Mechanical-Biological Treatment Plant in Hanover, Germany
– Experience in Mechanical Processing, Anaerobic Digestion and Refuse Derived Fuel Quality –

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The Hanover mechanical-biological treatment (MBT) plant can look back on 15 years of operator´s experience. The mechanical treatment facility has been working largely without any issues due to the simple technique and the comfortable redundancy and design. The biological treatment facility faces growing damage due to ageing of materials, which is accelerated by microbiological attack, and corrosive and abrasive ingredients in the residual waste. Comprehensive maintenance, renovation and replacement measures are planned.

The cost-effectiveness of MBT technology compared to the incineration of waste is on trial. Therefore, in Hanover changing treatment concepts are discussed. The demand for replacement of primary energy carrier by energy-intensive industrial plants (e.g. paper mills, cement kiln) is growing. One option of MBT is the intensified production of refuse derived fuel (RDF) and less deposit to landfill. Another is the conversion from residual waste treatment to biowaste treatment. MBT with fermentation stage give a positive contribution to the carbon footprint, mainly due to the utilization of biogas. MBT technology provides an important contribution to the resource economy.

1. Introduction

Since 2012, the amendment to the federal waste legislation and the life-cycle resource management law (Kreislaufwirtschaftsgesetz, KrWG 2012) is the legal basis of waste management action in Germany. The law requests in particular the promotion of recycling and other recovery of waste. According to a EU waste directive from 2010 a 5-stage waste hierarchy has been implemented into national law: Prevention > Preparation for Re-use > Recycling > Other Recovery > Disposal. Goal is also to minimize the amount of waste at the end of the waste management cascade, which is still today usually landfilling.

Since 2005, municipal solid waste has to be pre-treated prior to landfilling. There are generally two technologies available: incineration and mechanical-biological treatment (MBT). In Germany, plants with MBT technology are primarily operated by local authorities, while refuse incineration plants (RIP) are generally organized by private companies or as a cooperation between municipal and private operators. MBT is used predominantly for the preparation and pre-treatment of residual waste. Residual waste remains after the separate collection of recyclables, such as paper, glass, scrap metal, lightweight packaging and bio/green waste from municipal solid waste.

Due to the fact that there is no pure separation of the mentioned groups, residual waste still contains appropriately proportionate amounts of recyclable materials similar to the raw material. Due to its selective processing technology, the MBT process provides a flexible material flow management, i.e. it can generate recyclables by corresponding technical adjustments and significantly reduce the amount of waste to landfill.

Bio-waste as *waste for recovery* is collected separately in most German local and regional authorities and is composted. The German law KrWG calls nationwide until 2015 for the introduction of the biowaste bin, whereas organic waste digestion is a forward-looking project. Beyond that, the separation of *recyclables* (the german *Wertstoffe*) shall be anchored legally. It is assumed that further waste quantities and components will be deprived of residual waste.

MBT is usually carried out with two essential steps: the waste is processed first mechanically and then biologically (in detail see also DWA M388, 2014). In addition to the biological stabilization of organic matter, an anaerobic process produces high-calorific biogas for energy production. The digestate is treated in a way for example by drying (biostabilization), that a further use, e.g. as a refuse derived fuel is possible or by further aerobic maturation (inertization) with subsequent landfilling.

In foreseeable future no new MBT plants will be built in Germany due to sufficient existing waste treatment capacities. However, most MBT have been in operation for at least 10 years, so that now comprehensive measures are required for renovation, alteration or additional technical installation. Also, a paradigm shift is taking place: while the treatment goal was originally oriented to fulfilling the deposit criteria for landfill, recent efforts are a maximum material yield, i.e. at the end is not a deposit, but a refuse derived fuel (RDF) or even solid recovered fuel (SRF).

2. Waste management concept of the Hanover region

The Hanover region, home to 1.1 million inhabitants in an area covering about 2,300 km², is one of the largest municipal associations in Germany. The waste management association of Hanover Region (Zweckverband Abfallwirtschaft Region Hanover – AHA) is the public organized waste management authority. With 1,900 employees, it carries out the collection of waste and recyclables, and is running various waste amenity sites, composting facilities, a MBT plant and three landfill sites as well as street cleaning and winter service for the city of Hanover.

In the Hanover region, around 750,000 tons of waste are generated per year. After separation to different fractions of recyclables (glass, paper, biowaste and green waste, lightweight packaging, old wood, construction waste, electronic scrap etc.) around 300,000 tons remain as residual waste for disposal (Figure 1). This includes household waste as well as commercial and bulky waste. Biowaste and green waste are collected separately, treated in composting plants and put on market as quality compost for agriculture or gardening.

The residual waste, optimized according to origin, calorific value and transport distance, is forwarded to various treatment plants. Several quotas in external incineration plants and the aha's own MBT plant are available for residual waste treatment. About 66 percent of Hanover´s residual waste is taken to thermal recovery, after mechanical pretreatment.

The Hanover MBT plant is approved for an annual capacity of 200,000 tons. The mechanical waste treatment plant launched its operation in 2000, the downstream biological waste treatment plant has been put into operation in 2005. About 49,000 tons resp. 25 percent of the input remain to landfill after MBT.

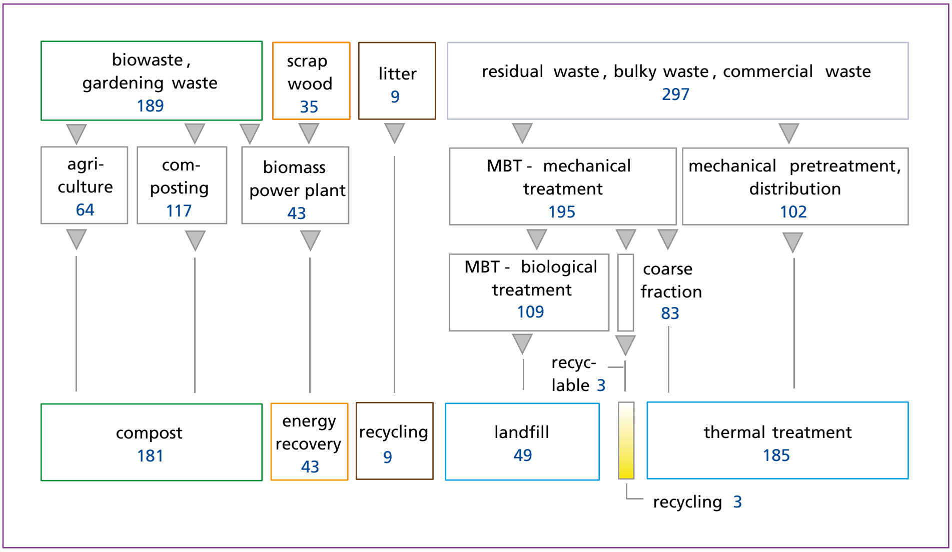

Figure 1: Amount and treatment pathways of organic and residual waste in the Hanover region; in thousand tons (as of 2014)

Figure 2:

Hanover waste treatment centre: MBT plant (background), bio-waste waste composting facility (centre), refuse incineration plant of the EEW Hanover GmbH (in the front)

3. MBT Hanover – approach

3.1. Mechanical treatment

In the mechanical processing step, the waste is being conditioned for subsequent treatment steps with simple shredding and screening technology, that means separation of waste components into materially or energetically usable fractions (such as metals, RDF).

The flow chart in Figure 3 illustrates the treatment procedure: collection vehicles unload the residual waste in shallow bunkers. From there, grabber excavators place the waste in shredders. Impurities are removed. Magnetic separators extract usable ferrous metals. Screening drums (mesh size 60mm) separate the high-calorific coarse fraction (containing any residuals of paper, wood or plastics) from the fine fraction which contains most of the organic material suitable for fermentation. On average, 55 percent are separated from the waste input as fine fraction. The high-calorific coarse fraction is used thermally in the nearby incineration plant. A further screening (mesh size 15mm) and a subsequent airstream separation of the fraction 15 to 60mm serve as preparation prior to fermentation. The air separation removes the inert heavy materials (stones, glass, sand) that are unsuitable for fermentation. From this waste stream, non-ferrous metals are separated, then it is fed to maturation directly.

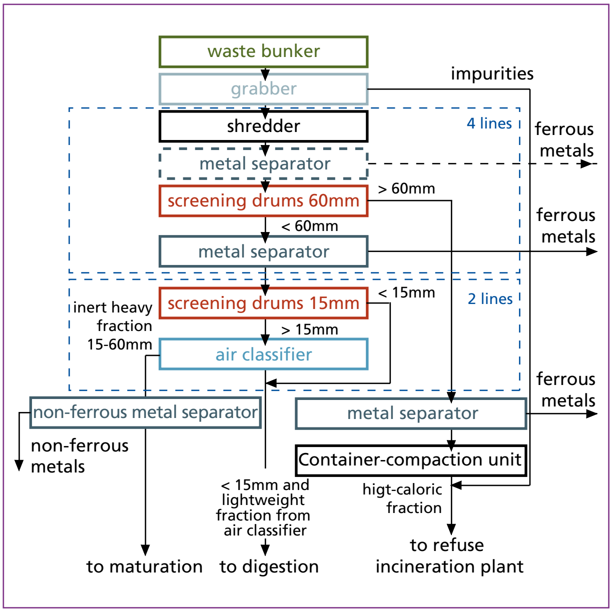

Figure 3:

Process flow chart of mechanical waste treatment facility

3.2. Biological treatment

The organically-enriched fine fraction is further treated in the biological stage. Here, biodegradable substances are reduced and humificated, respectively. Biological treatment involves three stages: fermentation, aeration, and maturation. The main components of the system are illustrated in Figure 4.

The light fraction resulting from air separation enters the fermentation process. Anaerobic digestion takes place according to the *VALORGA* procedure, as a so-called dry fermentation (dry matter content about 30 percent) and in the mesophilic temperature range (35 to 42°C). The waste is continuously fed into and taken off three fermentation containers (each 30m high, 4,200m^3 of volume). The anaerobic process has a nominal duration of about 20 days. The digestate then undergoes a three-stage dehydration process (screw presses, vibration screens, centrifuges) before being sent for aeration. Here, the digestate is intensively ventilated approximately 48 hours, primarily in order to stripping ammonia. Then the aerobic maturation takes another six weeks in table windrows, suction-ventilated, and turned once a week automatically by a stack turning machine. The resulting deposit will be transported by truck to landfill.

Exhaust air from MBT might be highly loaded with organic substances, ammonia and strong odor. To comply an elaborate air cleaning a treatment system is required consisting of acid srubbers and regenerative thermal oxidation (RTO). In Hanover this device has a total capacity of 122,000m^3/h. Threshold values for exhaust air from MBT to the atmosphere are listed in Germany´s 30th regulation to the Federal Immission Control Act (30. BImSchV). Acid scrubbers have great importance in the treatment of digestate, due to the fact that high emissions of ammonia occur during the aeration period.

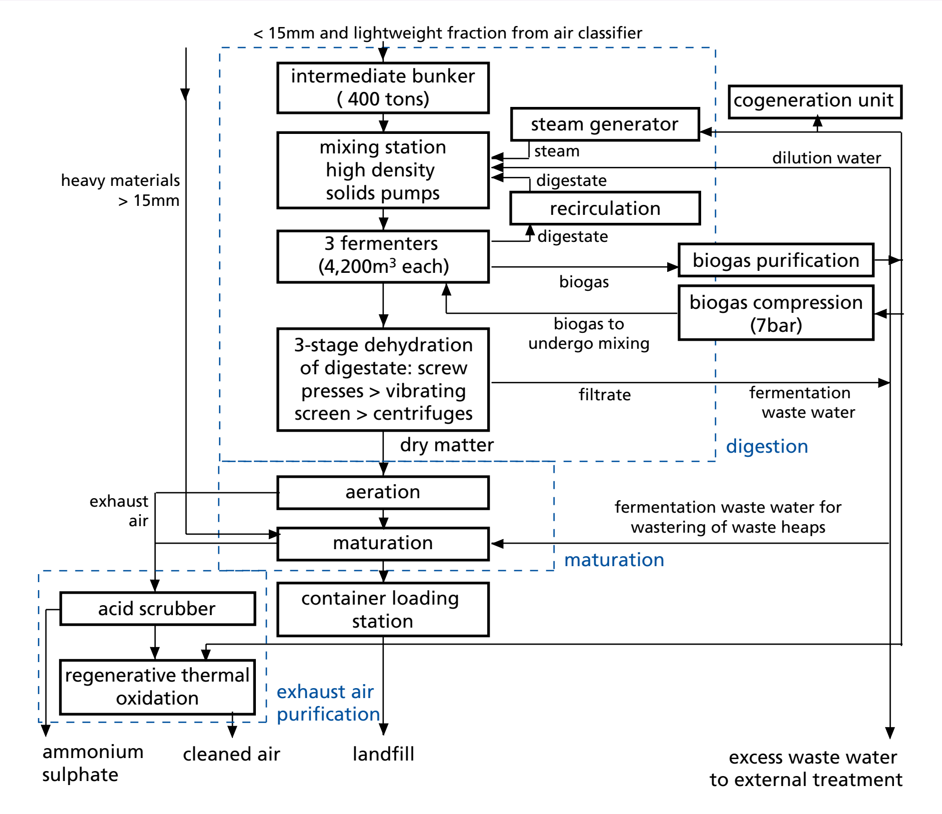

Figure 4: Process flow chart of biological waste treatment facility

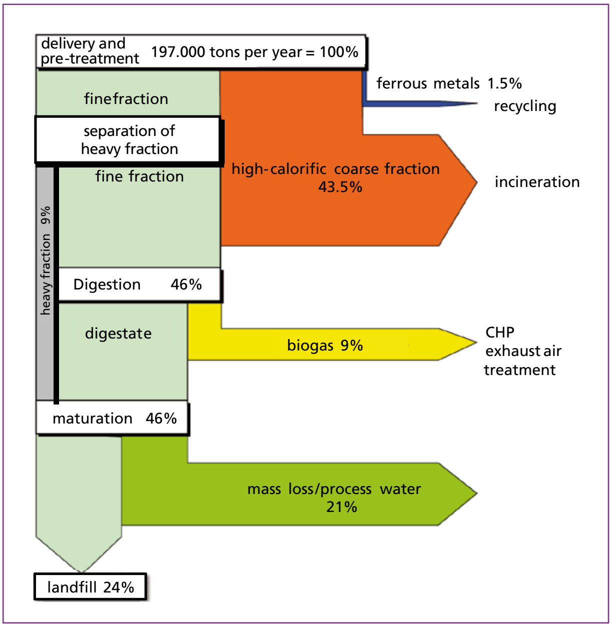

Figure 5:

Mass balance of Hanover MBT plant

The Hanover MBT plant is operated from Monday to Friday in three shifts. The waste input takes place between 6 am and 10 pm. The operation of the machinery equipment is about 12 to 14 hours per day. In the night shifts maintenance work takes place. Figure 5 shows the mass balance of the MBT steps.

3.3. Gas processing and utilization

Fermentation gas from the MBT and landfill gas from an old landfill are mixed and together led to a gas processing unit. The landfill gas is generated relatively evenly with about 1,000m³/h. Due to the missing supply of fresh waste on the since 2005 disused Hanover landfill, the methane content of 40 to 45 percent is relatively low. The recoverable amount of gas decreases since 2005 every year at a rate of about 10 percent.

The fermentation gas varies between 500 and 3,000m³/h, strongly dependent on the input of fresh waste (details in [4]). The methane content is measured at about 55 percent.

The mixed gas is fed via a compressor station to a drying unit. Siloxanes and hydrogen sulfide are absorbed in activated-carbon filters. Then, the gas passes through a gas storage with a capacity of 1,500m³. The gas storage serves less as a mass storage (buffer capacity approximately 30min), but rather to mix the different types of gas with regard to calorific value in order to protect the combined heat and power plant (CHP) engines.

Approximately 500m³/h are diverted for RTO as a fuel gas. The remaining gas (approximately 12.5 million m³ per year) is used for CHP (electrical and thermal capacitiy: 3.8MW). The electric current is consumed by the sites own local grid (approximately 15 million kWh per year). The surplus (approximately 7 million kWh per year) is fed into the public grid. The heat generated fulfills the demand for hot water and heating of the Hanover landfill site and waste treatment centre.

4. Experiences from the perspective of a MBT operator

4.1. Introduction

The Hanover mechanical treatment facility has been working largely without any issues for the last 15 years. This is due to the simple technique and the comfortable redundancy and design of the four parallel processing lines and allows a continued operation in case of partly standstill.

The manufacturer of the biological treatment plant launched the operation in mid-2005 and could not successfully conduct the trial operation. AHA took the wide range of technical problems as a reason to terminate the contract in 2007 and took over the operation in own responsibility. In the following years comprehensive system additions and alterations have been made to fix the production-related issues and where also published in Vielhaber & Middendorf [4].

In the meantime, the plant shows growing damage due to material deterioration, which is accelerated by microbiological attack, corrosion and abrasion.

In addition, the Hanover MBT must also compete with current market prices for residual waste treatment. The cost-effectiveness of MBT technology compared to the incineration of waste is on trial. It is therefore discussed changing treatment concepts. One of the considered option is the generation of more RDF and less deposit to landfill. Another is the conversion of the MBT to biowaste treatment.

4.2. Refuse derived fuel

In general fuels derived from waste are referred to as refuse derived fuel (RDF). A main distinction between RDF and solid recovered fuel (SRF) is that SRF is intentionally produced with respect of quality criteria, whereas RDF is usually a remaining fraction from waste treatment operations.

Contents of waste are known having higher calorific values on the basis of their composition and properties than the raw waste mixture. High-calorific fractions arise after the first screening, usually with a screen cut > 60 mm. This group is enriched with materials such as plastics, paper and wood, having an energy content usually greater than 11 MJ/t. High-calorific fractions have low processing depth, expressed for example in a much larger size, as opposed to SRF, and are subject to lower requirements by the recipient.

Figure 5 shows that about 45 percent of the residual waste to Hanover MBT plant can be recovered by simple shredding and screening technology and separation of ferrous metals.

In the first years of operation, also bulky waste was treated in the Hanover MBT plant in addition to household waste. However, bulky waste introduces a significant proportion of hard-to-treat fabrics (such as springs in mattresses, upholstered furniture), which at times overstrained the shredders. Therefore, an adapted processing technique in another place was installed.

AHA supplies three refuse incineration plants with household waste. With the nearby refuse incineration plant (RIP) of EEW Hanover there is a contractual commitment with respect to the calorific value only: it must exceed 13 MJ/tons waste. In addition to the bulky waste, the high-calorific coarse fraction from the MBT plant is delivered to the RIP as well. So, the mechanical treatment must be aligned to meet this value. All of these *secondary fuels* are subject to the usual prices of waste incineration.

A promising optimization measure is to further use the MBT output instead of landfilling. Additional RDF could be generated through biological drying and conditioning of the bio-stabilized material. Waste heat from the engine or from exhaust gas of the cogeneration plants could be increasingly used for drying purposes (e.g. drying of digestate or process waste water). Figure 6 shows a concept of further preparation of the fine fraction < 60mm: after fermentation and biological stabilization by drying of the digestate the material is conditioned by screening. Two more fractions can be produced as RDF to thermal recovery. Only small and heavy mineral particles remain to landfill.

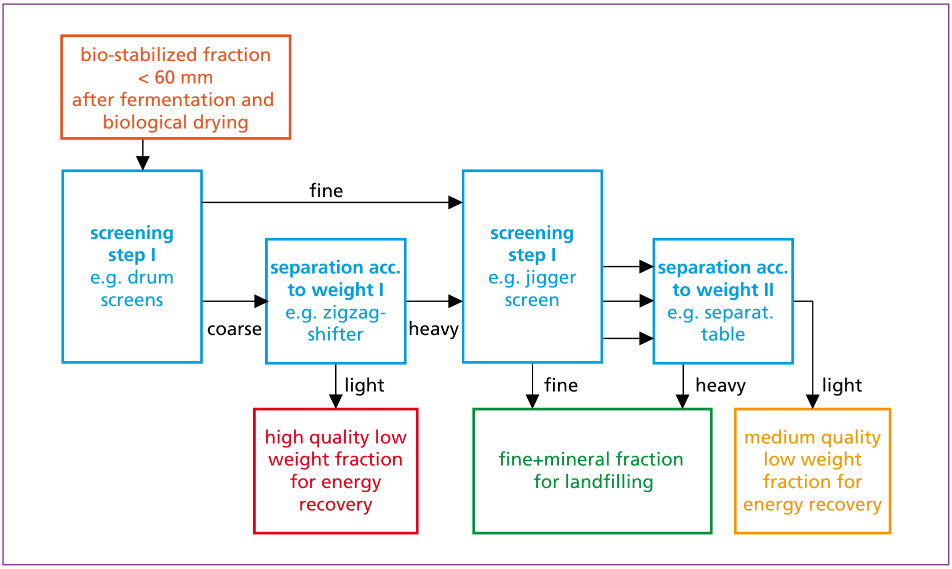

Figure 6: Possible concept of production of bio-stabilized RDF from the fine fraction

The further processing generates material with market acceptable conditions which is a better choice than the option of landfilling. This implies that the higher production costs can be compensated or even generate a benefit, depending on the current market situation.

4.3. Biological treatment

The biological treatment is the more complex and intricate part of the Hanover MBT. The Valorga fermentation process has been working very stable and with a rich gas yield in its more than 10 years of operation, also thanks to a skilled and attentive management. An extensive area of concern is ageing of materials due to the corrosive and abrasive ingredients in the fine fraction. Several comprehensive maintenance, renovation and replacement measures are contracted or planned:

Emptying of fermentation containers

Abrasion by mineral particles such as glass, sand or stones can lead to significant weakening of material of machines, pumps and other aggregates in the long-term. Additionally, sedimentation of minerals may occur within the fermentation containers. The deposition of inert materials 15 to 60mm before fermentation is realized, the grain size < 15mm enters the fermentation container.

In the bottom of each container 320 jets are installed to inject biogas with high pressure into the waste in order to mix it and to strip the methane to the top (according to the VALORGA process). Their function is documented regularly. It is assumed by AHA that despite of the gas injection substantial amounts of sediment in the fermentation

MBT and SRF

containers have deposited after 10 years of operation, blocking of pipes and reducing treatment volume as negative consequences. Currently, it is planned to clean from 2016 on successively one fermentation container after another, and to re-develop the steel-concrete wall – if necessary.

The planning of health and safety measures, explosion protection, structural analysis of the concrete walls, removal of digestate is currently carried out.

Renewal of automatic stack turning machine technology

Chemical corrosion (acids) or through appropriate environmental conditions biocorrosion (excretions of microbiology) in humid conditions can act aggressively on machines and components (concrete, steel construction, roof construction). In spite of general aerobic condition ammonia emissions occur during residual waste maturation. Ammonia is attacking the human respiratory tract, and copper within electrical cables as well.

After 10 years of operation, the steel construction in the maturation area (stack turning machine, conveyer belts and bridges, and maintenance docks) especially at joints is so damaged that the structure is partly impaired. Primarily for health and safety reasons, it was decided to renew substantial parts of the turning machine technology and electrical installations. End of 2015 one rotting process line will be emptied, the existing old stack turning machine dismantled and the new engine installed.

Corrosion protection measures are generally high-quality materials (e.g. stainless steel) or coatings, but these also require higher investment costs. Alternatively, deliberately simple, low-cost materials can be used, however they must be replaced at predictable intervals, as so-called consumables. A good accessibility is then an unconditional requirement .

4.4. Conversion

Plants with MBT technology increasingly have to face the market and are confronted with incineration prices declining for years in Germany. The Hanover MBT plant was designed for an operation term until 2020. Therefore, with regard to the close end of the operation period as well as due to economical pressure, AHA investigated for the Hanover region, how an improved competitiveness of residual waste treatment can be established. Miscellaneous alternatives between continued operation and the closure of the MBT plant are weighed against each other. The impact on economic efficiency, carbon footprint, and staff is being considered.

Core of further considerations is the use of parts of the MBT plant for the fermentation of biowaste. The advantage is that the procedural steps of residual waste or biowaste treatment respectively are almost identical. The adjacent biowaste composting plant (Figure 2) is subject to comprehensive remedial measures as well (start-up year 2000). At present aerobic composting, it is planned to add a fermentation stage prior to composting. The necessary investment would be saved in case of closure of the biowaste composting facility and could be spent for further operation of the MBT extended by biowaste treatment.

What makes the concept quite challenging, is that the separation of residual waste from bio-waste is mandatory under German legislation. Therefore, so far non-redundant system components need to be added. This applies amongst other things to:

- Gas utilization: different legal promotion depending on the origin of fermentation gas – gas from biowaste is highly subsidized, gas from residual waste is not.
- Exhaust air treatment: Exhaust air from residual waste treatment is subject to the German law 30. BImSchV, which means complex and expensive purification by acid scrubber and RTO; Exhaust air from bio-waste treatment is only limited of odour emissions, biofilter will be sufficient
- MBT output: from biowaste as waste for recovery finally arises a quality compost after composting which as a product is determined to the market (agriculture, gardening); from residual waste as waste for disposal according to the technical concept arises RDF or a deposit to landfill only.
- Process wastewater: waste-water produced from residual waste fermentation is very difficult to treat; waste-water generated from biowaste has fertilizer quality.

Therefore, the above mentioned concept will be an ambitious project with many years of planning, approval phase, and construction. At present no decision has been made yet.

5. Future trends

Waste treatment plants with MBT technology focus increasingly on the market. They pursue the goal of recycling and recovery of RDF, more and more against the background of rising raw material costs. Here, conceptions of plants with MBT technology in future can provide an even more important contribution to the resource economy.

Synergies can be used: the demand for replacement of primary energy carrier (mineral oil, gas, coal) by energy-intensive industrial plants (e.g. paper mills, cement kiln) is growing. MBT plant cover a share by providing RDF.

Co-treatment of biogenic waste (leftovers, sewage sludge etc.) is a desirable addition to the yield of energy through fermentation of residual waste. The self-supply with electricity and heat at the site through the gas-generated electricity is aspired. Alternatively, an economically interesting solution can represent purification of biogas and subsequent feeding into the natural gas grid. The german renewable energy law stimulates such possibilities by funding.

MBT with fermentation stage give a positive contribution to the carbon footprint, mainly due to the utilization of methane-rich gas [3]. Their energy efficiency and carbon footprint can be enhanced by a better utilization of the energy of RDF, by increase in biogas production and reduction of the demand for electricity.

The separation of plastics and metals by sensor-based techniques increasingly support recycling efforts. Herein lies another significant research and development potential.

In Germany, the focus is on the optimization or conversion of existing MBT plants: the addition of a fermentation stage can be useful in purely aerobic operated MBT. This results in a better use of the energy contained in the waste.

Another option is the conversion of existing equipment, such as the use of the biological stage for waste drying. It would be a recovery option for low-calorific fuel and additional separation of recyclable materials (such as pure-grade plastics). The proper separation of various types of waste from each other within a plant is challenging.

For the international sector, the MBT technology represents an interesting and simple method of waste treatment. MBT due to their high flexibility may be dimensioned for smaller disposal areas as needed and can still operate economically. Existing landfill volume can continue to be used. The MBT technology offers good opportunities to facilitate the technical and financial needs to adapt to other legal requirements.

6. Literature

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