Co-fermentation of sewage sludge, waste and substrates from agriculture

Wittmaier[*)], Martin; Wöltje[*)], Marco; Mico[**)], Mirel; Friedemann[***)], Jörg

*) Institute for Energy, Recycling and Environmental Protection at Bremen University of Applied Sciences (Institut für Energie und Kreislaufwirtschaft an der Hochschule Bremen GmbH), Neustadtswall 30, 28199 Bremen, Germany. www.IEKrW.de, Fon: 0049 (0) 421-5905-2311. Mail: wittmaier@hs-bremen.de

**) Polytechnic University of Tirana, Tirana, Albania

***) Bio-Verwertungsgesellschaft Radeberg mbH, Radeberg, Germany

Keywords

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1. INTRODUCTION

In Germany the fermentation and composting of organic waste has become an integral part of waste disposal. According to information provided by the Federal Statistical Agency of Germany [Statistisches Bundesamt (2013)], in 2010 encompassed about 9 million Mg of organic waste from private households and associated businesses, plus plant and vegetable waste from parks and gardens. In addition, about 1.9 million Mg dry weight of clarification sludge in 2010 [Statistisches Bundesamt (2013)] and other diverse organic substrates from agriculture, commerce and industry were also subjected to fermentation or composting .

In principle, clarification sludge and organic waste can be treated in biogas plants (digesters) and co-fermentation plays an important role in the production of secondary fertilizer and renewable energy.

2. PLANTS FOR CO-FERMENTATION OF SEWAGE SLUDGE, ORGANIC WASTE AND SUBSTRATES FROM AGRICULTURE

Biogas plants have long been used in the treatment of animal excrement and other substrates from agriculture, for the anaerobic stabilisation of clarification sludge, and for treating effluent heavily contaminated with organic material. The substrates to be fermented here are, as a rule, pumpable. More recently, a wide range of process has become available for fermenting solid, liquid and pasty substrates/waste. Depending on the substrate(s) to be fermented and the size of the plant, a wide range of different processing methods are used.

These range from simple agricultural biogas plants, which, despite low specific investment costs and a narrow range of possible substrates, can be very effective (see Fig. 1), to more sophisticated plants, which through preliminary treatment of the waste (e.g. particle size reduction, sanitisation) can treat a wider range of substrates, finally to industrial plants, which by using even more sophisticated mechanical pre-treatment are capable of fermenting solid waste and waste containing interfering substances.

Fig. 1: Agricultural biogas plant, overview.
(Source: Biogas Weser-ems GmbH, 26203 Friesoythe)

In order to provide a better understanding, in Section 3 the concept of co-fermentation of organic waste and sewage sludge at the BVR plant (near Dresden, Germany) will be presented as an example (see Fig. 2). In respect to accepting and processing solid, pasty and liquid waste the plant is particularly flexible and efficient.

Abb. 2: Co-fermentation plant for solid, liquid and pasty waste, as well as for clarification sludge. Overview and mechanical treatment of solid co-substrates.
(Source: Bio-Verwertungsgesellschaft Radeberg mbH)

3. CO-SUBSTRATES AND BIOGAS YIELDS

In Co-fermentation plants a wide range of liquid, pasty and solid substrates can be processed. However, the degree of substrate degradation and the yield of biogas can vary greatly, depending on dry solids content, dry organic content, substrate composition (fats, proteins, carbohydrates, mineral content etc.), and their bioavailability. For example, from fat, up to 1.200 m³ biogas/Mg original substance can be won, while clarification sludge, with 5% solids, will yield a mere 10 – 15 m³ biogas/m³ or liquid manure from cattle, with 8% solids, will yield a mere 15 – 30 m³ biogas/m³.

Substrate composition can be altered through pre-treatment or storage. While liquid manure and clarification sludge undergo a succession of different degradation processes before being used in a biogas plant, other organic waste (e.g. food waste) changes little. As a result, the degree of degradation achieved under anaerobic conditions varies considerably, for example, between clarification sludge and fresh organic waste from households. Compared with biogenic waste with a dry solids content of up to 50 % or more, clarification sludge and liquid manure are dilute substrates (dry solids content, 3 – 10 %). Thus, the addition of solid organic waste to clarification sludge can increase substrate solids content without significantly increasing hydraulic stress in the digester tower. Thanks to the higher content of readily degradable organic substances, a higher yield of biogas, based on digester volume, can be achieved.

4. EXAMPLE OF OPERATIONAL EXPERIENCE FROM THE BVR CO-FERMENTATION PLANT, DRESDEN/GERMANY

The starting point of the considerations for planning the BVR co-fermentation plant was the extension of the sewage treatment plant in Radeberg including plans for erecting an anaerobic sludge stabilising plant in a sludge digestion tower. Another reason was the apparent need for treatment capacities for various types of biological waste. During a first step various plant designs for mono- and co-treatment of sewage sludge and biological waste in fermentation and composting plants were investigated. Not only ecological standpoints but also primarily economic aspects were examined. As a result of these investigations, the following sewage sludge and biological waste fermentation concept was developed as the most advantageous concept from ecological and primarily economic standpoints.

The co-fermentation plant was erected during reconstruction and extension of the sewage treatment plant in Radeberg. Based on the federal Water Resources Law (WHG) and the State of Saxon's Water Law (SächsWG), the fermentation plant was approved as part of the sewage treatment plant, including a waste treatment plant as approved in the official plans for the extension of the Radeberg sewage treatment plant.

During planning great importance was attached to the flexibility of the fermentation plant. The target was to be able to process as wide a range of wastes as possible. Aside from the liquid and paste-like wastes such as e.g. grease trap contents usually processed in co-fermentation plants, the plant was designed to be able to accept solid biological wastes such as e.g. those which accumulate during the municipal collection of bio-waste containers, extremely soiled biological wastes and industrial wastes such as food waste etc. that are not usually processed in fermentation plants for clarification sludge. The approved acceptance catalogue included over 70 types of waste.

It had to be possible to process biological wastes with and separately from sewage sludge. Therefore the plant was equipped with two fermenters (see chapter 2, Fig. 2,) that can also be operated separately. The plant was started operating in the middle of 1999.

A basic flow diagram of the co-fermentation plant is shown in Fig. 3. At the moment approx. 35,000 m^3 of sewage sludge (TS content 5 – 6%) and approx. 15 – 20,000 Mg of biological wastes are processed annually in the plant.

Sewage sludges, liquid and paste-like as well as solid biological wastes are accepted separately in the plant. The dewatered sewage sludge is accepted by the Radeberg sewage treatment plant. Liquid and paste-like wastes can be stored in various, partially heated tanks. Solid biological wastes are accepted in a flat bunker. An initial rough sorting is carried out in the flat bin. Unsuitable charges can be separated here with the wheel loader and disposed.

From the flat bin the wastes are fed into the charging hopper of the shredder with a wheel loader. Then the shredded wastes are transported via ascending belts to Fe-separation and into the pulper. In the pulper waste materials are dissolved and the waste is shredded further.

Stones, bones etc. are removed out of the waste suspension via a heavy medium sewer port. Then the waste suspension reaches a sieve drum with various perforated segments via a weir. Sand and light-density materials are removed out of the suspension here. The waste suspension reaches a mash tank.

The processed wastes are transferred from the tanks via a macerator into the hygienisation tank. Hygienisation is carried out at a grain size < 10 mm at >70°C for over 1 hour.

After hygienisation the biological waste suspension is transferred together with the sewage sludge into the two fermenters. The sewage sludge can be fermented separately or together with the biological waste as well. This ensures that the biological waste can be marketed as compost in case in the future the costs for sewage sludge utilisation increase sharply. After the material is completely fermented (mesophilic, residence time 15 –20 d), it is de-watered by centrifuging. The centrifuged water is cleaned in the Radeberg municipal sewage treatment plant, the solid is utilised as secondary fertiliser.

The fermentation gas generated during fermentation is converted into electricity by two block heat and power plants. Excess electricity is fed into the mains. The generated heat is used for heating the sludge digestion towers, for hygienisation, for supplying the sewage treatment plant with heat, for heating the service building and for heating a school near the plant. The exhaust air from the treatment plant is captured centrally and cleaned by means of biological filters.

Figure 4 shows the amounts of mash from organic waste, clarification sludge and fat separator waste fed into the plant over a period of about one year. The mash from organic waste consisted of varying proportions of household organic waste from municipal collection, organic market waste and organic waste from a number of different production processes. The proportion of fat separator waste remained more-or-less constant over the period of one year. The amounts of sewage clarification sludge and organic waste were subject to large fluctuations.

As can be seen from Fig. 4, the total amount of mash, distributed equally between the two fermenters, fluctuates by more than 30% during the period under observation, from 200 to over 300 m^3/d. The fluctuations in waste volume are due partly to seasonal variations in the amounts available (e.g. organic waste from municipal collection) and partly to variations volume in the market. Despite the plant disposing over 8 buffer tanks, with a total capacity of approximately 1000 m^3, it is not possible to avoid such fluctuations in feed rate with their negative effect on operational efficiency. The problem could only be reduced by the use of storable substrates.

Despite the variations in quantity and composition of the mash being fermented, methane concentrations, the produced biogas and the biology itself are stable. The biogas is very suitable for fuelling a CHP plant. In contrast to methane concentration, biogas production, and with it the specific biogas yield per cubic metre of mash, varies widely. There is thus optimisation potential for plant operation in the controlled composition of the mash.

The mixed processing of different types of organic waste, fat separator waste and sewage sludge results in a balanced nutrient composition. Mean solids P_2O_5 content is about 3.3%, while nitrogen content is about 3%. The fermented, dewatered sludge is utilised as fertiliser or is composted with structure-rich material and utilised as fertiliser. The use of such fertiliser, made from recycled materials, helps to conserve natural sources.

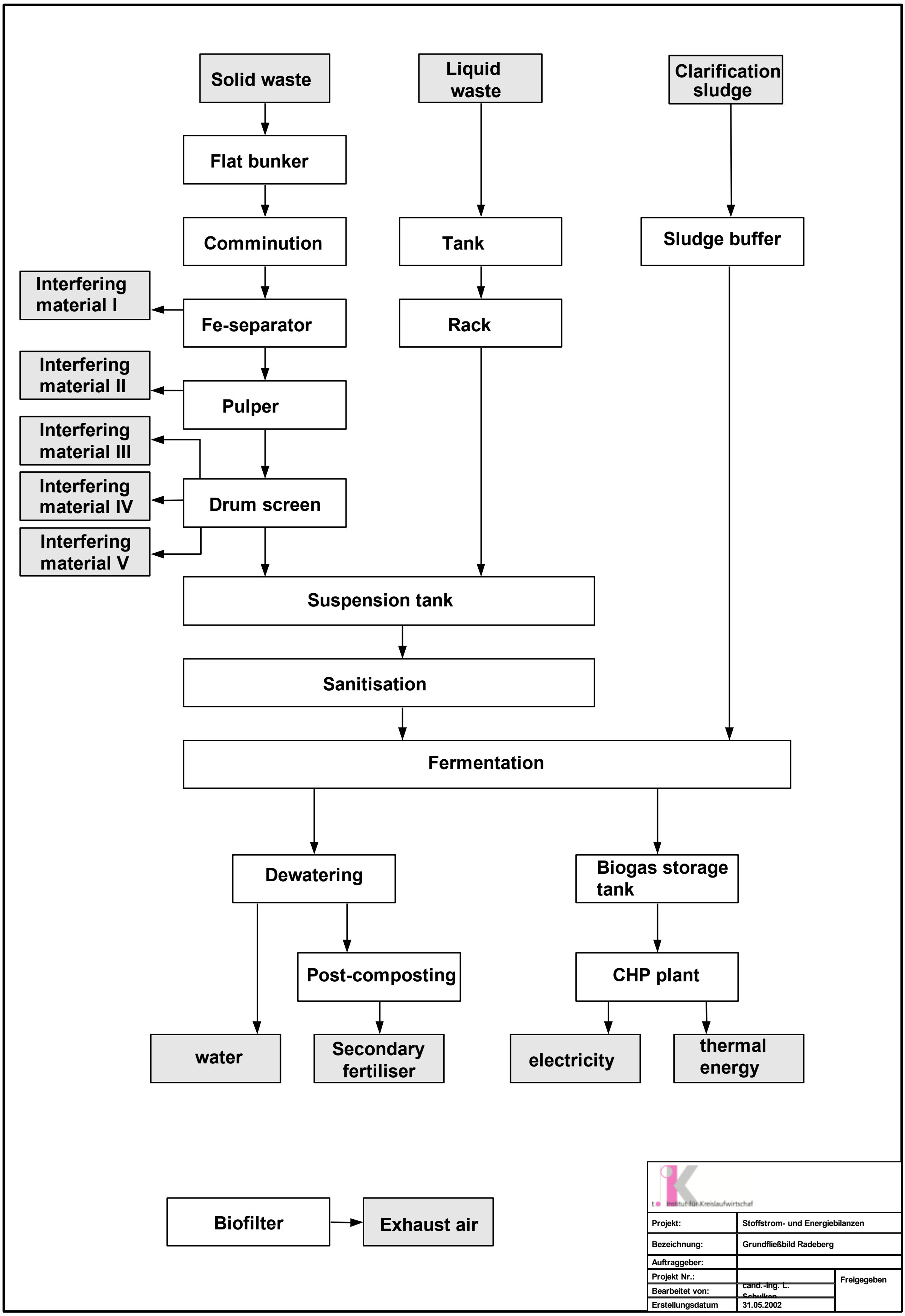

Fig. 3: Simplified basic flow diagram of the BVR co-fermentation plant, Radeberg.

The chances of utilising the spent sludge from co-fermentation as an agricultural fertiliser depend decisively on its heavy metal content. Fig. 6 shows a comparison of threshold values for heavy metals as laid down in German statutory regulations relating to clarification sludge (AbfKlärV) and the actual values for spent sludge from the Radeberg co-fermentation plant. The comparison shows the Radeberg sludge to contain very low levels of heavy metals, thus making it well suited for agricultural use.

Altogether, it can be concluded that the co-fermentation of biological waste and sewage sludge, under the given conditions, is technically feasible and economically viable. For the sewage sludge produced by the sewage works and for a wide range of biological waste the co-fermentation plant offers a reliable and secure means of disposal. Through the production of regenerative energy and thus reducing emissions of greenhouse gases, the plant also makes a positive contribution to climate protection.

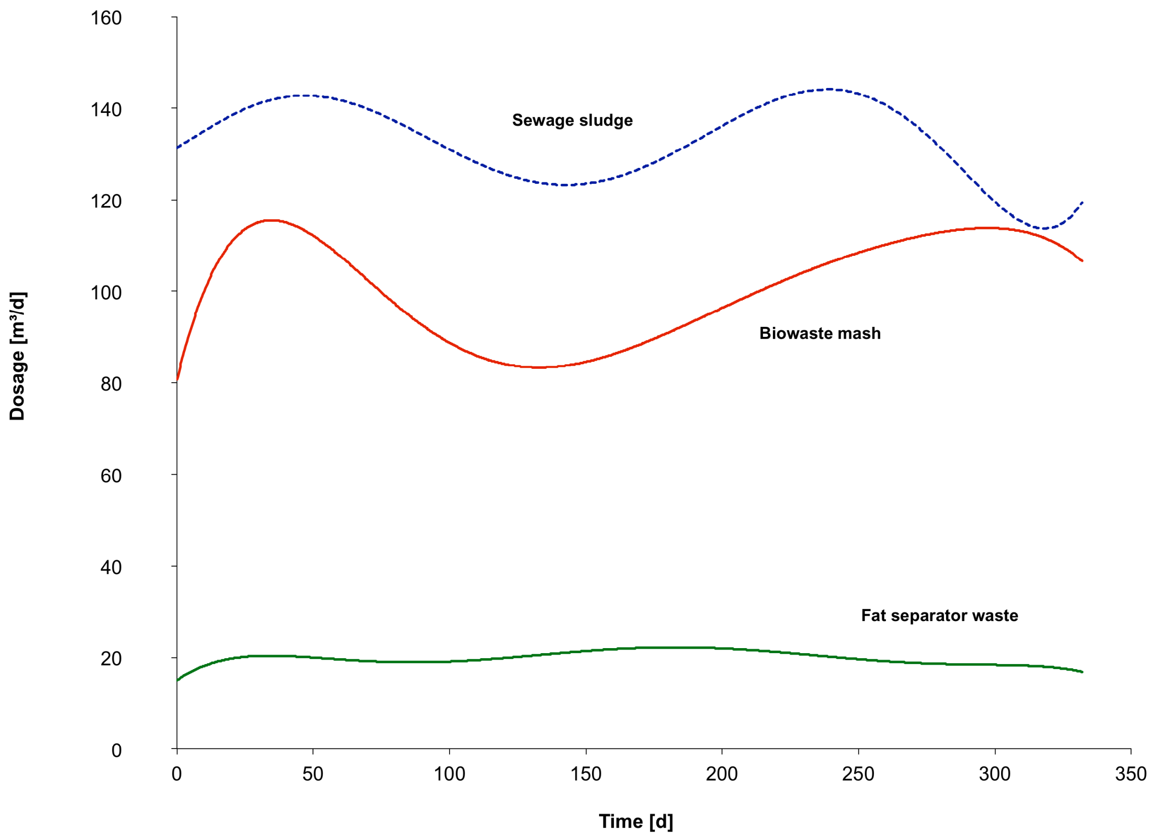

Fig. 4: Amounts of biowaste mash, fat separator waste and sewage sludge processed.

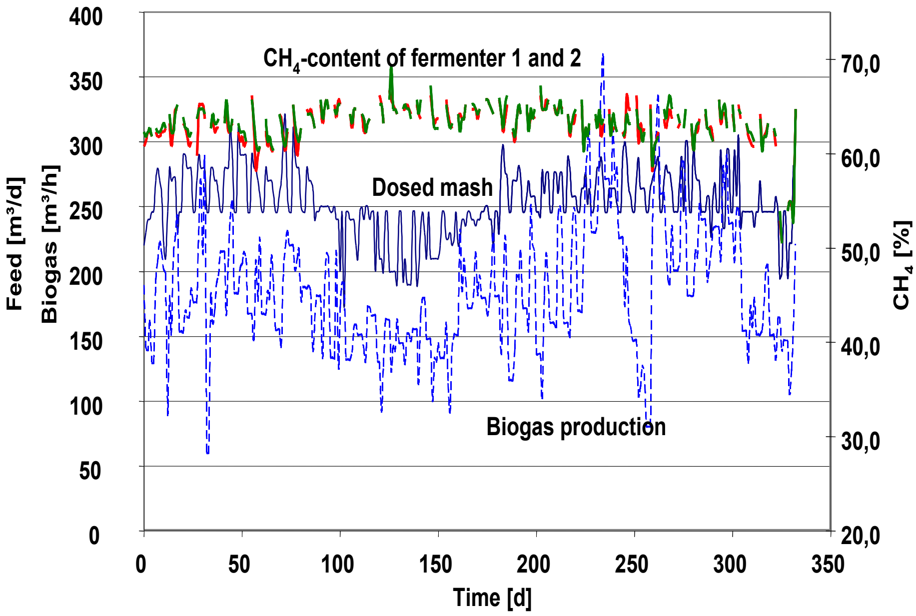

Fig. 5: Biogas production, methane content of biogas in both fermenters (fermener 1 and 2)

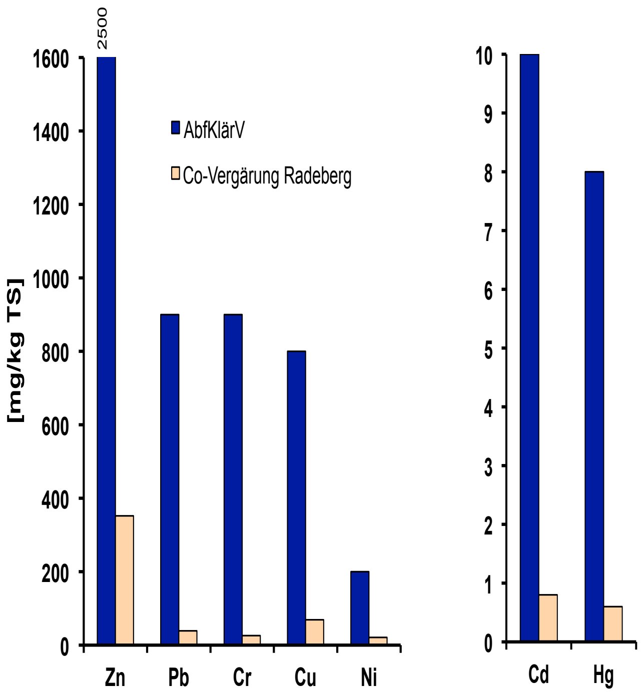

Fig. 6: Comparison of threshold and target values for heavy metal content in clarification sludge used in agriculture with the values for spent sludge from the Radeberg co-fermentation plant.

5. PERSPECTIVES OF CO-FERMENTATION IN ALBANIA

Biomass estimated in albania as a source of energy and is closely associated with firewood. In 2010, it appears that 93% of firewood are consumed for heating and cooking, and only 7% is used in other services. Biomass contributes through firewood in the energy balance of the country with 7.76%. Harnessed in support of biomass to 2008 is given licenses for construction, installation and production, to a thermal capacity of 140 MW. [National Agency of Energy (2003)]

Sludge management strategies need to be developed for each WWTP to identify sustainable and cost-effective outlets, and, in general, agriculture is likely to be the main beneficiary in Albania, if properly developed. This requires WWTPs to be designed to produce sludge of an appropriate quality that most readily secures beneficial use on land. Consequently, sludge management strategies should be an integral component of the initial WWTP design selection process to ensure an appropriate balance is achieved between affordable wastewater and sludge treatment, and securing outlets for the sludge.

Sludge is a novel product in Albania as so far the only experience of using sludge on land is in Kavaja. While the purpose of this study is to develop practicable and sustainable sludge management strategies for Pogradec, Korca and Kavaja, it is inevitable that the study has to address issues and concepts that have not yet been considered in Albania but need to be, urgently, in view of rapid increase in the quantities of sludge expected in the near future. Consequently, this report is intended to be both analytical and instructive to guide decision-making and future operations.

During our study as primary substrate was taken the sludge from the Waste Water Treatment Plant of Kavaja, fermented together additional co-substrate; fresh grass, cattle manure and chicken farm extract. Biogas production was monitored every day during one month, till the biogas produced volume is inconsiderable. Experiments and calculations showed up the encouraging results to go from the laboratory scale to the industrial plant of biogas production, in Albania.

Benefits that comes from the biogas production are the solid waste extermination and at the same time the environmental protection, reuse of different kind of wastes produced by industries, and human activities. This study, support the first biogas production plant in Albania, which is part of the Waste Water Treatment Plant of Durres, using the sludge that comes from it [Stanley E. Manahan (2005)]. Also other experiments will be developed to look for the possibility of including other organic waste disposal, as co-substrates to be mixed with the sludge of WWTP that accelerate the fermentation processes. This because organic waste like food waste or bio-containers from inner city areas are usually fluid or viscous and suit well for anaerobic fermentation (biogas production) as a favourable bio-treatment method.

[Renato Vismara (1982)]. The quality of sludge must be monitored routinely to ensure that sludge has appropriate physical, chemical, microbiological and aesthetic quality appropriate for the outlet and is compliant with the required standards.

The results obtained by the calculation of ideal gases, basing on the above mentioned monitored parameters, are shown in the graphs following (see fig. 7 – 9), every graph shows three samples production of each substrate.

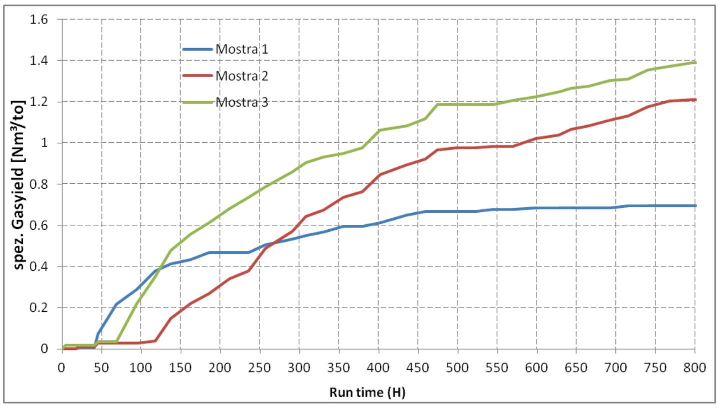

Figure 7: Diagram of biogas production of the sludge WWTP of Kavaja

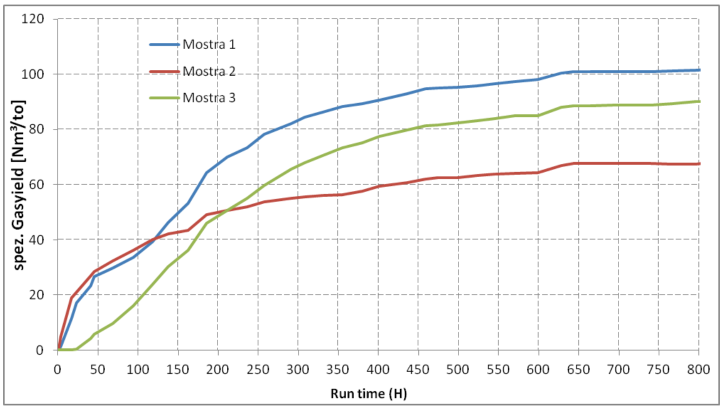

Figure 8: Diagram of sludge + grass biogas production

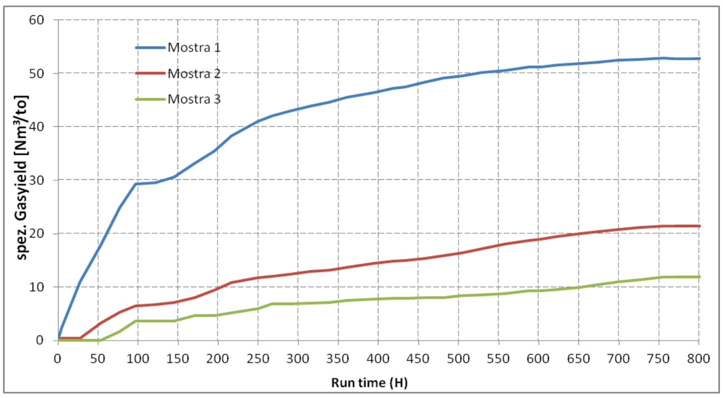

Figure 9: Diagram chicken farm extracta + sludge biogas production

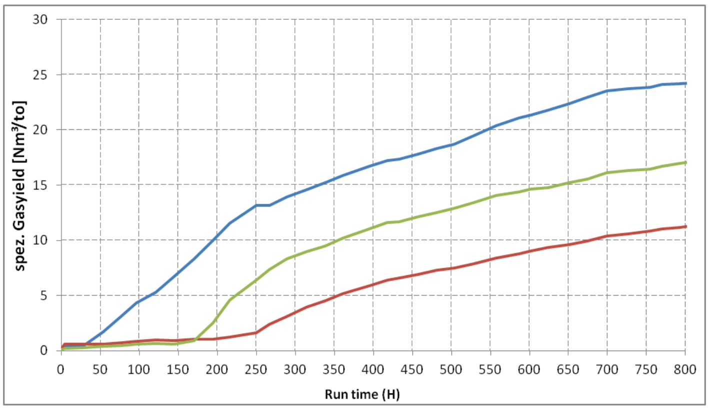

Figure 10: Diagram of cattle manure + sludge biogas production

All the three samples of the substrate are on the same conditions. The organic matter, based on the analysis of the three samples of sludge substrate, averages between 95.43% and 95.88%. The highest value of biogas production, was occurred in the samples of fresh grass, which correspond to the highest value of organic matter of this substrate

Taking into account that in Albania there is a large amount of wastes produced, such as: crops, sludge, agricultural residues (chicken, cattle, grass etc), industrial waste and organic fraction of household wastes, biogas production can be the best solution to reduce the solid waste quantity and produce energy at the same time, by renewable sources of energy.

6. CONCLUSION

The utilization of organic waste is an integral part of the cyclic flow of materials in an economy based on the principle of long-term sustainability. With the technology currently available it is possible to utilize in fermentation plants a very wide range of substrates from the solid waste and waste water, as well as from agriculture. In respect to size and technical standards, plant design can be also be greatly varied to meet a wide range of conditions and requirements that depend on a particular project. Such plants are particularly suitable for decentralised use.

Specific yields of biogas from various substrates fluctuate strongly. In Germany e.g., households alone produce approximately 4 million Mg of organic waste annually, which, if fermented, could be used to generate up to 560,000 MWh of electricity. If clarification sludge, liquid manure and other organic waste were also used, this figure could be substantially increased still further.

The Radeberg co-fermentation plant provides an example of how a single such plant can treat, both economically and ecologically, a wide range of liquid, slurry and solid substrates, producing in the process both renewable energy and high-quality fertilizer.

Current German limits on pollutant contamination for fertilizer derived from secondary raw materials can be readily complied with or considerably improved on.

By producing energy from renewable resources, fermentation plants make an active contribution to combating climate change. In view of shrinking reserves of mineral phosphate, the use of fertilizer from secondary raw materials is also a very positive development.

6. LITERATURE

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