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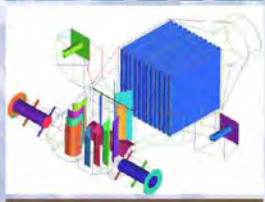

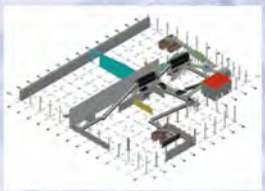

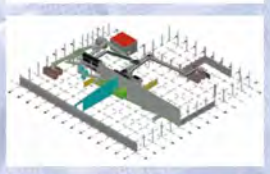

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Operational Experience in Composting Green Wastes Using the Example of Lodz

Bogdan Cieslikowski and Małgorzata B. Tomaszewska

1. Introduction

The assumptions of waste management in Poland are regulated in the National Plan of Waste Management. The most important obligations of the Republic of Poland, resulting from the membership of the European Union, put in the *National Environmental Policy for 2009 – 2012 and Its Outlook 2016*, are:

- 60 % recovery and minimum 55 % recycling of packaging materials until 31st December 2014;
- gradual limitation of dumped biodegrading municipal wastes, starting from 75 % of the quantity of such wastes produced in 1995 in 2010, through 50 % in 2013 to 35 % in 2020;
- collection of 25 % of used batteries and portable accumulators in 2012, to achieve 45 % collection level in 2016;
- annual collection of 4 kilograms of used household electronic equipment per 1 inhabitant.

Gradual limitation of the quantity of municipal wastes can be effected in a variety of ways. One of them is biological stabilization. The wastes can be fractioned in mechanical treatment and biological (oxygen and non-oxygen) stabilization processing (composting, intense oxygen biostabilization, fermentation), in order to reduce the content of organic matter in the waste, reduce its decay propensity, and to obtain the resultant stabilant waste for its storage safe for the environment. The processing is carried out in green waste composting plant installations. EU directives set requirements for the member states to further reduce the quantities of biodegradable wastes used for dumping, which is shown in the diagram below.

The municipal waste management in Łódź is carried out according to the *Waste Management Plan for the City of Łódź for 2009-2011 and Its Outlook 2012-2020*, specifying the main general and specific aims to be achieved in waste management.

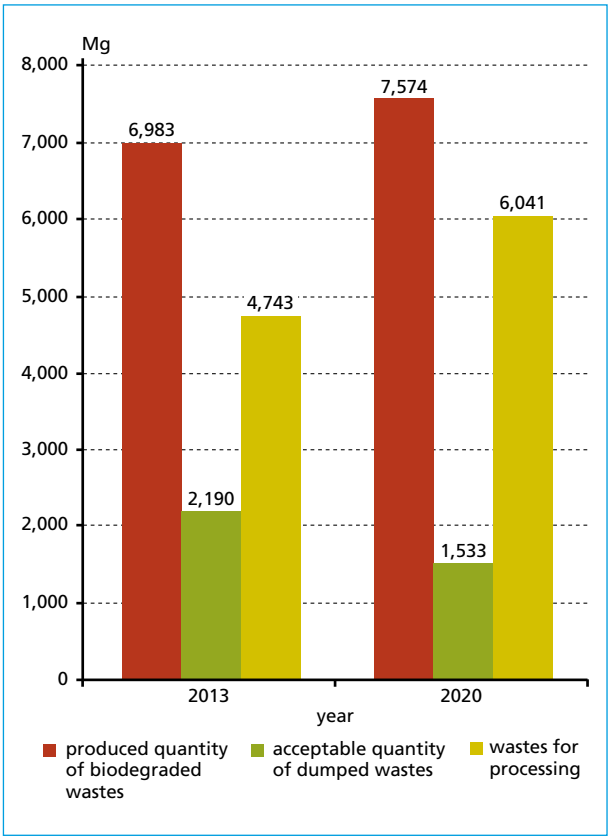

Figure 1:

Required reduction of dumping and the processing of biodegraded wastes

General aims

- Increased waste recovery, including the recovery of energy produced by wastes, in accordance with the environment protection requirements.
- Increased quantities of selectively collected large-size wastes and hazardous and building wastes of the municipal waste stream.
- Elimination of illegal waste dumping.
- Reduced quantities of wastes neutralized by dumping.

Specific aims

- Reduced quantities of biodegradable municipal wastes neutralized by dumping. According to the national waste management plan of 2006, the quantities accepted in Łódź, in comparison to quantities produced in 1995, are: not more than 75 % in 2010, not more than 50 % in 2013 and not more than 35 % in 2020.
- Reduced quantities of dumped wastes to maximum 85 % of wastes produced in 2014. The Plan assumes maximum use of the capacity of existing installations, including the composting plant and the development of the waste management system.

2. Description of the Composting Plant in Lodz

The City of Łódź built a pile composting plant in 1994, to process 7 thousand tons of plant wastes per year. The plant has been administered by a municipal unit – presently the Enterprise of Municipal Services in Łódź (Łódzki Zakład Usług Komunalnych). The Enterprise executes the municipal tasks of the City of Łódź, in regard to

- management of residential apartments and use premises,
- roads, streets, bridges, squares and organization of road traffic,
- waterworks and water supply, sewage system, maintenance of cleanliness and order and sanitary facilities, dumping grounds, neutralization of municipal wastes, heat supply,
- market places and market premises,
- municipal greens and trees,
- maintenance of entertainment grounds and sports facilities,
- municipal cemetaries.

The composting plant has been active until now. Wastes are composted by a natural method, in piles for 9 months. Wastes from market places, grass, branches, leaves and other wastes are composted. The compost is tested at the laboratory of the Chemical and Agricultural Station and at EKO - SERWIS Test Laboratory, to determine the possibilities of using it in agriculture and land recultivation. The ballast is transported out of the composting plant.

The dimensions of piles in the composting plant are the following: width of the pile base – 4.0-6.0 meters; height – 2.0-3.0 meters; pile length – 40.0 meters.

A layer of 0.3 meter of structural material is put at the bottom of a pile, covered with a layer of plant wastes (cabbage leaves, beetroot leaves, potato tubers, rotten fruit, grass and leaves from the city area, all decontaminated by manual segregation of the ballast). Such layers are put on one another and the top is covered with a layer of green wastes. Piles are built with a loading machine equipped with a scoop or a grasper. The material is dampened if necessary. Temperature is taken once a week. Dampening and temperature data are recorded on special forms.

Each pile is marked with a board specifying the dates of piling and subsequent inverting.

Two full tests are made for each ready compost lot every year, and two partial tests for each lot.

The following equipment is used in the composting plant:

- TIM SD-1000 grounding machine – 1 piece for the grounding of structural material.
- TIM TS 2000 compost screen.
- 515 C loading machine, use weight of 8,490 kg, scoop capacity – 1.53 m.

General rules of composting

Composting is the processing of organic wastes using microorganisms for the decomposition of organic substance. Natural processes are intensified by technical solutions optimizing biological transformation.

Optimum composting is determined by several factors:

- morphological composition of wastes;
- easily decomposed fraction;
- pH and the presence of toxic substances;
- activity of microorganisms;
- presence of organic compounds. water content.

Composting is affected by ambient temperature, intensity of aeration, composting process, facilities used to prepare wastes, processing time. Composting is a biogeochemical process, like mineralization, oxidation, reduction, transformation into soluble and volatile forms, absorption of organic substances. The final result is ripe compost containing considerable quantities of humus compounds.

The City of Łódź, as the first municipality in Poland, obtained non-returnable financial aid from EU Cohesion Fund to implement big infrastructural projects for the purpose of environment protection, by sewage treatment and waste management.

The project entitled *Municipal Waste Management in Łódź*, No. 2000/PL/16/P/PE/006, worth EUR 18.213 million of qualified costs, was implemented between 2001 and 2009, with 60 % support of the Cohesion Fund.

Within the project, a complex waste handling plant was built, consisting of municipal waste sorting and reloading station, ballast storage place; and the existing composting plant was reconstructed.

The reconstruction of the composting plant cost EUR 4.7 million. The new part of the plant is used for intense composting with M-U-T Kyberferm technique. The annual capacity of the plant 12 thousand tons.

Processing technique for intense composting

Composting can be divided into preparation, basic processing and final processing stages. The preparation stage covers the storage and landfilling of wastes, together with their balancing. It includes the weighing and registration of supplied wastes. Wastes are weighed on a truck balance at the entrance to the composting plant. Wastes are stored in bunkers, structural material (timber, bushes, straw) is stored separately.

Easily decomposed wastes are not stored longer than 24 hours because non-oxygen processes hinder the oxygen process of composting. Non-oxygen decomposition of wastes causes unpleasant odour and affects the environment. Sorting is a preparatory stage for composting, to separate the following ballast substances: ferrous and non-ferrous metals, glass, glass and ceramic cullet, plastics, rags and textiles, rubble etc. Sorting is carried out manually on a conveyor belt or mechanically, by separators and electromagnets. The preparation stage includes grounding. Grounding affects the basic processing stage, because microorganisms have more access to substrates if the area is bigger, contact with oxygen is also better and ripening can be made faster.

The composting of wastes is carried out under artificial and natural conditions. Artificial conditions are generated in closed facilities. Intense composting is static and dynamic. Closed bioreactors enable composting by periodical air suction plus moistening with the processing water. Processing air must be cleaned twice, in the tower washer and in the biological filter. The processing temperature in the bioreactors must be set so that optimum

operation for mesophil bacteria is enabled, to provide for correct decomposition of quickly decomposed organic substances. In such a case, the temperature of after-treatment air coming out into the washer is about 40 – 44 degrees centigrades, and the air humidity level exceeds 0.93, water is regularly decomposed in the composted layers. It enables aerobic processing and about 2.0 ratio of water to losses after roasting.

Final ripening

The ripening of fresh compost from bioreactors is carried out on a hardened surface under a roof. Piles laid for the final ripening are inverted with a specialist Topturn X53 inverter, equipped with a truck for the side laying of piles. The piles are inverted and dampened with a mobile winch with a hose feeding water to the inverter, which is important for better ripening in piles. Dampening depends on the degree of decomposition of organic substance. It is recommended to dose moisture when the compost is ripening, and to give it up at the last stage. The ripening time is about 9 – 10 weeks. The truck is used to move piles to the left or to the right, or to stock up two or three piles, to provide optimum conditions of the decomposition of hardly decomposed organic fraction and to improve better handling of the surface under the roof.

The final stage of ripening is the preparation of compost for customers. The compost is cleaned, packed and prepared for transport. A compost screen and a packing machine are used.

Use of compost

Ripe compost can be used for:

- fertilizing and improving soils in agriculture, forestry, gardening, fruit-growing and on green city area;
- improving the quality of roads and sports and entertainment facilities, also for shapening the landscape;
- recultivation of land, e.g. dumping grounds;
- filling biological filters.

Ripe compost is dark brown and absorbs sunbeams, increasing the temperature of soil. Compost absorbs a lot of water and its capacity can increase by 40 – 60 % more than the soils, because the compost gels swell.

Humus substances swell or shrink along with the changes of compost humidity, making the access of water and air easier. Compost can improve the structure and conditions of soil or fee fertilizing substances. After ploughing, compost and the soil are further decomposed into humus, to complete demineralization, being transformed into CO_2, NH_4 and other substances. The most important recipients of compost in urban areas are vegetable farms, users of community and home gardens, city green enterprises, agricultural farms. Compost fertilizing stimulates growing sugar beets and beetroots, spinach, lucerne, clover, tomatoes, potatoes; leguminous plants to a lesser degree.

The following wastes can be supplied to the composting plant:

- biological waste after dual segregation at their source, from residential areas;
- green wastes from vegetable and fruit markets and from city market places;
- structural material from gardening farms, park and lawn caretakers, individual suppliers, home gardens;

- 20-80 mm fraction organic wastes from the sorting plant of municipal wastes in Łódź (Lublinek suburb);
- sometimes, waste sediments from Łódź Group Sewage Plant (GOŚ ŁAM), in the form of condensed, stabilized and drained sediment;
- supplementary components can sometimes be used: food industry wastes like mill cake, (beet) pulps, bark, sawdust, animal hair, natural fibres.

The experience of the composting plant proves that not all above mentioned wastes can be used for compost fulfilling all legal requirements for organic fertilizers. The best results can be obtained by using green wastes.

According to the catalogue of wastes of the decree of 27th September 2001, issued by the Minister for Environment Protection, the following wastes can be composted in the Composting Plant:

Table 1: According to the catalogue of wastes of the decree of 27th September 2001, issued by the Minister for Environment Protection, the following wastes can be composted in the Composting Plant

Code	Type of waste
02	**Wastes from agriculture, fruit growing and food processing industry**
02 01 03	Waste plant mass
02 01 07	Wastes from forestry
02 03	**Wastes of plant processing – vegetables and fruits**
02 03 04	Inedible wastes
03 01	Wastes of wood processing
3 01 01	Wastes of cork and bark
19 05	**Wastes of oxygen decomposition of solid wastes (composting)**
19 05 01	Non-composted fractions of municipal and similar wastes
19 05 02	Non-fermented fractions of plant wastes
19 05 03	Substandard compost (unfit for further use)
19 08	**Wastes from waste sewage plant**
19 08 05	Unstabilized municipal waste sediments
19 12 12	Other wastes after mechanical waste processing
20 01	**Municipal wastes from selectively collected fractions**
20 01 08	Biodegradable kitchen wastes
20 02	**Wastes from gardens and parks**
20 02 01	Biodegraded wastes
20 03	**Other municipal wastes**
20 03 02	Wastes from market places

Accelerated composting

Fractions prepared for composting are loaded to bioreactors made of reinforced concrete, closed during intense aeration with special roller gates. After the intense ripening stage

is completed, fresh compost is removed from the bioreactors and laid in piles for further ripening. Optimum conditions of intense ripening in the bioreactors are provided, i.e.:

- average processing temperature – 42 degrees centigrades;
- duration of the cycle – 14 days;
- average daily addition of water – 1.4 cubic meters;
- handling of condensate (condensers, retention tanks) – about 5 cubic meters;
- conditioning of fresh air all year round.

The use of MUT – Kyberferm technology (based on a computer programme controlling aeration, dampening and temperature measurement) prevents non-oxygen processes in the composted material and the release of methane.

Description of the most important composting processes:

Aeration of the stock

The stock is aerated by pulling air down from the top, according to idle and active phases designed in 10 different cycles. The cycles are controlled automatically and based on the degree of compost ripening, i.e. the balancing of the decomposition of organic fraction. Air in the reinforced concrete bioreactors is brought from the inside of the production room which also means its ventilation at the same time. Each bioreactor is equipped with a perforated floor, enabling ventilation. The floors consist of stainless steel elements, on which loading machines can move. The elements have orifices enabling the flow of air. Air flowing through the composted mass provides oxygen and takes out heat produced during aeration. The heat is taken out in the form of saturated steam during alternate idle and active cycles. The temperature of processing air during normal operation is 42 – 46 degrees centigrades, the best condition for microorganisms and decomposition of organic substance. Air is led through pipelines laid in the floor. Resultant condensates are taken out of the installation through the same pipelines. A condensate collector is installed on the pipeline for each bioreactor. Condensate is carried through a collective pipeline to the processing water tank. A vertical pipeline with air controlled closing dampers is installed behind every condensate collector, to control the idle and active cycles. The quantity of processing air, pressure, temperature and relative humidity are measured at the vertical pipelines. The individual pipelines are combined in a collective pipeline leading to the main aeration ventilator. Fresh air brought into bioreactors is measured with sensors placed in a weather station. A bypass is used to accelerate ripening in winter time. By using appropriate control, hot air is passed by the bypass from a working bioreactor for 1 – 2 days to another bioreactor where the works begins.

Dampening of stock

Ripening process reduces humidity in the composted mass. To ensure optimum ripening and maximum organic fraction decomposition, the composted material must be dampened. Dampening is carried out with special pipelines and spray nozzles. A pump installed in the processing water tank supplies mechanically cleaned processing water (sometimes with the addition of fresh water) to water pipelines equipped with magnetic control valves. The water is carried to individual bioreactors from there. A flowmeter doses water as set by a control programme. Under normal conditions, one spraying a day is required. Water for dampening is carried through pipelines to spray nozzles and the whole surface of the stock is dampened.

Due to the active stage, enabling the suction of air from the bottom, regular *sucking in* of water into the composted stock is achieved. No *dried nests* are present in the composted material that could adversely affect the composting process and stop intense composting. Fresh compost with dry nests, taken out of the bioreactor for final ripening, begins to work and produces unpleasant odours. The quantity of added water depends on the degree of the decomposition of a composted fraction and it is determined separately for each bioreactor.

Cleaning of processing air

The M-U-T Kyberferm technology ensures that the processing air flowing out is saturated and has correct temperature. This minimizes the quantity of air passed to the atmosphere. The processing air is cleaned in two stages: wet cleaning in a washer and in a biological filter. The washer is manufactured as an absorption tower with vertical flow of cleaned air. The air is 100 % saturated with steam, due to water fog produced in the washer. Such a solution prevents the drying of the biological filter. Neutralizing chemical solutions are added to the washer to collect and precipitate ammonia compounds present in the processing air. The solution of sulphuric acid is added to circulating water producing the water fog. The acid is kept in a special tank. Sulphuric acid is brought to the washer with the control of a dosing pump and a system of pipelines. Sediment emerging during the washer operation is pumped into a concrete tank and used as an agricultural fertilizer.

The biological filter, removing unpleasant odours of the processing air, is made as a concrete low load surface construction. the cleaned air is distributed in the biofilter with pipelines laid in canals and covered with perforated plates.

The loading machine is moved on the plates, which allows trouble-free exchange of the filtering compost stock. The exchange cycles of the stock in the biofilter depends on the chemical loads of the material. Any exchanged fraction of the material is tested for its usability as compost. It can be used on dumping grounds, if it contains chemical compounds disenabling its agricultural use. The exchange of the stock fraction in the biofilter should be made every 2 years or more often, when the stock has been used up. The filtering stock is a mixture of compost, structural material and bark. A big area of the filter ensures its low surface load. The washer and the biofilter guarantee high degree of cleaning and low release of unpleasant odours. The most important function of the washer is the reduction of odours of the processing air, which is likely in the composting of sediments.

Sulphuric acid must be added then, and the side effect of the cleaning is ammonium sulphate. Ammonium sulphate is removed by waste removing trucks. Sulphuric acid need not be added in the composting of biological and green wastes.

Controllling of the composting process

The controlling of ripening process is carried out with a processor, in accordance with the patented M-U-T-Kyberferm technology. Each bioreactor is controlled separately. On the basis of measurements of the quantity of processing air, its pressure, temperature and humidity, parameters and humidity of the stock material, the processor determines the balance of unloading the easily decomposed organic part.

This is the basis of the process control, addition of water and air and setting the idle and active cycles. The control programme is flexible and can be adjusted to the higienization of the stock at higher temperatures (e.g. 60 degrees centigrade maintained for 4 days). This is enabled by suction cycle based on the stock temperature. The temperature control is effected by a temperature gauge connected to the processor. In multi-stage loading, unpleasant odours can be prevented with partial airing. Before composting, the weight and the quantity

of wet stock material are coded in the computer programme. The starting phase lasts for two days and is changed into automatic control. All processes in individual bioreactors are displayed on a screen. The process can be controlled and corrected in the programme. The decomposition of the stock fraction is shown on the screen and printed as a document.

One biofilter of 205 square meters area works for 10 bioreactors.

The bioreactors are equipped with:

- perforated plates made of high grade steel, condensate tanks, low removable doors, segment thermometers;
- aeration system with pipelines, hatches, main ventilator, processing air washer;
- chemical substance dosing station, auxiliary ventilator in the washer, air pipelines;
- *lock-out* system, hatches, condensate taking out and dampening system, pipelines, dampening pump, compressor station and fresh air pipelines, electric installation control.
- Installed power – about 70 KW, consumption – 54 kW.
- Power voltage – 3 • 400 V/415 V, 50 Hz.
- Control voltage – 220 V AC.
- Security – neutral earthing.
- control system with software, modem connections, cables.
- 1 bioreaktor is loaded per 1 day.

Scope of equipment

10 stationary bioreactors made of reinforced concrete operate for the composting plant in Łódź, of 12,000 tons annual capacity. One bioreactor is loaded and one bioreactor is unloaded every day.

The composting time in a bioreactor is 14 days (10 working days).

Bioreactor dimensions:

- width – 4.0 m,
- length – 9.5 m,
- height – 4.0 m.

The bioreactors are constructed as a big box of reinforced concrete, in which 10 bioreactors are separated. The bioreactors are put together in the common production room for the preparation of the stock and composting.

3. Final ripening

After intense composting in bioreactors, the compost is carried in a loading machine to the ripening field in piles, under a steel roof construction. The construction is designed for the final compost ripening. The dimensions of the roofing constructions are: width – 28.0 meters, length – 2 • 36 meters + 15 meters = 87 meters, height – 6 meters. The flooring is sealed and hardened, with drain connection. Fresh compost is dumped from the loading machine and laid in piles. The strength of the flooring is satisfactory to carry heavy loading machines and compost inverters.

The Topturn X53 inverter inverts compost, forming longitudinal piles of trapezoidal cross section. The dimensions of such a pile are: width of the base – 5,300 millimeters, pile height up to 2,200 millimeters. Piles are inverted again, usually once a week, and dampened during the inverting. Their capacity decreases during ripening. A truck is used by the inverter to form new piles – on the left and on the right side of a liquidated pile. The inverter is equipped with dampening installation, including an extension arm, a winch, a spiral hose and connections. The dampening water is water taken back from the tank, sometimes with the addition of fresh water. Scoop valves are installed near the roofing construction.

It is recommended to reduce dampening along with the ripening of compost, and to give it up during the last stage of decomposition.

The recommended ripening period, including the final ripening, is 9-10 weeks.

The inverter has a tearing board for the bottom tightened layer of compost, to prevent its decaying. After 4 weeks the compost will be screened and left for further ripening for 6 weeks, dampened and inverted if necessary.

A composting product is an organic fertilizer named *Humussy* (*Próchniaczek* in Polish) accepted for sale by the Minister of Agriculture and Agricultural Development, decision No. 186/07 of 2nd July 2008, amended by decision No. 186a/09 of 9th January 2009, issued for the Enterprise of Municipal Services in Łódź.

The decision established the following quality requirements for the fertilizer:

- total nitrogen content – at least 0.5 % (m/m)
- content of potassium, as calculated into K_2O – at least 0.3 % (m/m)
- content of organic substance in dry mass – at least 30 % (m/m)

Systematic tests of the compost are made by EKO- SERVICE in Łódź (as regards the sanitary condition) and the District Chemical and Agricultural Station in Łódź (as regards microcomponents and heavy metals).

Tests are also made for the presence of parasite ovi, Salmonella type bacteria, pH reaction in H_2O, content of dry mass, organic substance, organic C, N, P_2O_5, K_2O, Pb, Cd, Cu, Cr, Zn, Hg . Samples of wastes from a control well on the area of the composting plant are tested regularly.

Average values of all determined parameters are within the acceptable standard limits.

Composting wastes coded as 19 05 03, the so-called *substandard compost*, are passed to recultivate the waste dumping ground at Kasprowicza street in Łódź (Nowosolna dumping grounds).

The quantity of green wastes delivered to the composting plant is increasing. One of the reasons is the development of educational programmes by the City of Łódź, aimed at teaching its inhabitants correct behaviour with wastes. A programme named *Leaf* is taught in autumn. The inhabitants of Łódź can accumulate leaves and grass from their private grounds free of charge at different places of the city, and they are transported to the composting plant. Green wastes can be delivered free of charge by the inhabitants directly to the composting plant, where even 5 sacks of green wastes per 1 inhabitant can be left. Green wastes can also be delivered free of charge to the Voluntary Waste Delivery Centre at 1 Zamiejska street in Łódź.

The quantity of compost produced since the start-up of the bioreactor composting plant grew rapidly between 2006 and 2008; it has been on a stable level of about 11 thousand tons per year since.

Table 2: Sale of compost

Year	Sale of compost tons
2005	1,628,28
2006	2,098,51
2007	3,262,52
2008	5,053,71
2009	4,794,95
2010	5,750,11

Organic fertilizer can be sold in loose form or in 20 kilogram sacks. The sale of organic fertilizer has been growing.

The sale of the organic fertilizer is enhanced by promotional actions, organized to encourage potential buyers. The promotion includes information leaflets, radio spots, also compost samples distributed during fairs for community garden users. In future, to ensure the sales of all produced compost, it is planned to enlarge the use of compost in city green facilities and in road dividing lawns. The system of municipal waste management will be developed to reduce the quantity of biodegradable wastes produced in Łódź.

A feasibility study of the Project *Municipal Waste Management in Łódź – Part II* indicates the necessity of completing the existing installations. The installation of thermal processing of municipal wastes should be added, of the annual capacity of 200 thousand tons. The City plans to finance the installation with money obtained from the Cohesion Fund of the Infrastructure and Environment Operative Programme. The installation will reduce the dumping of biodegradable wastes effectively.

4. Summary

Due to the technology of composting in bioreactors made of reinforced concrete, the composting is three times shorter than the traditional pile composting was.

The quality of produced organic fertilizer was improved, which was confirmed with the decision of 2007, issued by the Minister of Agriculture and Agricultural Development, permitting the marketing of a new fertilizer named *Humussy*.

Further educational and environmental actions and programmes are necessary to propagate the selective collection of wastes for the composting plant.

Further actions are necessary for the propagation of organic fertilizer produced in the composting plant, to be used in city green areas and in gardening.

A thermal installation of processing municipal wastes is needed in the system of waste management in Łódź to reduce the dumping of biodegradable wastes.

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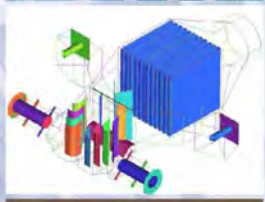

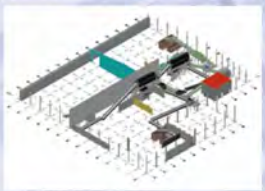

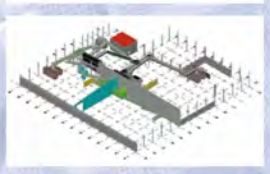

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