Extensive Environmental Technologies for Treatment of Municipal Solid Waste and Waste Water

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Umfassende Umwelttechnologien zur mechanisch-biologischen Abfall- und Abwasserbehandlung

Abstract

Mechanical and biological treatment has been established as a concept of handling municipal solid waste. The biological process aims to degrade the organic fraction of the waste to a stabilized product through fermentation and rotting processes. The final maturation produces a depositable residual waste. The other option -drying process- reduces the moisture content of the waste and facilitates solid recovered fuels. From municipal solid waste the organic fraction and water are the main sources of emissions on landfills and therefore waste treatment is especially focused on wet organic fraction. There is a direct relationship of organic waste and water content through biological degradation and dewatering of solid waste. An extensive management of mechanical-biological treatment contains processing of solid waste together with process water. Proven technology as Membrane BioReactor system for waste water treatment is shown.

Abstract deutsch

Weltweit gewinnen die Behandlung und Verwertung der Siedlungsabfälle unter wirtschaftlichen und ökologischen Gesichtspunkten an Bedeutung. Die mechanische und biologische Abfallbehandlung hat sich als ein Konzept zur Aufbereitung von Siedlungsabfällen aus Haushalten und Gewerbe etabliert. Dabei steht die biologische Behandlung im Zentrum der Aufbereitung. Die biologische Umsetzung zielt auf den Abbau durch Vergärung und Rotte, um den biogenen Abfallanteil zu reduzieren und ein stabilisiertes Endprodukt zu erzeugen. Bei den Endrotteverfahren wird ein ablagerungsfähiger Restabfall angestrebt, die Trocknungsverfahren verringern den Wassergehalt und ermöglichen eine anschließende Stofftrennung (Ersatzbrennstoffe, Inert- und Reststoffe). Durch Abbau und Entwässerung entsteht ein vergleichsweise hoch belastetes Prozess- und Abwasser, das einer Reinigung zu unterziehen ist. Dabei wurde die Eignung des MembranBioReaktor- Systems bestätigt, das vielfach bei der Aufbereitung von Deponiesickerwasser zum Einsatz kommt.

Keywords

anaerobic digestion, biodegradation, mechanical-biological treatment, membrane bioreactor, percolation, process water treatment, solid recovered fuel, waste water treatment

WEHRLE Umwelt GmbH is a division of **WEHRLE-WERK AG**, Emmendingen Germany, (medium-sized company established in 1860) and is working in the field of environmental technologies. WEHRLE Umwelt GmbH designs, builds and operates:

- **Mechanical and biological plants for the treatment of municipal solid waste**

  BIOPERCOLAT® and PERCOTRY®

- **Biological waste water treatment plants**

  MBR (Membrane BioReactor; BIOMEMBRAT®)

  SBR (Sequencing Batch Reactor)

  Anaerobic waste water treatment

- **Membrane process plants**

  Ultrafiltration, Nanofiltration, Reverse osmosis

As the first European company to operate in the sector of MBR technology, with more than 70 successful operating plants, **WEHRLE** has an extensive track record in providing MBR solutions for industrial effluent, as well as leachate and waste water from mechanical-biological treatment of solid waste. In the field of mechanical-biological treatment of solid waste **WEHRLE** is active since 1997.

1 Mechanical and Biological Treatment of Municipal Solid Waste

1.1 Introduction

Worldwide treatment and utilisation of municipal solid waste from economic and ecological aspects is gaining increasing importance. The protection of natural resources and the prevention of negative environmental impacts are at the centre of sustainable waste management.

In most countries, industrial and household solid waste are deposited at dumpsites. Landfill disposal, in particular of waste containing organic fractions, is producing significant emissions (outgasing of odours and methane, release of leachate). For this reason, there are specific requirements concerning the location and the operation management of landfill sites. European regulations require a pre-treatment and especially the reduction of organic fraction before disposal on a dumpsite (EC Landfill Directive 1999):

Waste recovery of recyclable fraction

Biological treatment of biodegradable solid waste:

recovery of organic fraction (composting)

production of biogas (anaerobic digestion)

mass reduction of biological degradable solid waste

Municipal solid waste consists of difficult to define mixtures of organic fractions containing recyclable and non-recyclable materials and mineral components. Mechanical and biological treatment of municipal solid waste has been established as one concept of handling household and commercial wastes. Mechanical processing in combination with biological conversion produces recyclable fractions from the waste mixture and reduces the amount of waste. The organic fraction can be degraded or converted using the biological processes of composting or anaerobic digestion. The final maturation produces a residual waste which could be deposited on landfill. Another way of treatment could be the drying process which reduces the moisture content of waste and enables the subsequent separation of waste (solid recovered fuel and inert material etc.).

In consequence the organic fraction and water are the main sources of emissions on landfills and therefore waste treatment is especially focused on wet organic fraction. Up to 80 % mass of solid waste could be hold by organic fraction and water. There is a direct relationship between proportion of organic fraction and water. Additionally water keeps the centre in biological processes (composting, anaerobic digestion) of mechanical-biological treatment (see Fig. 1). Firstly, the solid waste is utilised as an energy source through the production of biogas and process heat. Secondly, the mass of waste is greatly reduced by degradation and dewatering.

In case of recovery waste-to-energy the water content of waste decreases the calorific value which could be to low for incineration process. The mechanical-biological treatment reduces the water content and produces solid recovered fuel for industrial combustion. The solid recovered fuel has a high calorific value which is able to be transported and stored (waste-to-energy).

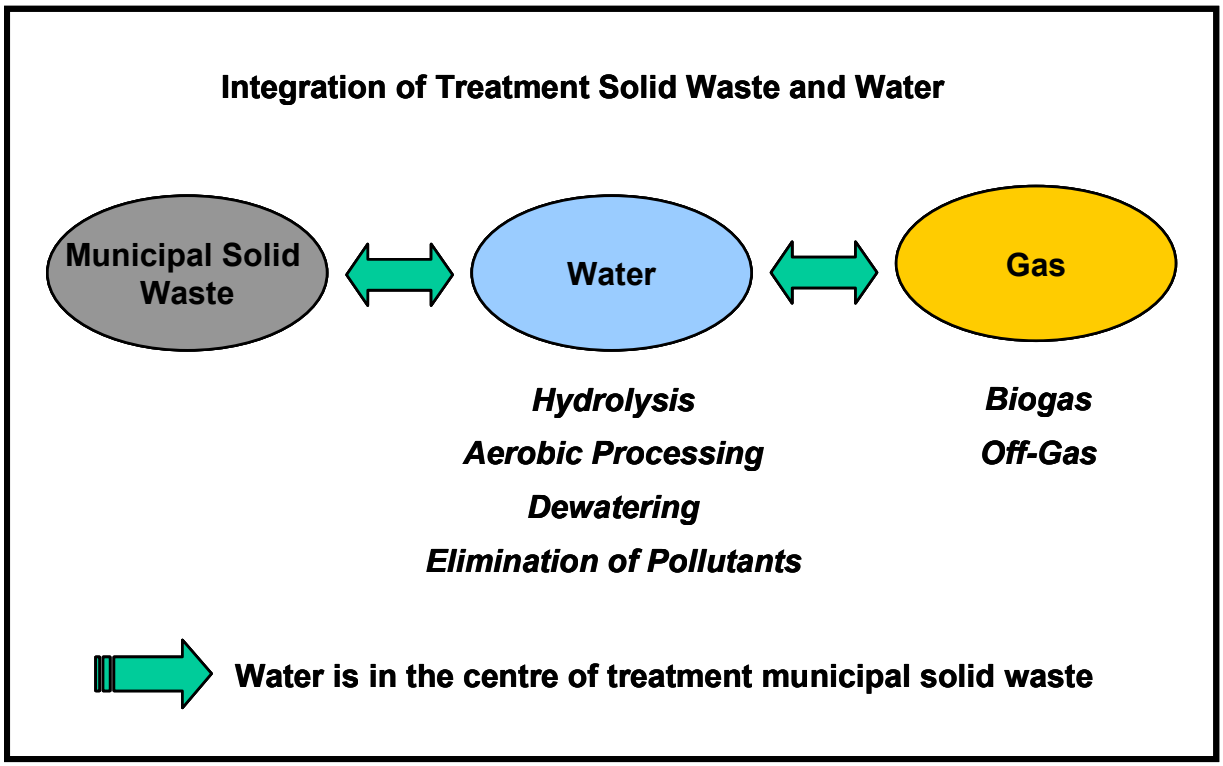

Figure 1 Waste and water at mechanical-biological treatment

1.2 Mechanical-Biological Processes BIOPERCOLAT® and PERCOTRY®

The **BIOPERCOLAT®- process** is an innovative mechanical-biological waste treatment for municipal solid waste and biowaste with an advantageous combination of aerobic processing and anaerobic digestion. BIOPERCOLAT® was developed at mixed solid waste and focused on an accelerated degradation of organic fraction. It is a two-stage-procedure with the main units (see Fig. 2):

- Mechanical pre-treatment
- Percolation and hydrolysis
- Rotting / biological drying
- Anaerobic digestion with biogas utilisation
- Process water treatment.

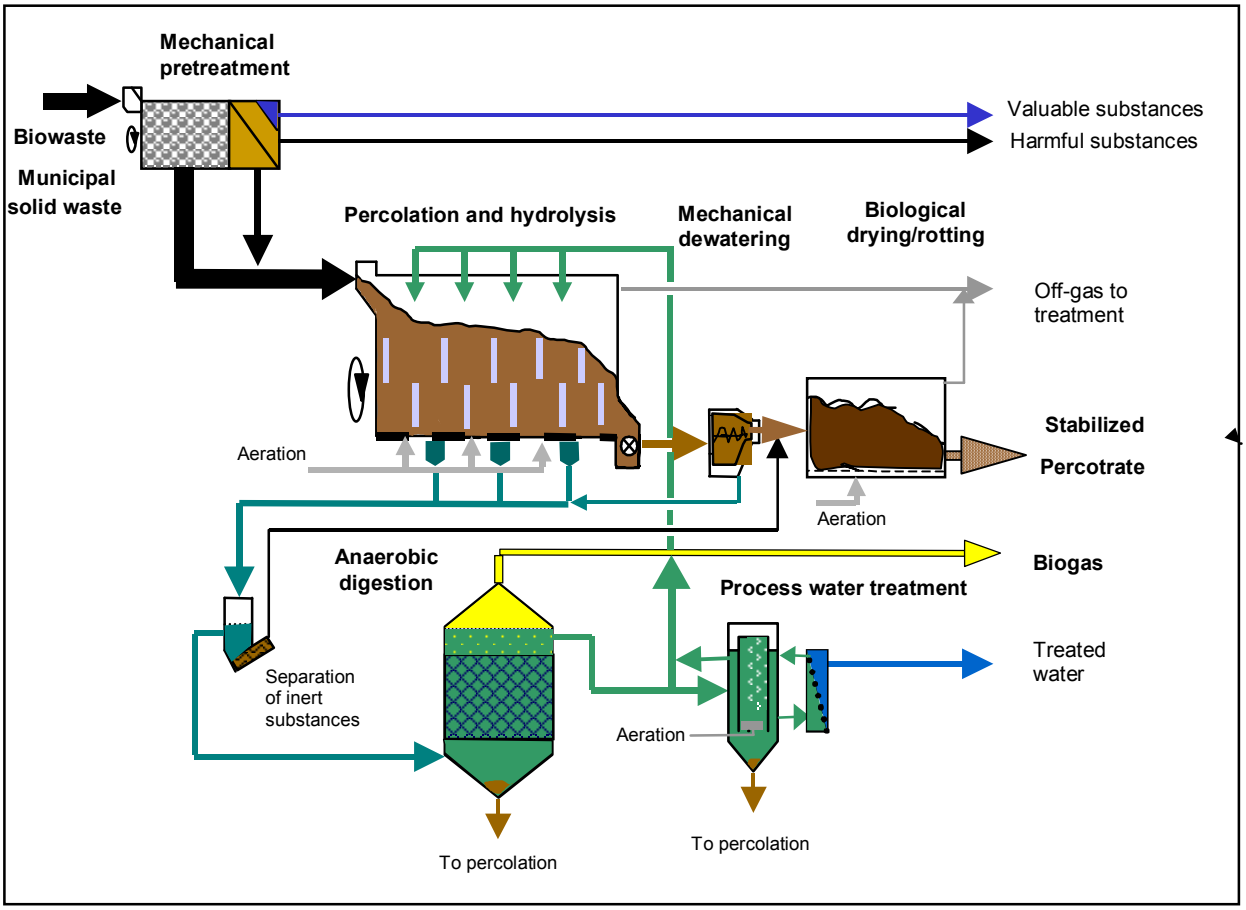

Abbildung 2 Scheme of BIOPERCOLAT®- process in combination with biological drying / rotting (PERCOTRY® - process)

In a simple mechanical pre-treatment the municipal solid waste is sieved (cut-off 100 – 150 mm) and valuable substances are removed. The screen overflow (plastic foils, paper, cardboard, package) can be utilised.

The screen underflow which contains the bio-organic fraction goes to the percolator. Easily soluble and odoriferous substances are washed out (percolation). Solid organic waste substances are degraded aerobically within the percolator (hydrolysis). Waste circulation and biological process are supported by mechanical breaking and decomposition of waste. During retention time of 1 – 3 days a high biological activity is growing up and accelerates the subsequent digestion and rotting.

The percolation leachate is converted anaerobically into biogas after separation of inert substances (sand). The anaerobic stage consists of a bio-film digester which is operating in the mesophilic temperature range under a retention time of 5-6 d. The biogas arising is used for energy production in a combined heat and power generator.

The process provides enough energy for self-sufficiency through biogas utilisation. The surplus power and heat can be delivered to third parties.

The effluent of the anaerobic digester is reused as process water for the percolation. Part of the circuit water and the excess waste water are treated in an aerobic process water plant (see chapter 2). The organic fractions and nitrogen compounds are removed by denitrification and nitrification in a membrane bioreactor system (**BIOMEMBRAT®**). The activated sludge is separated from purified water by ultrafiltration and biomass is concentrated in reactor.

The percolated solid waste (Percotrate) is dewatered by an intensity screw press. The output Percotrate is either treated in subsequent rotting to break down biological activity before landfilling. It is also possible to reduce moisture by aerobic drying to produce solid recovered fuel (waste-to-energy). The aerobic percolation prepares excellently the Percotrate for final rotting or biological drying. There is no break between anaerobic digestion and rotting as know from other systems. **PERCOTRY®** is a dynamic procedure to accelerate biological processes. The Percotrate is turned over by a conveyor system which conserves the structure of waste.

1.3 Case Study and Results Plant Kahlenberg (Germany)

WEHRLE developed the **BIOPERCOLAT®-** process to mechanical and biological treatment of mixed municipal solid waste including biowaste. In 2000 the first **BIOPERCOLAT®**- plant commissioned at Zweckverband Abfallbehandlung Kahlenberg, Germany, with a capacity of 20,000 t/a. In this case the solid waste treatment is mainly focused on the weight reduction and stabilisation of the municipal solid waste. The organic proportion of the waste is converted to biogas. The dewatered and dried Percotrate allows material and energy utilisation (waste-for-recovery and waste-for-energy).

Concept Kahlenberg has following process stages (see Fig. 3):

- **BIOPERCOLAT®**

  Mechanical pre-treatment (screening, separation of metals and bulky refuse)

  Biological treatment (degradation, biogas production)

- **PERCOTRY®**

  Biological drying (increasing calorific value for solid recovered fuel)

- **Mechanical separation** (solid recovered fuel and inert material)

This process combination is one of the first of its kind to combine anaerobic digestion with subsequent production of solid recovered fuels from mixed residual waste.

Contrary to the conventional mechanical-biological treatment the residual waste is not landfilled but is in fact reused as a source of energy.

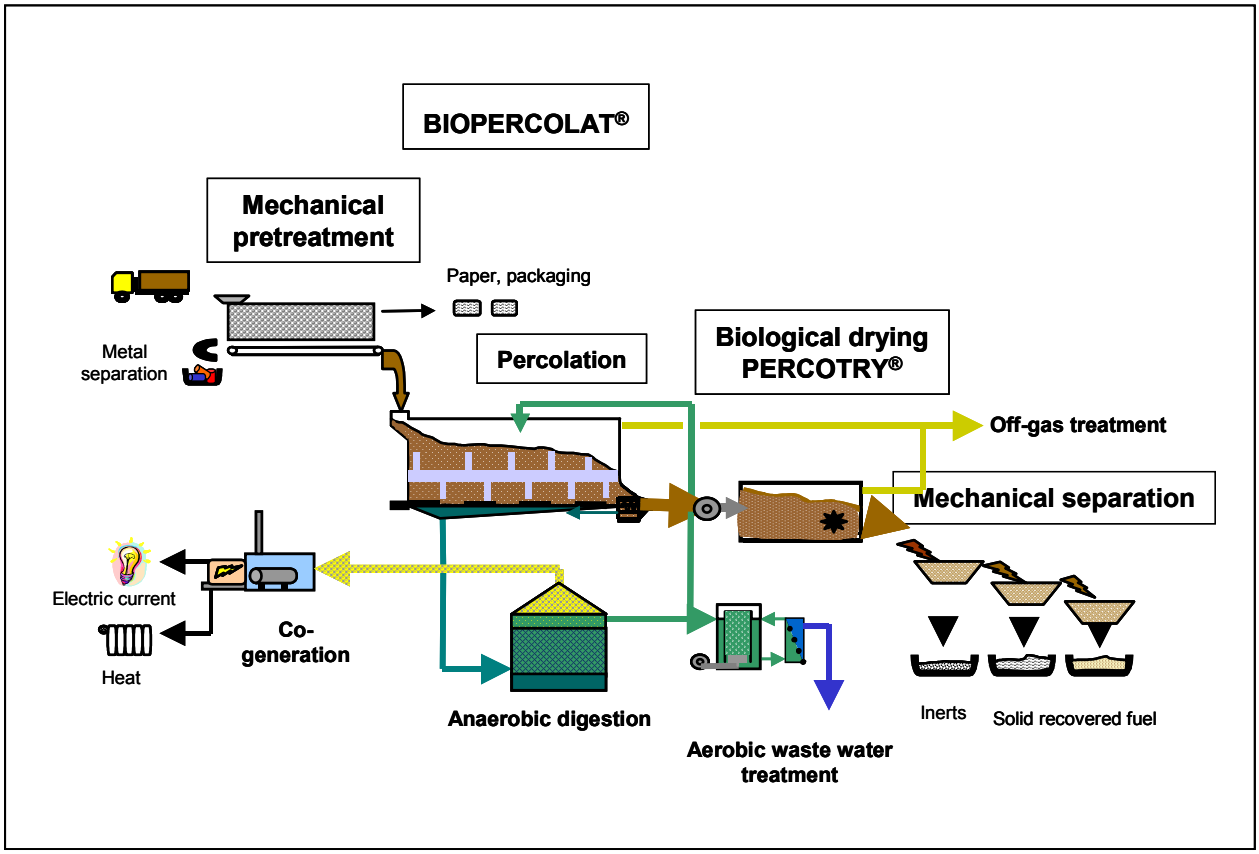

Figure 3 Concept Kahlenberg exclusively built for Zweckverband Abfallbehandlung Kahlenberg, Germany

At Kahlenberg the Percotrate is stabilised by biological drying to obtain a higher calorific value (solid recovered fuel) and to separate inert material. The biological process of the percolation supports an effective drying within 9 d of retention time. The dried percotrate with a residual moisture content of 15 % contains a calorific value of approx. 18,000 kJ/kg. The municipal solid waste is reduced to about 35 % dried percotrate which can be used for energy utilisation (see Fig. 4).

Another 11 % are removed by biological degradation. Converted it results in a specific biogas production of about 70 m³/t (70 % by volume CH_4) of treated solid waste. The plant operation is self-sufficient in energy and more than one third of electricity is for sale. Warming up the anaerobic digestion (mesophile) needs approx. 50 kWh/t and heat for sale is up to 200 kWh/t.

Degradation and dewatering result in excess water (30 %) which is treated by an aerobic waste water treatment (membrane bio-reactor system). About 10 % of inert substances are discharged from original municipal solid waste.

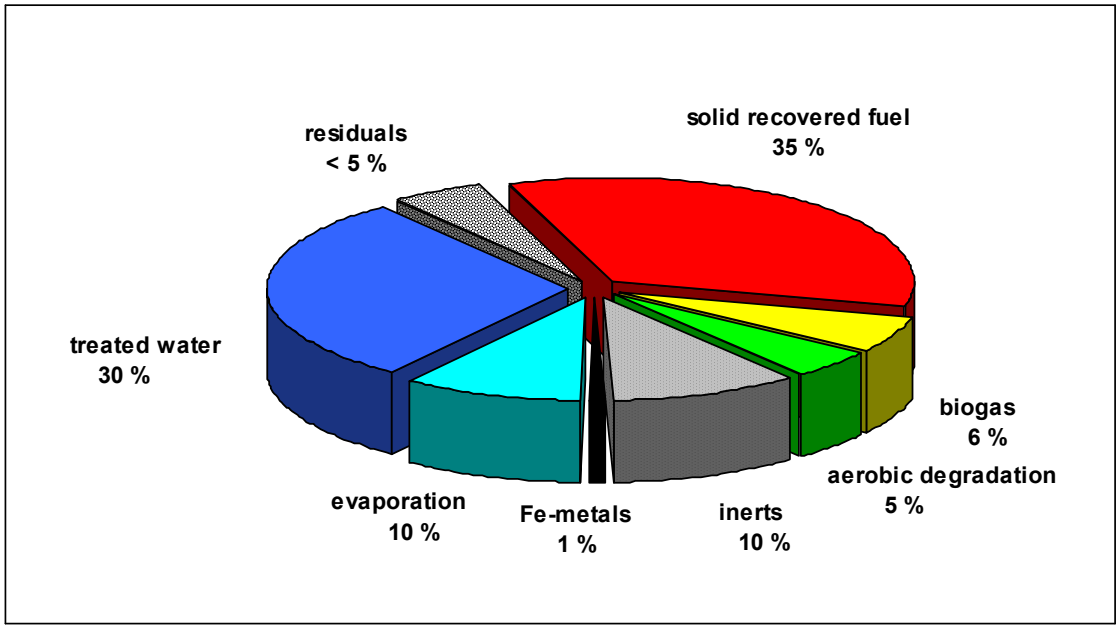

Figure 4 Mass balance of concept Kahlenberg (PERSON, SCHREIBER, 2001)

The first BIOPERCOLAT®- plant was operating successfully and formed the basis of the decision to extend its remit to the entire waste stream. In July 2004 WEHRLE received the order from Zweckverband Abfallbehandlung Kahlenberg to deliver a BIOPERCOLAT®- plant with total throughput of 100,000 t/a. At this time plant is under construction of technical equipment, commissioning will begin at February 2006.

2. Waste Water at Mechanical-Biological Treatment

2.1 Introduction

Biological degradation of organic waste and dewatering at mechanical-biological treatment of municipal solid waste are producing waste water which is mainly polluted with BOD, COD and ammonia. In case of anaerobic digestion process water is required for pulping and irrigation. Excess water from dewatering of digestat has to be treated before discharge (see Fig. 5). As higher the organic fraction and water content of solid waste there are more and more process water which has to be purified. From anaerobic digestion up to 0.5 m³/t waste-input has to be treated (BÖHNING u. DOEDENS, 2002; LOLL, 2000). Even composting plants have to reduce ammonia in process water otherwise the off-gas is high loaded and biofilter will be damaged.

The waste water treatment has to clean-up the process water which will be recycled to biological treatment of waste. Mostly removal of BOD, COD and ammonia are required. The excess water for discharge has to be treated to higher limits which needs a combination of treatment technologies.

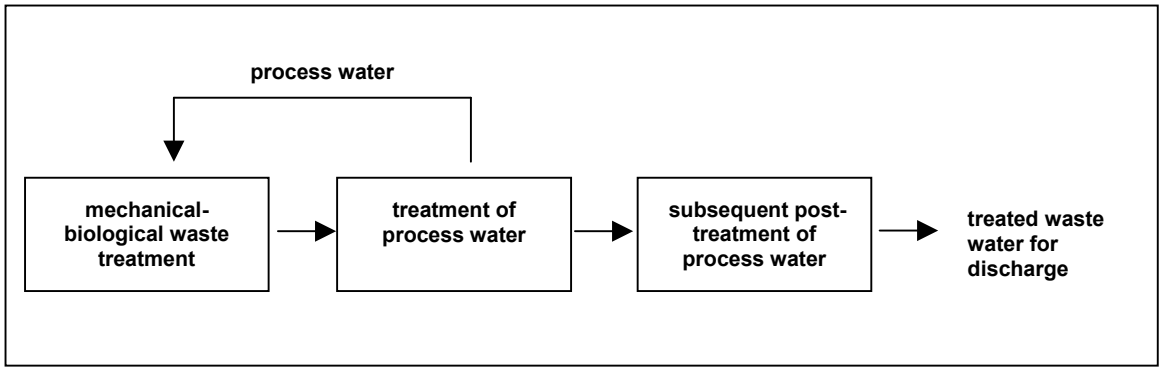

Figure 5 Treatment of waste water at mechanical-biological treatment of municipal solid waste

The pollution of waste water mainly depends on composition of treated municipal solid waste (organic fraction, water, etc.) and process of anaerobic digestion (wet, dry) / rotting. The process water from mechanical-biological treatment could be compared to leachate water from landfills (see Tab. 1)

Table 1 Comparison of process water from mechanical-biological treatment of solid waste with leachate water from landfill

components	process water from MBT		leachate water from landfill		discharge limits	elimination
mg/l	medium	max.	medium	max.	Germany	% (medium)
BOD_5	4,000	8,000	300	1,500	20*	99
COD	20,000	50,000	2,500	6,000	200*	98
N_t	2,500	4,000	1,200	3,000	-	-
NH_4-N	2,000	3,000	1.000	2,500	-	-
N_{inorg}					70*	97
P_t	25	40	5	10	3*	88
Hydrocarbons	5	20			10*	
AOX	2	5	2	5	0.5	90

*for discharge to water course

These data of process water from mechanical-biological treatment of solid waste and leachate water from landfill are taken out from projects and operation plants of **WEHRLE** in Europe. Comparing process water with leachate water shows that pollution of process water is several times higher than contamination of leachate water from landfills. The reason is that biological processes in waste treatment plant are optimized and accelerated contrary to lower-intensive and long-lasting processes at landfill.

Referring German limits of discharge more than 95 % of BOD, COD and ammonia have to be eliminated. The contents of heavy metals depend on the acid solubility at anaerobic digestion. With regard to leachate there are additional particularities in process water from mechanical-biological treatment of solid waste. There is a high content of suspended solids (3-4 % DS) which have to be taken out by filtration (organic fibre) and sedimentation (sand). The biological conversion of organic waste puts 4,000 – 6,000 mg/l Chlorine into solution. The water treatment plant has to install non-corroding materials. From dewatering of digestat there are chemicals of flocculation and precipitant in the process water which could damage biological treatment and membrane filtration. The temperature of process water is up to 40 °C, a cooling system is required.

2.2 The BIOMEMBRAT® for treatment of process water Case Study ECOPARK II, Barcelona (Spain)

BIOMEMBRAT® is a high-performance bio-process, originally developed in year 1980 by the University of Stuttgart, and further optimised and applied by **WEHRLE**. At this time more than 70 reference plants are in operation at landfills or to treat industrial effluents. Since three years **BIOMEMBRAT®** - process is transfered to purify process water from mechanical-biological treatment of municipal solid waste.

It combines the advantages of activated sludge processes with membrane filtration (see Fig. 6) to degrade compounds as BOD, COD, ammonia, nitrate, AOX and hydrocarbons. The BioReactor performance can be further enhanced under excess pressure of up to 3 bar, this being achieved by air and/or oxygen supply.

This operation has a positive effect on highly contaminated waste waters i.e. leachates from landfills and, due to a higher oxygen solubility in the waste water, leads to a considerably improved supply and utilisation of oxygen. The reduced air/gas discharge decrease the stripping of waste water contaminants into the process off-gas.

The separation of the activated sludge from the treated waste water is achieved by membrane filtration according to the cross-flow-principle. The volumetric load can be regulated by the modular construction and operation of the membrane filtration modules, as well as by changes in the process parameters (pressure, flow velocity).

The retained activated sludge is continuously being recycled in the activation process by ultrafiltration, biomass concentrations up to 35 kg MLSS/m³ can be maintained in the BioReactor, and a high sludge age can be achieved.

The treated waste water leaving the BIOMEMBRAT®-plant, known as a permeate, is completely free of suspended solids and bacteria. If required, a further removal of non

biodegradable substances by the incorporation of ancillary treatment processes i.e. fixed bed activated carbon, oxidation plants or membrane filtration (i.e. nanofiltration) are possible.

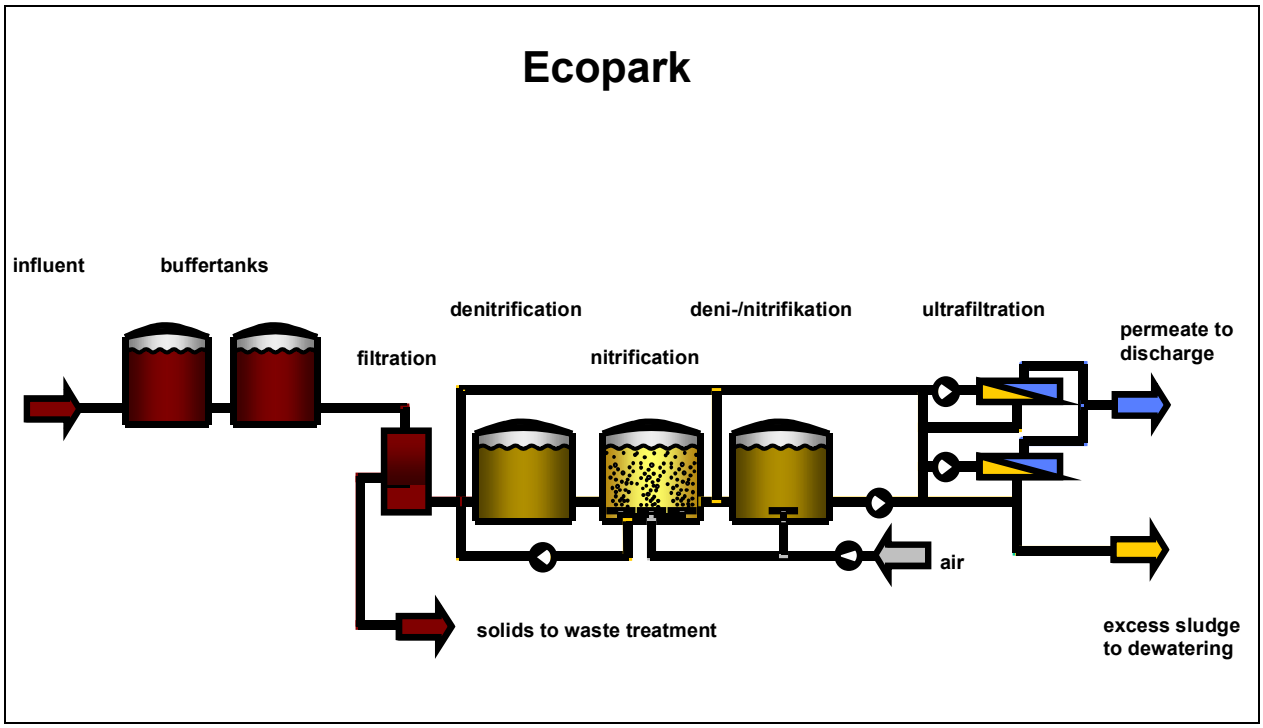

Figure 6 **BIOMEMBRAT®-**process at ECOPARK II, Barcelona

The mechanical-biological treatment plant ECOPARK II is designed for throughput of 240,000 t/a mixed municipal solid waste and biowaste. Approx. 70,000 t/a mechanical pre-treated waste is fed into anaerobic fermentation which is a wet digestion VALORGA®- process. Approx. 50,000 m³/a process water is generated from biodegradation and dewatering. The **BIOMEMBRAT®-** plant is operating since one year and was designed as followed:

Table 2 Design of **BIOMEMBRAT®**- plant ECOPARK II

compounds	influent	effluent	elimination %
throughput (m³/a)	50,000	50,000	
COD (mg/l)	10,000	1,500	97
NH_4-N (mg/l)	4,000	10	99
NO_3-N (mg/l)	-	50	99

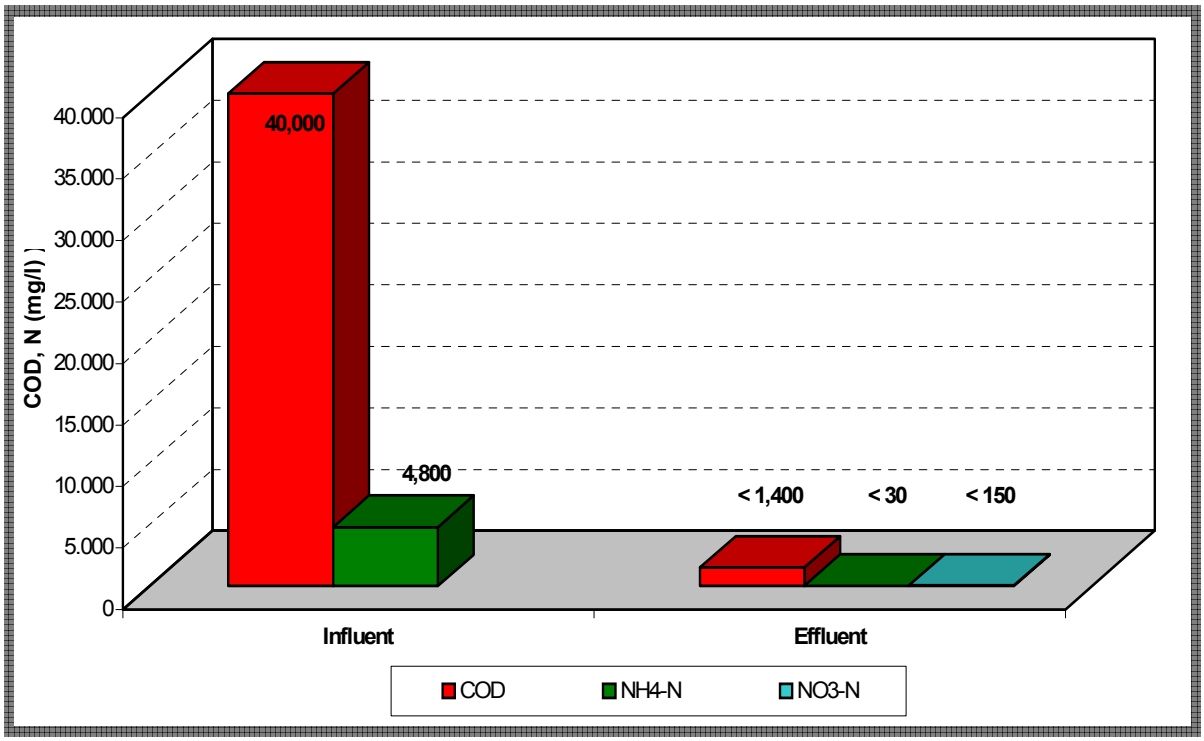

Figure 7 Influent and effluent of **BIOMEMBRAT®**- plant ECOPARK II

After one year of operation the COD-load of influent is up to four times higher than designed plant (see Tab. 2). At treatment of solid waste the suspended solids in process water are not separated efficiently. Nevertheless the limits of effluent are achieved with **BIOMEMBRAT®-** process. The fluxrate of cross-flow ultrafiltration is more than 200 l/m²xh which is an excellent performance in this application with lots of chemicals of flocculation and precipitant in the process water (dewatering digestat).

3. Conclusions

The biological processing keeps the centre of mechanical-biological treatment of municipal solid waste. The biological degradation and dewatering produce a stabilized residual waste for landfilling or solid recovered fuel for industrial combustion. Most of pollutants are leached into process water by biological treatment of solid waste. From application of leachate treatment there is a proven technology as Membrane BioReactor system which has to be modified for process water from waste treatment. The cost for treatment of process water are approx. 10 % of total costs for waste treatment.

4. Literature

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