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Research Note

Combined Treatment of Sewage Sludge and Solid Waste Organic Fraction – the Duplex-Technology

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P A P E R I N F O

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A B S T R A C T

The energy demand of the wastewater treatment is contributing with a significant share to the running costs. Through optimization of the technology and the process control, the specific energy demand can be reduced to < 20 kWh/PE·year. Only with the technology of anaerobic digestion of the sewage sludge and additional co-substrates a complete covering of the energy demand is possible. The treatment of the additional organic residues in the digester increases the specific gas production, contributes to a good economy of the wastewater treatment and solves at the same time an organic waste problem. As co-substrates a wide range of organic residues are available, like grease, residues from food production (slaughterhouse, fruit juice, diary etc.) and agricultural residues or products. Also the organic fraction of the solid waste is an effective co-substrate after a suitable pre-treatment. For application of this technology for smaller plants, a compact technology with an integrated digester has been developed (H-Batch system). Use of organic solid waste fraction as substrate (DUPLEX-technology) an energetic autarkic operation is possible for wastewater treatment plants larger than around 15,000 PE. This technology can especially been applied where the infrastructure for the waste water treatment and the solid waste treatment has to be developed at the same time.

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Energy efficient waste water treatment

The treatment of wastewater needs energy for transport, aeration, mixing and the mechanical equipment like scrapers, weirs, dewatering facilities etc. With a demand of electricity of around 25 to 75 kWh per person and year the energy costs are the main part of the operation costs of wastewater treatment plants (WWTP). Choosing efficient process technology, using energy efficient equipment and optimized process control contributes to reduce the electric demand, but the wastewater treatment usually still remains the main public energy consumer in a municipality. Electric energy can be generated from the biogas gained from the anaerobic digestion of the wastewater (only warm climates or industrial wastewater) or the sewage sludge produced during the treatment process. This energy can be used to cover partially the demand of electric energy. In optimized systems around 65 % of the required electric energy can be covered by electric energy self-produced from the sewage sludge in digesters. This technology up to now was limited to bigger WWTPs, e. g. > 50,000 PE, as a result of the required specifically high investment for the digester, the gas treatment and the gas usage facilities.

Energetic autarky operation

New developments focus on the increase of the economy of the digesters by the use of thermal hydrolysis or by adding energy rich co-substrates to the digester. The specific biogas production in a digester can thereby be increased from usually around 0.75 up to 2.5 m^3N biogas per m3 of digester volume. For thermal hydrolysis and co-fermentation a wide range of successful large scale application are realized and operated. With these technologies an energetic autarky operation can be reached [1]. As one example of an energetic autarky operation using co-fermentation the wastewater treatment plant Rheda-Wiedenbrueck/ Germany will be presented. On that plant municipal wastewater (76,000 PE) is treated biologically together with wastewater from a meat factory (butchery of pigs, capacity 30,000 pigs/day, approx. 650,000 PE). At first, the industrial

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wastewater is pretreated separately. For this industrial wastewater stream is pneumatically transported via a 2.3 km long pressure pipe-line from the production site to the pretreatment site. This is located to next to the municipal WWTP. In the separate pre-treatment of the slaughterhouse wastewater, almost 90 % of the COD-load and approx. 60 % of the nitrogen load are removed by a chemically enhanced flotation step. Flotation tailings are used as co-substrates and are mixed with primary sludge and excess sludge of municipal WWTP. All sludge is digested anaerobically in one stage and finally dewatered. Because of short transport distances for flotation tailings, the location of pretreatment next to municipal WWTP is beneficial in this process. Accordingly, the responsibility for good and stable operation of the flotation unit is placed on municipal staff. Figure 1 gives an overview of the existing facilities at the treatment plant.

Biogas is produced in the anaerobic digestion process and is subsequently converted into electricity using CHP-units with an installed capacity of 4 MW electricity. Overall, the energy consumption of the WWTP Rheda-Wiedenbrueck (approx. 1.2 MW ectricityel) is covered by this and excess electricity can be fed into the public grid.

Following pre-treatment, the wastewater from meat factory is biologically treated together with the municipal wastewater of Rheda-Wiedenbrueck. This treatment step includes biological phosphorus elimination as well as conventional nitrogen removal via nitrification and denitrification.

The extensive degradation of floatation tailings and of raw sludge in the digester results in a high nitrogen load in sludge liquor, which is treated by Nitritation/ Denitritation (first phase) and Deammonification (second phase) using the PANDA/ PANDA+technology.

The sludge liquor contains a nitrogen load of up to 1.4 t/d with peak ammonia concentrations of more than 2,500 mg N/l. There is almost no biologically available carbon left. Without further measures the BOD_5/TKN-ratio of the inflow to main stream biological treatment would be 1.7. Therefore, sufficient nitrogen elimination is not possible without extensive external carbon dosage, which leads to significant increase of operational costs and sludge production or with a nitrogen removal in his partial stream.

3 PANDA – Partial Augmented Nitritation Denitritation with Alkalinity Recovery.

PANDA technology is an application of nitritation/denitritation as an activated sludge process in two subsequent steps [2] (see Figure 2). In the first (aerobic) reactor, stable nitritation is maintained by controlling the flow rate in a way that the sludge age (HRT) is kept low enough to wash out slow-growing NO_2-oxidizing bacteria. For complete denitritation acetic acid can be added to the second (anoxic) reactor. An internal recirculation is an important feature of the PANDA concept utilizing the alkalinity recovered by denitritation to increase nitritation efficiency. Currently, PANDA+ technology which makes use of the anammox conversion instead of denitritation is tested in full-scale. It holds the potential for further savings of energy and chemicals.

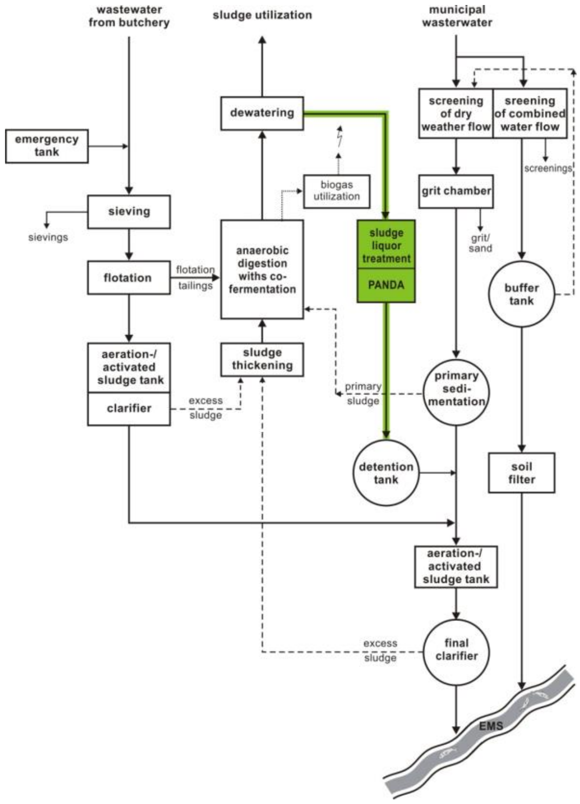

Figure 1. Schematic process configuration at WWTP Rheda-Wiedenbrueck (PANDA process highlighted)

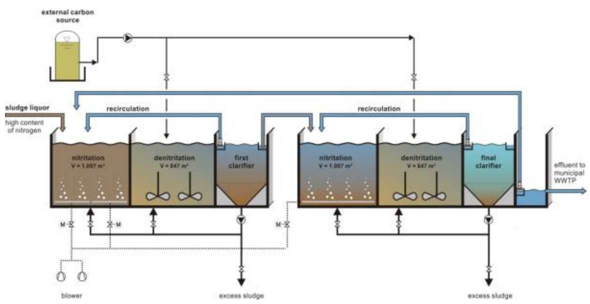

Figure 2. Process scheme of a two-stage PANDA plant for sludge liquor treatment [2].

The total volume for nitritation at the PANDA plant is 2,194 m³ while the existing volume for denitritation sums up to 1,694 m³. The plant has easily been integrated into the existing structures due to compact concrete design of the plant and its low footprint (Figure 3). Each stage is equipped with a recirculation pipe to enable utilization of recovered alkalinity from denitritation to increase the efficiency of the nitritation step. Additionally, a fraction of the effluent can be recirculated to the inflow of the plant. Acetic acid can be dosed as carbon source for denitritation.

Figure 3. View of the PANDA plant at Rheda-Wiedenbrück during construction

The operation results over more than 5 years show a stable efficient process. The process of nitritation/ denitritation (e.g. PANDA) and deammonification (e.g. PANDA +) allows a stable and efficient nitrogen removal of the sludge liquor. By using these technologies, also the nitrogen problem which can be caused by nitrogen rich co-substrates can be used effectively.

Biogas production on small wastewater treatment plants

For application of the co-fermentation technology also for smaller plants a compact technology with an integrated digester has been developed (H-Batch system) and applied. By this, the size of the economical feasible application of digestion can go down to wastewater treatment plants with a capacity of around 15,000 PE.

There is a wide range of approved organic co-substrates like grease from the cleaning of grease chambers, production residues from food production (like slaughterhouses, diaries, canning factories, fruit processing, fish processing), from beverage production (distilleries, production of beer or fruit juice), from agriculture (manure, whey, corn, sugar beets). There are approved technologies for the pre-treatment of the co-substrates to get an efficient and easy operation mode.

In a new development also the organic fraction from the solid waste treatment is used as cosubstrate (DUPLEX-technology) [3] (Figure 4). The residue from the digester can be composted together with further organics. The required sorting can be placed beside the wastewater treatment plant. The usual amount of sewage sludge and organic fraction of the solid waste fit together in a best way. The required digester volume is equal to the size like for the digestion of the sewage sludge alone, but with co-fermentation of the organic waste the specific gas production per m³ volume is much higher. This solution contributes to a most efficient, energetic self-sufficient and economic wastewater and solid waste treatment.

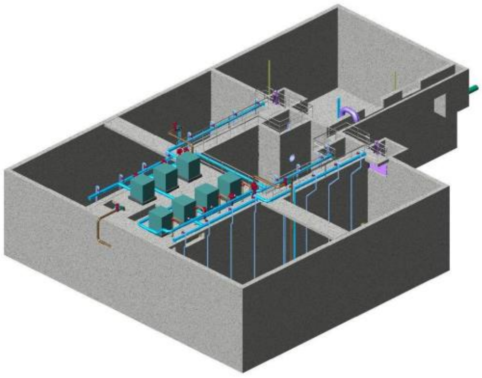

Figure 4. Scheme of a H-Batch reactor with an integrated anaerobic stage and additional storm water storage tank

The high environmental value of this application is significant especially in areas where no regulated solid waste treatment is provided. This is a main result of a feasibility study for 4 cities in Moldova (size between 18,000 and 42,000 PE), considering the DUPLEX technology as one option. The technological aspects, mass balances and operation conditions will be presented as well as specific adapted refinancing and fee calculation schemes for that combined waste water and solid waste treatment technology.

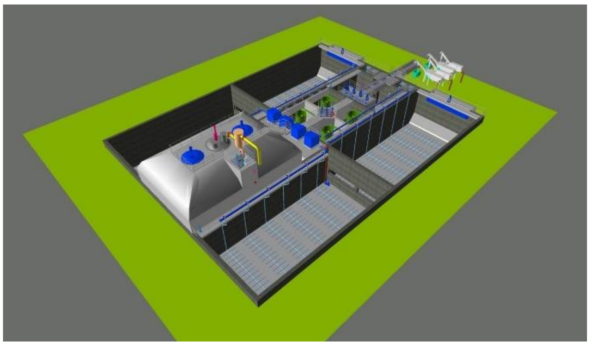

Figure 5. DUPLEX-technology for energetic autarc treatment of wastewater and solid waste

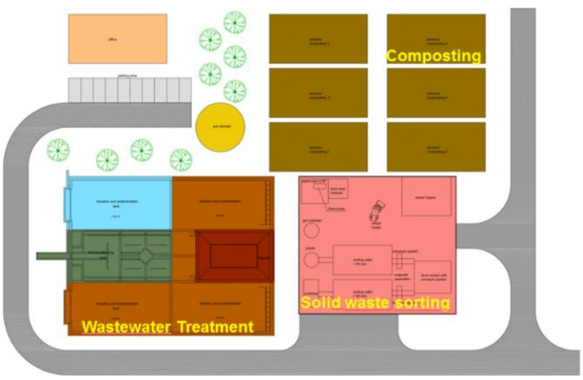

Figure 6. Example for a DUPLEX plant (capacity 20,000 PE)

CONCLUSION

The co-digestion of organic residues together with conventional substrates is a possibility of producing environmental friendly energy without intensifying the food feed fuel conflict. By the use of organic residues as substrates for energy production natural loops can be closed and the energy can be obtained from substances which otherwise would have to be disposed. By the usage of existing digesters on municipal waste water treatment plants co digestion can be implemented easily and on short term. Innovative technologies for an economically viable and efficient N-elimination from the arising sludge liquor exist and have been approved in full-scale especially for the treatment of high-loaded part streams. Hereby, the extensive utilization of carbon sources for energy production (anaerobic digestion) can be realized minimizing the negative impacts of low C/N-ratios on nitrogen elimination at the same time. Especially the additional treatment of co-substrates such as raw-sludge or flotation sludge from industrial wastewater with high organic loading becomes an interesting measure to optimize biogas and energy production in anaerobic digesters.

According to the results of feasibility studies, trial operations and practical experiences it is shown that with the concept of co-fermentation an economic feasible anaerobic treatment of sewage sludge combined with further energy rich co-substrates (like the organic fraction of the solid waste) and using compact technology (like H-Batch system) is possible down to a size of 15,000 PE.

The usage of the organic solid waste fraction (after suitable sorting) can contribute to an energetic autarky operation of the waste water and solid waste sorting facilities (DUPLEX concept).

Due to the successful implementation of the treatment of organic residues in means of co digestion in existing biogas plants of different kinds as well as due to the big potential of co digestion in the future in means of utilizing the remaining energy potential from varying kinds of organic residues it can be stated that this technique can contribute to a sustainable management of waste water and organic waste fraction from municipalities and industries.

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