Sand im Getriebe der Vergärung?

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Waste Fermentation and Sand – no Problem?

Abstract

Anaerobic digestion of biowaste and organic fraction from municipal solid waste (OFMSW), containing certain amounts of contraries such as sand, gravel, glass and plastics is a rather young technology. The growing experience with industrial scale implementation shows the necessity of changing the overall process.

Keywords

NMT-Process, BioFluff, Pulper, Lohse, BTA, Linde-KCA, BRV, Haase, Horstmann, AMB, Kompogas, WABIO, EcoEnergy, WAASA, Valorga, Dranco, MSW, biowaste, anaerobic digestion, OFMSW

1 Introduction

Separation of contraries such as sand, gravel, glass and plastics as a pre-treatment for anaerobic digestion of biowaste and the organic fraction of municipal solid waste (OFMSW) is chiefly implemented to protect the plant equipment. This applies mainly to wet anaerobic digestion but recently also to dry anaerobic digestion.

Scum layers are a common problem in wet anaerobic digestion and recently also for the anaerobic digestion of Renewable Raw Materials.

Anaerobic digestion (AD) of suspensions containing particulate matter has been widely implemented over the past twenty years. Problems with contraries removal and development of scum layers in the AD reactor are discussed. The technology of anaerobic digestion is therefore possibly not appropriate for suspensions containing particulate matter.

The pre-treatment for removal of contraries is generally used only for protection of the equipment and has no further purpose as to energy efficiency, waste management or lower emissions from the plant.

"Problems can never be solved by thinking the same way they were produced."
Albert Einstein

After evaluating the experience in anaerobic digestion to date, EcoEnergy has specified new requirements for the treatment of biomass regarding energy efficiency, waste management and emissions.

Energy efficiency of biomass treatment

In general the quality of anaerobic digestion of biomass is measured by maximum biogas yields. Economically the separation of materials unsuitable for AD beforehand would be much more sensible, these could be incinerated or recycled .

Most AD processes are designed to treat the largest organic fraction regardless of the anaerobic degradability and regardless of dry matter content. For example the incineration of dry wood can be carried out with higher energy efficiency than the anaerobic digestion of dry wood. Accordingly the anaerobic digestion of wet organic industrial waste with high biogas yields is more energy efficient than incineration of this wet material.

Organic matter, free from contraries and soluble, can be dewatered by simple screw press reaching a dry matter content of more than 50 %. The so dewatered material is already suitable for energy efficient incineration.

With an anaerobic digestible fraction of less than 50 %, as in f. ex. sewage rakings, thermal treatment like incineration or gasification even without drying is superior to fermentation. This is economically and with regard to energy recovery the better alternative.

Waste management requirements for biomass treatment

The former three-step hierarchy of waste management will change into a five-step hierarchy (avoidance – reuse - recycling - energy recovery - disposal). From organic waste the fractions sand, gravel, glass as well as compost or fibres can be recycled. Recycling of compost and fibres depends on the successful removal of pollutants, contraries and easily degradable organic matter. Pollutants are mostly dissolved in the liquid phase or attached to the fine inert particles. Only by aerobic or anaerobic biological treatment they are incorporated into organic matter, if not biodegradable. Therefore composting and most AD processes are not suited for removal of pollutants. Compost should further be free from abrasive materials such as sand to allow pelleting for better logistics and storage properties.

There are similar quality standards also for incineration in power plants, especially in modern coal fired combustion. Here the content of heavy metals, chlorine and ash has to be quality assured. Landfilling will in the future only be possible if there is no other economically reasonable way.

Emissions from biomass treatment

Emissions have to be minimized also in biomass treatment. CO_2-emissions increase through the energy consumption for the treatment as well as through the consumption of natural gas for exhaust air treatment and the unused energy from composting. Emissions and odour emissions should also be avoided, especially near residential areas.

During a research project from 2004 to 2006, sponsored by the “Deutsche Bundesstiftung Umwelt”and scientifically supported by University Duisburg-Essen, EcoEnergy developed a technology for sustainable biomass treatment. The results show that composting as well as anaerobic digestion of suspensions containing particulate matter can become superfluous.

2 Development of anaerobic digestion

The generation of swamp gas was discovered in 1776, in 1821 Faraday identified methane as hydrocarbon and Avogadro named the chemical formula for methane (CH_4).

In the beginning of the 20th century scientists discovered that methane was produced by bacteria. Experiments with biogas production from sewage sludge let to the implementation of anaerobic digestion of sewage sludge in Germany in the 1920s.

The anaerobic digestion of sewage sludge reduces the volume of the sludge and the use in farming is much improved. Today the energy recovery is still not the economical motivation for anaerobic digestion of sewage sludge but the main reason is reducing the disposal costs. In the beginning of the 50s several agricultural demonstration plant were built but were soon disused due to the low prices for fuel oil. The interest in biogas production began again in the 70s during the oil crisis.

In Germany, the “Act of power input from Renewable Energy” in 1990 brought the breakthrough for anaerobic digestion, but still focused on waste treatment. The substrates were mainly manure and co-substrates such as fodder and spoiled silage, not saleable potatoes, fat etc.

From 1992 to 1995 five anaerobic digestion plants exclusively for separately collected municipal biowaste, without co-fermentation were commissioned.

Experiments with anaerobic digestion of OFMSW were conducted in test plants in Quarzbichl (dry AD), Münster (wet AD) and Kahlenberg (percolation).

The first industrial scale plant was commissioned in Bassum for dry anaerobic digestion of OFMSW and sewage sludge. The total capacity for AD of OFMSW in 2004 was 35.000 tons per year.

Between 2005 and 2006 eleven AD plants for MSW with a total capacity of nearly 1 Million tons per year were commissioned. Five plants were with wet AD, three plants were with dry AD and three plants had a percolation process.

Following the “Renewable Energy Sources Act” in 2000 with an amendment in 2004, concerning specially the advancement of Renewable Raw Materials, the young AD technology is currently booming without being prepared to full extent.

3 Anaerobic digestion of biowaste and OFMSW

The anaerobic digestion of biowaste and OFMSW is a rather young technology and still in the development phase.

Many suppliers of AD technology in the market over the last ten years are now insolvent or no longer active in anaerobic digestion because of the high-risk product AD of waste. The companies MAT Müll- und Abfalltechnik GmbH, Geotec, farmatic biotech energy ag, Envital Umweltsysteme GmbH, Hese Umwelt GmbH were insolvent directly due to technical risks of the product. Firms as Noell (Anaergie-Verfahren), Bühler (Kompogas), Thyssen (WAASA), Lurgi/ML (Methakomp), Paques (Prethane-Biopaq) and AN biotec (Aquatherm) and others closed the division MBT. Further companies as Herhof Umwelttechnik GmbH, Babcock Borsig Power Environment (Steinmüller-Valorga und DBA-WABIO), were insolvent for other reasons. Linde-KCA’s section environmental technology, Linde-BRV and Horstmann were sold recently. These companies consider dropping their activities in the field of anaerobic digestion of waste, especially with wet mechanical treatment.

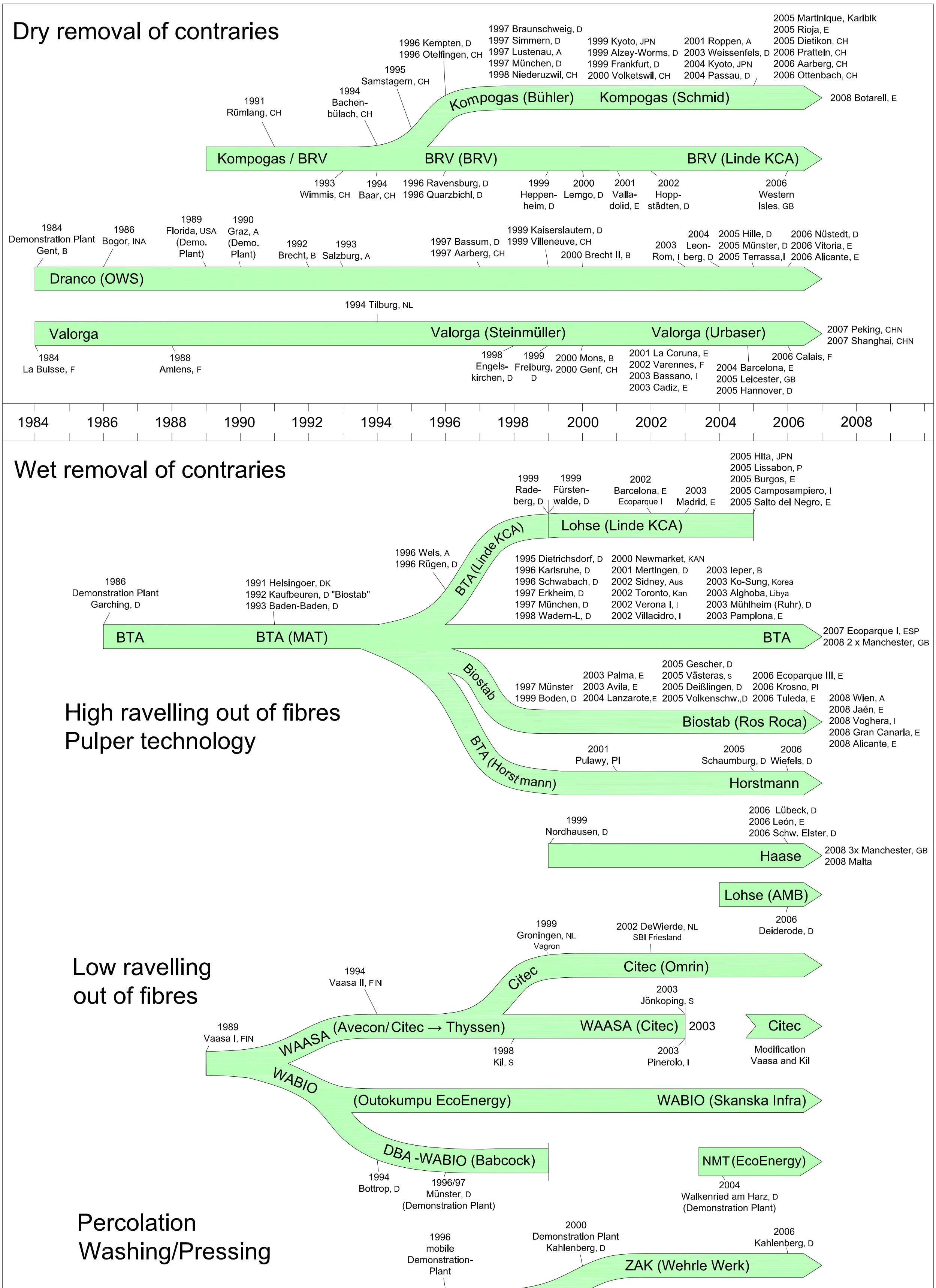

Figure 1 :
Development of anaerobic digestion
(not exhaustive)

4 Mechanical pre-treatment technology

4.1 Pre-treatment

For pre-treatment, biowaste and MSW are first shredded and screened to particle size of < 40 mm to < 120 mm and metals are separated. Further treatment varies depending on the AD technology.

Anaerobic digestion processes can be classified into wet and dry processes, where solids are digested, and processes where the waste is washed (wash process) and the water is put through anaerobic wastewater treatment. Percolation, processes with hydrolysis and separation processes yielding wastewater enriched with easily biodegradable organic contents are counted as wash process in this regard.

4.2 Removal of contraries

4.2.1 Removal of contraries before and after dry AD

Sand, stones, gravel, glass, hard plastics and plastic foils are not removed before anaerobic digestion and are put into the fermenter together with the biomass < 40 mm to < 60 mm.

If the material contains too much stones, gravel and glass, the AD and dewatering equipment is protected by separators for hard material. However the separation does not work effectively due to the consistency of the input with typically 25 % to 55 % water content. In the projects Hille (Dranco), BarcelonaEcoparque II (Valorga) and the spanish project Rioja problems with sediments occurred.

In the projects Hille (Dranco) and Rioja in Spain (Kompogas) the capacity of the heavy fraction separators has therefore been doubled or refitted to achieve a higher separation rate. The AD plant in Kaiserslautern (Dranco) is equipped with a ball mill for pre-treatment, crushing glass and stones, to avoid problems with sedimentation in the dry anaerobic digestion process.

With the exception of partial dry anaerobic digestion where the fermentation residue is not dewatered, these processes leave the sand problem to the dewatering step. In Hannover (Valorga) a three-stage separation unit is installed for treatment of the fermentation residue and wastewater.

Generally screw presses for dewatering of the fermentation residue suffer damage from the high load of contraries. Most problems in the operation of dry anaerobic digestion plants originate in insufficient separation of contraries after AD even if the MSW was pre-treated extensively before anaerobic digestion.

Also in the dry anaerobic digestion plant for biowaste in Braunschweig (Kompogas) additional sand removal equipment was installed in 1998 in the separation unit for fermentation residue.

4.2.2 Removal of contraries before and after wet anaerobic digestion

In wet anaerobic digestion contraries interfere by sedimentation and by building scum layers. Consequently many different methods for removal of contraries were developed.

The organic fibres are ravelled out to a varying degree in the mixer as a first step of the wet pre-treatment. The processes can be distinguished into processes with high ravelling out of fibres, like the pulper technology, developed by BTA in the demonstration plant Garching, and processes with low ravelling out of fibres like the WABIO-process, developed by Outokumpu Ecoenergy OY in the Vaasa demonstration plant, Finland.

The water content of the waste is regulated by adding circulation water to the waste in a mixer until the contraries can be separated by sink-and-float separation in the mixing tank. For reducing equipment size, several removal steps with declining dry matter content are installed.

Unintentionally the last step of contraries removal is the anaerobic digestion process itself, because due to biodegradation the fermenting suspension has a 50 % lower dry matter content and correspondingly lesser viscosity than the added fresh suspension, see figure 2.

On industrial scale, OFMSW was treated by anaerobic digestion first in 1989 as co-fermentation with sewage sludge in Vaasa, Finland with the WABIO-process. The waste was screened at 50 mm and mixed batchwise in simple mixing tank. Lightweight materials were separated using a skimmer and coarse gravel > 5 mm was also separated. The second stage of contraries removal was the reactor, equipped with a conical bottom and a discharge for removal of scum layers. First experiments in wet pre-treatment and anaerobic digestion were conducted in the demonstration plant Garching, BTA, in 1986. Separation was carried out batchwise and the fermenter was equipped with a sand discharger.

The described phenomenon has not sufficiently been taken into account in many recent industrial scale projects and has been the reason for several problems. The importance of wet pre-treatment has consequently been underestimated in nearly all current projects in Germany. Insolvencies and company takeovers are not the only consequences of an insufficiently matured technology.

The pre-treatment units in the following projects are or were already either reconstructed or additional separation steps set up: Wiefels, Sachsenhagen, Südniedersachsen, Schwarze Elster and Lübeck.

In the Barcelona Ecoparque 1 project the complete pre-treatment equipment was changed and the reactors were reconstructed. After successful Implementation the project Madrid will be reconstructed accordingly.

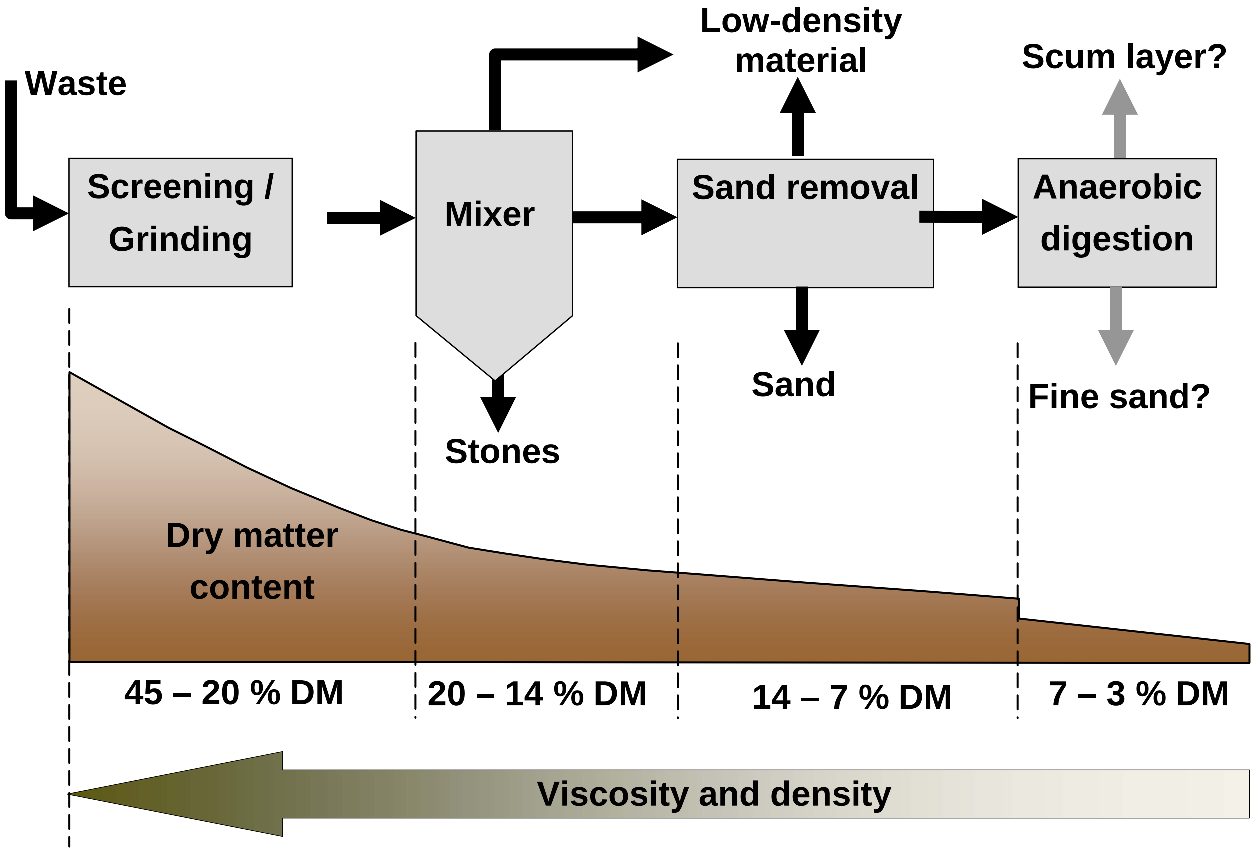

Figure 2 : Principle of contraries removal for wet anaerobic digestion

With a dry matter content of under 5 % in the AD reactor the suspension has are very low stability and mixing equipment is mostly undersized for effectively avoiding scum layers and sedimentation.

Thickening of the suspension before entering the AD reactor is a possibility to reach a higher stability. With biowaste however, flocculant is needed contrary to OFMSW. Particularly with pulper technology thickening is difficult to achieve because of the high degree of fibre ravelling out and consequently high viscosity.

Technologies with lower ravelling out of fibres like the Wabio- or WAASA-process are therefore better suited to remove contraries at a higher dry matter content. The WAASA-process has been optimized in Groningen and De Wierde into a continuous, three-stage system for the removal of contraries. The patent owner of the WAASA-process, Citec, Sweden has stopped marketing the process for AD of suspensions with particulate matter due to the problems with contraries removal. The plants in Vaasa (FIN) and Kil (S) were redesigned so that only the liquid phase without particles enters the AD or rather waste water treatment.

4.2.3 Removal of contraries with wash processes

Wash processes transfer the solved organic matter into a liquid phase free from particulate matter. By using anaerobic digestion technologies known from waste water treatment, degradation performances of up to 95 %, depending on the amount of refractory CSB can be achieved and biogas is produced.

Depending on the process varying degrees of solution of biodegradables are achieved. The removal of contraries is effected either before or after dissolving depending on the wash process.

With solid waste hydrolysis or percolation is often implemented upstream from solid-liquid separation. AD for solid waste has been done with the following wash processes, developed in the last 15 years: Aquatherm, Prethane-Biopaq, IMK, BTA two-stage, adapted WAASA-process and the percolation processes ZAK and ISKA.

In the Prethane-Biopaq-process, Paques, installed in 1992 in Breda (NL) an UASB-reactor was used for AD of wash water from hydrolysis of market waste for the first time. Governmental approval for a further plant for AD of 75 000 tons per year OFMSW was granted in 1996 but the plant was never built, because the company evaluated the risk of contraries removal as too high.

In 1995 the company AN biotec built a plant in Ganderkesee using the Aquatherm-process. The process contains a wash screw press, where the material is rinsed with hot water and then pressed. The liquid phase was digested with UASB-technology. Percolation retention time was six hours. The IMK-process, implemented in Herten in 1996 for biowaste, is very similar to the Aquatherm-process. The material was heated using aerobic hydrolysis and washed during the three days retention time. The wash process consisted in daily pressing, wetting and mixing. Abrasion and wear on screw presses and pumps has been a challenge. The process water was treated and recycled.

A percolation process (ZAK) was developed since 1996 in Kahlenberg, the demonstration plant was built in 2000 and in 2006 an industrial plant with a capacity of 100 000 tons per year. The process is related to both the Aquatherm and the IMK-process. Coarse stones are removed from sieved MSW by a ballistic separator. In a large paddle screw the material is mixed continuously and washed (percolated). The wash water is then treated in a three-stage wet mechanical separation unit before entering the AD. After percolation the solid material is dewatered by a screw press and then dried in a biologically, similar to the dry stabilate process.

As in the dry stabilate process the solids are dried biologically and freed from stones, glass and gravel by means of separating tables, after separating into five fractions. To conclude, the process contains a pre-treatment as before and after a dry anaerobic digestion, a sophisticated waste water treatment as in a wet anaerobic digestion and an additional RDF production as in the dry stabilate process. The process is rather complex but the effort seems well justified. The ISKA-process has been developed together with the ZAK-process in 1996. ISKA has built a demonstration plant in Buchen, focussing rather on treatment preparing a material for land filling than on production of RDF. Two large scale plants were built in Germany in Buchen and Heilbronn. Both plants will close in 2007 according to announcements of EnBW.

4.3 Advancement of wet mechanical treatment

Figure 1 shows the development of contraries removal for anaerobic digestion of solid waste. The DBA-WABIO-process was dropped by Babcock after the merger with Steinmüller in 1999. EcoEnergy has further advanced the philosophy of the DBA-WABIO-process with low ravelling out of fibres into a wash process.

Sand-free organic fractions are produced by a three-stage inert separation and simultaneous production of three organic fractions, washed stepwise with process water. The organic fractions are further separated into particle sizes of 100 µm to 10 mm, 10 mm to 30 mm and 30 mm to 80 mm. The organic fractions are separately dewatered by screw presses. Thus the press force is applied evenly to the material, because no coarser particles are blocking off gaps where the dewatering is hindered.

As an additional distinction of the NMT-process the process water is heated to > 65 °C for destabilising the cell walls and to enable a better cell disruption during dewatering in the screw press. This destabilising effect is due to the structure of the plant cell wall, consisting of not easily biodegradable cellulose fibrils. The fibrils are embedded into a matrix of hemicelluloses, lignin and pectin and are connected by hydrogen bonding. The hydrogen bonds destabilize at a temperature higher than 65 °C so that only low shear force is already sufficient for cell disruption.

EcoEnergy has thus achieved dewatering biowaste and MSW to a dry matter content of > 60 % - inert free - with simple screw presses without prior anaerobic digestion, percolation or hydrolysis. The low water content is due to the above described effect of thermo-mechanical-cell lysis (TMZ) since the cell disruption releases the cell water.

A further advantage of the process besides the high yield of easily biodegradable organic compounds is the selective disruption of the native organic fraction by TMZ into particles < 5 mm. The particle size of the fossil organic fraction is not altered by TMZ.

The hard plastics and plastic foils can therefore be separated easily from the native organic fraction by screening.

Dewatering of the inert fraction can be achieved without drying. The inert fractions are already dewatered and cleaned in the process with circulating water and fresh water so that they can be recycled.

The process ensures that the native organic fractions contain few pollutants. Chlorine is separated with the fossil organic fraction (PVC) or is present as a soluble salt in the wash water. Dewatering is done without thermal drying so that 50 % to 90 % of the soluble pollutants, depending on the waste water treatment and press adjustment, are removed. In the waste water treatment the sludge is the pollutant sink of the process and can be disposed.

EcoEnergy could further verify by experiment, that 65 % to 80 % of the biogas production, generated with AD from the total material, would also be yielded using the NMT-process combined with high performance AD of the process water.

The dried and screened native organic fraction (BioFluff®) is then prepared according to the chosen way of recycling or energy recovery. BioFluff® can be defined as low polluted, dry stabilised, ravelled out biomass and can be widely used as raw material. For use as fertilizer the material can be pelletised, for use as fuel the material can be pelletised or pressed into briquettes. BioFluff® can also be used as raw material for insulation, as building material or filter material or even for ethanol anaerobic digestion. Pelletising or briquetting is recommendable for most applications for logistic reasons since BioFluff® has a rather low density.

In the research project "Wet mechanical treatment of waste" (NMT-process), sponsored by "Deutsche Bundesstiftung Umwelt" and scientifically supported by the University Duisburg-Essen, EcoEnergy could demonstrate by the shown biological, physical and mechanical possibilities that composting as well as anaerobic digestion of suspensions with particulate matter in the future are not technically justifiable anymore.

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