organic residues in general (Waksman Institute of Microbiology, 2018). After Waksman, the study of composting has been extended to almost the developed world and virtually continues until today, resulting in continuous improvement of the whole process.

The composting process can be optimized by controlling the quality of the feedstock and a number of operational parameters. There are many different technologies available for the composting of the organic fraction of solid municipal waste. These range from the simple open-air systems (windrow composting and aerated static pile composting) to more sophisticated contained systems. Various composting technologies are being used in the EU to pre-treat organic wastes before they are landfilled according to the Landfill Directive. There is a number of environmental problems or potential problems, which are associated with composting, including odor, leachate and bio-aerosols.

Odor is caused by one or more volatilized chemical compounds which are generally found in low concentrations and humans and animals can perceive by their sense of smell. Odor is perhaps the most common problem associated with composting, and the failure to adequately address it has led to numerous neighbor complaints and the closure of many large scale facilities. Fortunately, for the most part odors can be controlled, but proper management can demand time and money.

The nature of the odor emitted from the composting process will depend on the type of material being processed and the stage within the composting cycle. Due to the necessary reliance on microorganisms to degrade the organic waste, there will always be some odor emitted at each stage of the process. The key to good composting is to manage the process to avoid excessive odor emissions.

Research on composting operation odors includes identifying the origin, mechanisms and parameters for odor production, quantifying odor generation, defining "low odor" processes, and measuring odor in the ambient air surrounding a facility. Specifically, in this research the development of an innovative semi-open composting system for municipal wastes treatment is proposed using a built-in deodorization system for odors elimination.

2. Proposed design of a composting facility

2.1. Technical Description

Initially municipal organic wastes are placed inside a three wall cemented storage and mixing room of 0.8 m height, with a 20°slope for waste liquid removal. Then the mixing of raw material with by-products (manure, pruning) takes place used as a basis to achieve the ratio of C/N for best results (Argyropoulou et al. 2005; Georgakakis et al. 2000; Mari et al. 2003). After this procedure is completed, the new material is transferred through a truck loader inside the main facility, placed in a triangular heap (windrow) and begin the composting process.

The proposed plant is designed, at first, to deal with approximately 100 ton of organic waste, about 80 m^3, on a 90-day cycle. This amount is determined on the operating dimensions of a compost turner (BACKHUS 16.30) and by the dimensioning of the main building facility. Due to the research nature of the process (the use of municipal solid organic waste for compost production along with a built-in deodorization system), the selected plant, compost stirring equipment and duration were found to be more suitable for this kind and extend of work.

Organic material is deposited in a windrow of 3 m wide, 1.3 m height and 25 m length, inside the greenhouse with controlled ventilation, which is stirred periodically using the compost turner (BACKHUS 16.30), a machine which can stir a windrow with the above characteristics with an enrichment of fresh air from the windows of the facility. As the machine moves through the heap oxygen is injected in the windrow and so the composting process is accelerated. Turning also ensures a higher degree of homogeneity and compost quality by repeated mixing and therefore regular decomposition. Due to this material homogeneity the amount of material retained during sieving is reduced and the amount of compost increased.

The composting system main unit, dimensioning 9.6 m width, 30 m length, 4.5 m gutter height (side height) and 5.85 m ridge height, is constructed of a metal frame and covered by tarpaulin. Its shelter is a Multi-span greenhouse unit (type Serra 192 Gothic 1), with double inflated polyethylene covering on the top. The metal frame of the building is made of galvanized steel tubes (type Z 275) and consists of, arches, posts, joiners, support bars and ties, frame and wind reinforcement and a gutter made from galvanized iron sheet. The coverage of the 2 facades is calculated until the side height, to open with a roll up (Rolled) driven by a motor (on-off). The roof is covered by double inflated polyethylene, UV stabilized, 450 microns, (insulated with fiberglass sheets) with antidrip effect the inner layer and life time up to 8 years, fixed by special rail & plastic clips for strong resistance and easy replacement. On the sides, there is a single polyethylene covering 9.6x2.2x4.0 m (type SERRA 192).

To ensure the required ventilation in one side of the structure, four sliding windows are placed with aluminum cover polycarbonate sheets. Along the opposite side, a closed metal duct is placed with air inlets and air adjustable blinds. In the middle of the conductor there is a metal collector, where the gas loads, through the metal duct will be driven. Within the collector, there are prefilters and bag filters for dust retention. Following that in the collector, there are inlets for integration of ozone generators. Finally, (before the chimney exit) a fan achieves air removal of the unit with 3 alternations per an hour.

The material undergone this 90-day procedure, will be carried outside the main composting unit and will go through a vibrating sieve. The sieve is tilted from 14 to 19 degrees and is based on a strong foundation by inserting springs. Below the sieve, there is a conveyor belt which leads the screened material in the repository.

Finally, a metal building dimensioning 11.0 m length, 9.4 m width, 5.0 m height and a 20% roof slope, in which houses the final composting product in the stage of its ripeness and storages it, will be constructed. Coverage of the entire building, ceiling, side and curtain walls will be made from colored trapezoidal metal sheet thickness 0.5 mm. A sliding door will also be constructed measuring 3x3 m in front of the building.

2.2. Scientific Methodology

There are three main activities in any composting facility which can produce odors: a) the receipt and storage of raw materials, b) leachate and recycled water and c) the composting process itself. Emissions from the composting comprise odors of a cocktail of chemicals, but particularly ammonia, amines, mercapatans and terpenes (Argyropoulou et al. 2005; Georgakakis et al. 2000; Mari et al. 2003; Heroux et al. 2004; Pagans et al. 2006; Manios, 2003; Triantafyllou et al. 2017; Kremalis et al. 2018). The main principles for preventing odor emissions are maintaining the process under aerobic conditions using good design, operation and process management.

The microbial ecology of a composting system is very complex and not fully understood. However, it is possible to influence the biochemistry of the composting process, and hence the production of odor-producing chemicals, by changing the physical and chemical environment in which the composting micro-organisms operate. Ensuring that the composting process is kept aerobic, it will make a major contribution towards preventing the formation of odorous chemicals such as hydrogen sulphide. This is probably the most important single step that an operator can take to prevent odor problems and it is, thus, far more effective to address odor at the design and planning stage of a new plant than to seek to abate nuisance odors retrospectively.

This selected technology of windrow composting under greenhouse with built-in odor control appears versatile enough to handle changes in feedstock type, quantity and seasonality. The exact nature and quantity of feedstock will change with the time of the year, in the local population and local industry. Changes in legislation may also produce significant changes in both the types of wastes and quantities of wastes available for composting. It is essential that the composting technology chosen is capable of coping with these changes. For example, the ability for modular expansion in reaction to increased feedstock quantities is a highly desirable aspect.

The primary releases of odors can be greatly reduced by ensuring that the composting process does not become anaerobic (Schlegelmilch et al. 2005). The research particularly focuses on defining exactly this aspect of the composting process in order to control odors. More specifically the research deals with (Tchobanoglous et al. 1993) :

2.2.1. Aeration

A minimum of 5-15% oxygen is normally recommended. The optimal level of aeration in any particular situation will depend upon the activity of the composting mixture. The supply of oxygen is also intimately related to the control of composting temperatures and the moisture of the composting waste.

Too great a supply of air may cool the compost excessively or cause the compost to dry out. An effective aeration system will balance all of these requirements and also take into account any costs associated with the supply of air (Rosenfeld et al. 2004).

2.2.2. Moisture

The optimum moisture for composting will depend very much upon the water holding capacity of the composting mixture. Typical levels are between 50% and 70%.

If the moisture level is too high for a particular mixture the void spaces may be filled with water and aeration compromised. Unacceptable levels of leachate may also be produced with associated odor and water pollution problems (Sawhney et al. 1994; Wershaw et al. 1995). Considerable quantities of nitrogen and other nutrients may be lost as leachate (Goldstein et al. 2005; Spencer et al. 2006; Schlegelmilch et al. 2005).

2.2.3. Temperature via aeration control

Temperature, along with the supply of oxygen, is one of the most important control parameters in composting. Each composting micro-organism has an optimum temperature at which it will operate effectively. Suitable temperatures vary from ambient (c. 25°C) up to 58-60°C, depending upon the micro-organism. If temperatures are too low, the activity of the micro-organisms will be reduced, while if temperatures are too high, the micro-organisms may be killed. The optimum temperature for composting will vary according to the stage of that the composting process, and the type of micro-organism which predominates during that stage. During the early stages of composting the optimum may be 45-55°C, while during later stages when activity has decreased the optimum will be lower.

2.2.4. Oxidation of gaseous emissions with O_3

A very efficient method for treating organic odors is applying advanced ozone oxidation (Gage, 2003). The main advantage is that where other odor control systems have problems with high humidity, the advanced ozone oxidation will be still able to effectively oxidise the odor compounds. In spite of claims to be able to treat ammonia odors, ozone will not oxidize ammonia (Rosenfeld et al. 2004).

Actually, composting will be produced via enclosed aerated windrows alone (typically aerated windrows are used after initial processing in rotary drums or with in- vessel containers); aeration of the windrows will be done via a machine using fresh air from the windows of the greenhouse and not through aeration trenches on the construction hall floor; deodorization will be performed via ozone generators inside the duct where emissions will be forced. The ozone generators to be used are designed for continuous operation in ambient air and utilize a unique US patented double dielectric barrier discharge technology to achieve ozone outputs of 15 g/h and 30 g/h. They are especially suited for odor removal applications requiring large scale air purification such as food processing plants, farm buildings housing livestock, chemical plants and sewage treatment plants. The generators are typically installed and connected to emission ducts of restaurants, kitchens, food (meat and fish) storages, and food processing industries.

3. Discussion and expected results

With the current research, an innovative commercial product is developed aiming to treat municipal bio-waste using solely enclosed aerated windrows in an odorless manner. The proposed "modular semi-open composting system" consists of aerated windrows housed in a greenhouse, where the mixture of dewatered sludge and by–products (manure, pruning, etc) are delivered.

This unique commercial product (unit) is adequate to be constructed and operate close to residential areas (e.g. industrial areas), since the odorous emissions, which are usually a nuisance to the surrounding residents, generating complaints and leading to a lack of acceptance of the facility, are eliminated. The "modular semi-open composting system" could be also addressed to the Balkan area and Southeastern Europe in general including markets, where it is applied to the population needs of cities larger than Athens (Greece), depending on the production of municipal sludge and other raw materials of these cities. The know-how gained by the enterprises, helps them to earn a considerable place in the aforementioned markets where they are already active, considering the corresponding EU legislation on waste treatment (Waste Framework Directive 2008/98/EC) and Bio-waste treatment and the upcoming review of the implementation of an entire Waste Framework Directive by the end of 2020.

The added value of the composting system is illustrated from the following points:

- This research will boost a development in the employment of environmental technologies of indeed major and growing importance, which is centralized composting facilities. This issue has occupied many communities (urban, rural and industrial). However, new facts and developments, primarily regarding technological issues, the legislative-regulatory framework (Landfill Directive) and socio-economic factors pose a continuous challenge for schemes and practices for more efficient and optimized waste management schemes and environmental technologies.
- The innovativeness of the whole facility lies in a) the simplicity of the applied composting system, b) the greenhouse design and c) the novel deodorization system used. It is a standard composting facility which incorporates the necessary technological and managerial means to better manage waste for producing optimal final product (compost) in a shorter time and eliminating odor release.
- The composting facility, which is developed, has a strong potential as regards replication and transferability. Specifically, it is modular, allowing for further expansion or easy adjustment where needed.

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