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Detailed information on energy research

Reducing energy use from waste treatment

Energy-efficient purification of exhaust air from mechanical-biological waste treatment plants

BINE Information Service

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Residual household waste lands in the grey waste container. It is either thermally exploited in a waste incineration plant, or it is taken to a plant for mechanical-biological waste treatment. Here, the waste is sorted: Energy-rich parts are used for energy, while metals are recycled. The residues are treated in rotting boxes before disposal on landfills. The exhaust air from the process has to be purified. This takes up almost two-thirds of the energy consumption of waste treatment plants. Researchers, in collaboration with their project partners, have developed a more efficient method.

For unavoidable waste, the German Closed Substance Cycle and Waste Management Act specifies the target hierarchy of prevention, preparing for re-use, recycling, other recovery and disposal. The mechanical-biological waste treatment (MBT) plants also operate according to this principle. There, the usable parts are first removed. The residues are then taken to the rotting boxes. In the boxes, the organically degradable portions are oxidised through aerobic microbiological conversion processes. The residues which cannot be used must be stabilised in this way before it can be stored in a landfill site. This pre-treatment prevents relevant emissions of methane and other climate-relevant gases from occurring.
Researchers at the Department of Processing and Recycling at the RWTH Aachen University and the Institute for Sanitary Engineering, Water Quality and Solid Waste Management at the University of Stuttgart are studying how the amount of energy required for mechanical-biological waste treatment, in particular for biological process management and the subsequent exhaust air treatment, can be reduced. As project manager Erdogan Coskun explains, “MBT processes always

Mechanical-biological waste treatment

In Germany, around 45 mechanical-biological waste treatment plants (MBT) process around five million tonnes of mixed household waste every year. Currently, there are about 330 plants operating in the EU, with a total capacity of 33 million tonnes per year. Experts predict that by the end of this decade, around 440 plants will be in operation, with around 46 million tonnes per year.
Around 40 % of the quantity of domestic waste created every year is pre-treated before further use or deposition in landfill sites in MBT plants. The exhaust air which is created during stabilisation of the waste which is rich in organic matter through aerobic treatment must be purified in order to meet the valid emission threshold values. According to the 30th German Federal Immission Control Act, limits to the total carbon content of 55 grams per tonne of waste input and 20 to 40 milligrams per m³ of exhaust air must be observed.
In order to achieve these values, the exhaust air from the MBT is usually purified using regenerative thermal oxidation units (RTO). During the post-combustion, the organic pollutants contained are oxidised up to produce carbon dioxide. This process requires so-called supporting gas combustion. The fluctuating and comparatively low carbon load in the exhaust air is not sufficient on a permanent basis for autothermic oxidation.

include a biological treatment stage under aerobic conditions, which is designed as an intensive and/or subsequent rotting. For every ton of waste treated, an exhaust air flow of up to 8,000 m³ is created, which is charged among other things with volatile organic carbon compounds." This exhaust air must be collected and purified in order to be able to uphold emission threshold values. The exhaust air is purified by using biofilters, washers and regenerative thermal oxidation units (RTO). However, since RTO units are not designed for the exhaust air from MBT plants, their use in MBT is only possible when a considerable amount of energy expenditure is involved. Around 100 kWh is needed for every ton of waste, of which around 65 % is used for exhaust air treatment. The increased energy consumption for exhaust air treatment can be traced back to the use of supporting gas (e.g. natural gas, biogas) in the RTO units.

Biological stabilisation of the material in the rotting box

In order to conduct practical tests with the MBT, researchers are working with the district of Aurich in Großefehn. Here, the specific energy consumption for the treatment of household waste is around 80 kWh per ton. At the test plant, two-thirds of this amount alone are accounted for by the need for supporting gas in the RTO. The researchers are developing measures for improving energy efficiency along the entire process chain, from the mechanical to the biological waste treatment through to the purification of the exhaust air. Their aim is to reduce the specific energy consumption by around a quarter to 60 kWh per ton. Transferred to all MBT plants in Germany, this amounts to an energy saving potential of over 100 GWh.
In the biological treatment stage during the aerobic degradation process of the organic constituents, a clear concentration peak of ethanol occurs in the exhaust air at the beginning of the process (Fig. 3). After four days, nitrogen compounds are predominantly degraded, after which the ammonia concentration in the exhaust air increases considerably. After the material is transferred to the box, ammonia and carbon compounds are released at increased levels. During the rotting process, the organic load in the exhaust air consistently decreases. During the first seven days, over 80 % of the carbon load is emitted, with even less than one per cent during the final two weeks of the rotting phase.

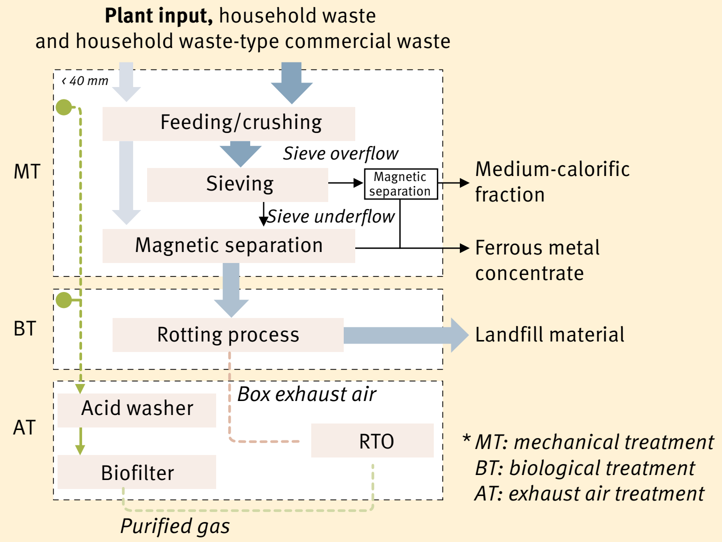

Fig. 1 *Process flow chart at the MBT Großefehn*

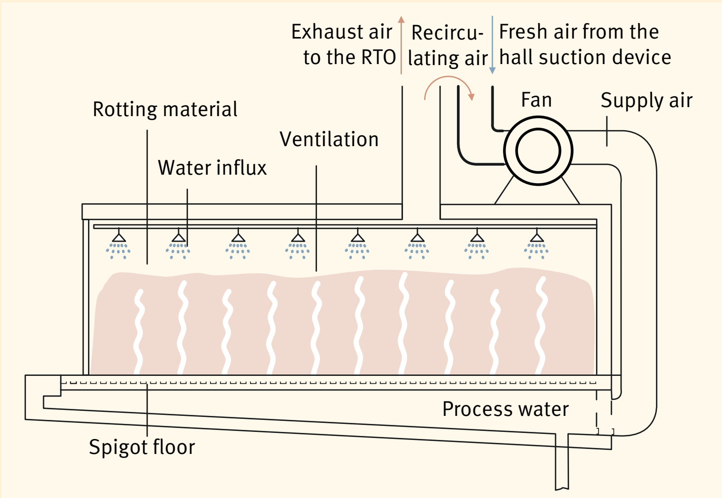

Fig. 2 *Cross-section of the rotting box at the MBT Großefehn*

Exhaust air purification through regenerative thermal oxidation (RTO)

Over half of the 45 MBT plants in Germany also use biofilter systems in addition to RTO technology. These systems make it possible to treat exhaust air flows with lower levels of contamination, e.g. from the mechanical treatment, comparatively easily and in a less energy-intensive way. Thanks to cycle management of exhaust air flows, the exhaust air volume to be treated can be reduced. As a result, the specific energy content of the exhaust air increases at the same time. The RTO therefore needs less external energy for auxiliary combustion. The researchers are using the MBT in Großefehn in the Aurich district as an example to study how such a plant

Rotting days [d]	*0–7*	*8–28*	*29–42*	*0–42*
			Middle load [g/h]	*Load [g/t]*
Components				
Nitrous oxide	*7.0*	*7.6*	*8.2*	*22.7*
Ammonia	*154.1*	*554.0*	*112.6*	*925.2*
Methane	*41.1*	*36.7*	*12.3*	*80.5*
Acetic acid	*46.5*	*6.2*	*5.1*	*34.4*
Methanol	*70.2*	*12.0*	*9.9*	*58.0*
Heptane	*138.1*	*29.4*	*5.1*	*104.8*
2-butanone	*258.5*	*42.85*	*36.5*	*211.9*
Ethanol	*757.0*	*32.2*	*9.0*	*383.1*
Total carbon	***645.7***	***46.5***	***0.4***	***343.1***

Fig. 3 *Development of the middle exhaust air load (in g per hour) from a rotting box (with 385 t input) during the course of the six-week rotting phase. The load occurring per tonne of rotting material is shown highlighted in blue.*

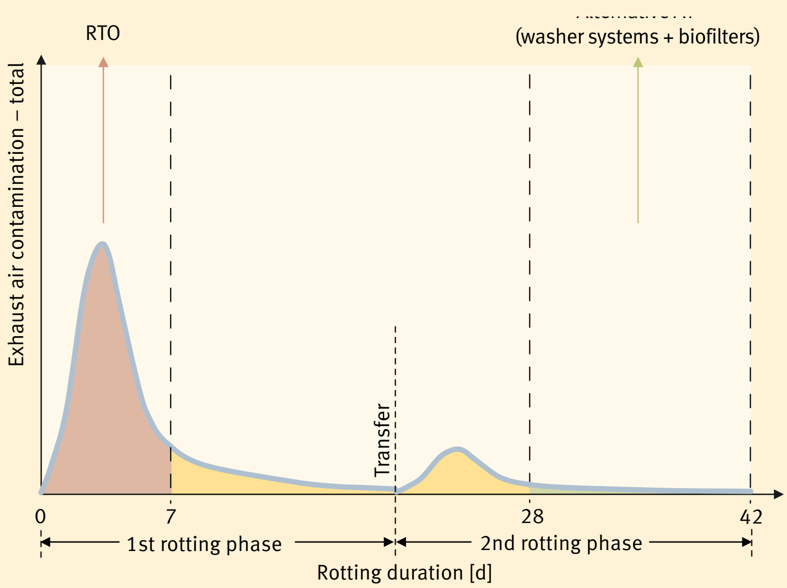

Fig. 4 *Carbon concentrations in the exhaust air during the course of the rotting process: initially exhaust air treatment using RTO, in the intermediate phase, depending on contamination, RTO and/or washers and biofilters; these are sufficient in the end phase.*

can be operated more efficiently. For this purpose, optimisation potential is being investigated in the mechanical and biological treatment stage. Additionally, in an alternative exhaust air management system, the exhaust air from the biological treatment is divided according to contamination grades. With the exhaust air concept at the MBT in Großefehn used to date, a part of the exhaust air flow from the hall suction device with low contamination from the mechanical treatment is used for ventilation in the biological treatment. The excess exhaust air flow from the mechanical treatment is conveyed to biofilter systems. The entire exhaust air flow from the biological treatment stage is treated using RTO.

For the more efficient operation of the plant, the researchers examined among other things what measures they could take to reduce the exhaust air volume flow to the RTO and therefore the energy consumption for the exhaust air treatment. They aim to achieve this by dividing up the exhaust air flows from the BT according to degree of contamination and treating them separately. For this selective recording of the exhaust air flows, they are installing a new exhaust air collection pipe, which in each case captures the exhaust air from all reactors of a block of 15 boxes in total with a medium and low total carbon load.

In a project completed in mid-2015, it was possible to demonstrate that an enlarged sieve opening width in the mechanical treatment leads to improved ventilation behaviour in the biological treatment. As a result, less energy is required for ventilation. The material influx into the rotting box was changed, and rougher material could be introduced below and finer material above. Depending on the method of operation and rotting stage, the quantity and contamination of the exhaust air change with time (Fig. 3).

Within the six-week rot, three phases with strongly differing concentrations can be seen. The methods for purifying the exhaust air can be selected accordingly. The highly contaminated exhaust air in the initial phase (the first 7 days) is treated using RTO, the medium-contaminated exhaust air (up to day 28) is treated either with RTO or with a combination of filling body, nozzle floor washers and biofilters, while the exhaust air with low contamination between days 28 and 42 is also treated with a combination of washer systems and biofilters (Fig. 4).

Dividing up exhaust air flows for more efficient treatment

If only the exhaust air flows with a high level of contamination are conveyed to the RTO, the exhaust air quantity in the RTO to be treated is reduced; at the same time, the carbon content in the remaining volume flow increases: as a result, less supporting gas is needed to operate the RTO.

The aim is to achieve the highest and most constant carbon concentration possible in the exhaust air.

In order to throttle the exhaust air flow to the RTO, the researchers divide the exhaust air flows from the biological treatment stage according to their degree of contamination and convey them to separate treatment methods. For this purpose, they are constructing a new exhaust air collection pipe, which can capture the exhaust air from an entire box block. The process control system can, thanks to a newly-developed regulation algorithm, convey the exhaust air flows to the respective collection pipe using automated vents. This exhaust air management is used with 15 rotting boxes out of a total of 30. The exhaust air with medium to low contamination is purified using the alternative exhaust air treatment.

They are also transferring the MBT process to a model. On the basis of the results, guidelines on energy-efficient exhaust air treatment in MBT plants are being produced which can be used in other plants.

Reference plant in Großefehn

The MBT in Großefehn has a treatment capacity of around 60,000 tonnes per year. The plant is divided into mechanical and biological treatment, as well as an exhaust air treatment plant. First, the waste mixture is separated into different fractions: The light fraction, which has a high calorific value, can substitute fossil fuels in power stations. Further material flows such as metals are used as raw materials. The fraction of the domestic waste which is rich in organic matter is subjected to a six-week aerobic treatment in 30 rotting boxes during the biological treatment stage of the MBT in Großefehn. The final product of the biological treatment can then be deposited in landfill sites. The exhaust air from the plant is purified using biofilters, washers and a regenerative thermal oxidation plant (RTO).

More efficient treatment plants

Waste management has increasingly moved away from a focus on removal of waste towards recycling management with high proportions of recycling. In this way, its energy balance has also improved due to the recovery and use of energy-intensive valuable materials.

Old paper, old glass, packaging and organic waste in particular are increasingly being collected separately and re-used as valuable materials. This saves on raw materials, reduces the use of primary energy and thus also decreases CO_2 emissions. A further contribution is the use of carbon-rich waste fractions as substitute fuel, for example for cement plants and industrial operations.

Through the development of improved treatment processes and plants, operators can further increase the level of energy efficiency in waste management.

Composting plants process the organic waste from the bio-waste container. They consume energy in particular for the mechanical ventilation during the composting process. A new method makes it possible to also generate energy in the plants. For this purpose, with the involvement of researchers from Aachen, an innovative combination of composting and digestion has been developed: First, a screw press separates organic matter from the pre-treated organic waste. This is then used in the biogas plant to generate energy. The remaining solid fraction is composted. As a result of this pre-treatment and separation, the plants can process more material with their existing systems. At the same time, the specific energy consumption per tonne of organic waste is reduced by 10 to 15 %.

The purification of municipal wastewater also requires a large amount of energy. Currently, sewage treatment plants account for almost a third of electricity costs for municipal infrastructures. Around one per cent of electricity consumption in Europe is used to operate them. In the European research project Powerstep, 15 partners are working to change this situation. The research institutes and companies aim to to convert sewage treatment plants which until now still require energy for purifying wastewater, and to turn them into energy generators. The researchers predict that the amount of electricity that can be generated is the equivalent of up to 12 large power stations, if all the European sewage treatment plants are converted and the chemical energy potential of 87,000 GWh per year can be utilised.

Project participants

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Links and literature

- RWTH Aachen, Institut für Aufbereitung und Recycling | www.ifa.rwth-aachen.de
- MKW Großefehn | www.mkw-landkreis-aurich.de/index.php
- Plasmaair AG | www.plasmaair.de
- University of Stuttgart, Institute for Sanitary Engineering, Water Quality and Solid Waste Management | www.iswa.uni-stuttgart.de
- Arbeitsgemeinschaft Stoffspezifische Abfallbehandlung (ASA) e. V. | www.asa-ev.de
- Projekt Powerstep | www.powerstep.eu

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- Organic waste: combining compost and biogas. BINE-Projektinfo 17/2014
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