ANAEROBIC DIGESTION IN GERMANY – PERSPECTIVES OF INNOVATIONS FOR THE COMING DECADE

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Abstract
The digestion of organic waste and residues has increased in importance during the last ten years in Germany. New plants have been built mainly for the treatment of agriculture residues (e.g. liquid manure) and municipal solid waste (primarily separately collected organic waste). The potential of biogas generation with 8.7 bill. m$^3$/a, which is provided by the accumulating amount of organic waste, is presently hardly utilised at all. Looking ahead, the more efficient use of this great bio-mass resource is an important aim.

Many digestion plants do not operate at full capacity, others are overloaded. That fact is due to an improper and uncertain data base during the planning phase. If the conditions have changed in a few years, the plants will not be in the position to operate in an optimal way any longer. Additionally a lot of organic waste accrues only in certain regions during a certain season. The integration of this kind of waste in central, stationary plant concepts seems to be impossible. Therefore a further development of digestion plants should enable an adapted, dynamical processing of biological waste. A combination of using existing capacities and the application of mobile, controllable reactor-units would effect variable capacities of the digestion plants, that would provide the opportunity to respond to alternating loads.

The paper gives an overview to the state of the art in Europe and Germany and introduces an innovative concept for a future plant, which is able to readjust the capacity of the process to varying conditions.

Introduction
During the last decade the capacities of biogas plants have increased significantly. On the one hand government aid for the generation of renewable energy results in increasing plant construction in the field of treatment of agricultural residues, on the other the digestion of separately collected organic waste has become more and more important due to the problems of composting plants with odour, high energy demand and handling materials with a high moisture content.

Most of the plants treating agricultural residues are based on the mode of the single stage wet digestion and are run in the mesophilic temperature range. The throughput of those plants varies greatly, depending on the size of the farm. For a cost-efficient operation a minimum size of 100 livestock units (approx. 2000 Mg/a) is recommended (biomasse-info.net 2002), the largest plants have a throughput exceeding 100000 Mg/a. An advantage of agricultural digestion plants is the assured utilisation of the end product of the fermentation process, the digested farm manure on the farm’s own land. Fig. 1 shows the increasing number of those agricultural plants in Germany.
Fig. 1.: Number of Digestion Plants (Fachverband Biogas 2002)

A similar uptrend of digestion capacity is apparent in the biological treatment of separately collected biowaste.

The capacity of those plants is shown in the following numbers.

- 1993: 30000 Mg/a
- 1996: 19 plants with 350000 Mg/a capacity,
- 1998/99: 44 plants with approx. 1.2 Mill. Mg/a capacity

(Kompost Atlas 1998/99)

In spite of that positive trend, the potential of accruing organic waste is not utilised at all. The table shows the quantities and the gas yields of different types of organic waste.

Fig. 2.: Biogas potentials in Germany (Bilitewski et al 2002)

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<tr>
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<th>Quantity (Mio Mg/a)</th>
<th>Theoretical gas yield (billion m³/a)</th>
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<tbody>
<tr>
<td>Liquid manure, dung</td>
<td>190</td>
<td>5.1</td>
</tr>
<tr>
<td>Biowaste, yard waste, abattoir waste, waste from foodstuff industrie</td>
<td>25</td>
<td>2.6</td>
</tr>
<tr>
<td>Biomass from closed agricultural land</td>
<td>48</td>
<td>9.6</td>
</tr>
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Assuming a technical usable amount of 50 % of the theoretical gas yield, there are 8.7 billion m³ of biogas to convert into 17 billion kilowatt-hours of electrical power, the electrical demand for 4.8 Mio households. At the moment the agricultural digestion plants have an installed load of 400 Mio kilowatt-hours, corresponding to an electrical demand of 114 Mio. households.

That means, that according to the data given in Fig.2 97 % of the organic material is still unused. (Bilitewski et al 2002, Gomez 2002)
The objective for the next decade will include the improvement of the utilisation of the existing mass of organic waste. That objective can be achieved by an improved utilisation of existing capacities and the construction of new plants.

The future plant
The future plant conception will move from the large scale digestion to flexible local systems. Large scale digesters do not have the capability to adapt to changing input amounts or characteristics, but amount and characteristics of organic waste can vary greatly. Another important point will be the utilisation of the end product. A split up from the philosophy of “End of the Pipe” is connected with that aim. The future belongs to material flow management in connection with product-oriented waste treatment. One result could be the development of treatment plants which are adapted for specific material flow. Those plants can act dynamically regarding changing input materials, but it can react to changes of the demanded product quality as well.

Basic requirements for such a dynamic plant conception are the development of small, moveable and flexible reactors, an adequate process control, and the knowledge of degradability characteristics of different organic materials (waste, faeces, etc.) regarding their influence on the dynamic growth of the microbial population or the effectiveness of degradation.

The advancement of a plant consisting of small, moveable digesters could be seen in:

- small and modular designed segments grant the possibilities of a more specific and flexible treatment of changing substrates,
- they can be controlled more flexibly,
- they grant a higher yield of methane,
- they can be easily transported,
- they allow the possibility for a dynamical increase or decrease of the plant capacity and
- they could be used aerobic as well as anaerobic.

Up to now the process stability of the fermentation process in full-scale digestion plants is guaranteed by a quite homogenous input flow and the experience of the operators. The problem of small-sized plants is generally the lack of trained operators. That means that in the absence of adequate process control problems occur if the composition and the amount of the substrate changes. Such problems can result in a varying gas production, long retention times, lower gas yield and in the worst scenario in a complete breakdown of the biological process. Therefore a feasible control system is absolutely necessary to meet the requirements of a plant conception based on small, movable digesters. Fig. 3 shows a scheme of a control system, which is in ongoing development at the Bauhaus-University Weimar.

The main item of the system is the process control unit. Thus it is via sensors directly connected with the reactor. Such sensors may include measurement categories like pH-value, temperature, gas amount, analysis of gas components (CH₄, CO₂, H₂S, H₂) and amount of input substance. If available, additional information like characteristics of the input substance (e.g. dry matter, loss of ignition, COD or TOC) can be integrated.

An expert system operating with fuzzy control will effect a state detection of the process and an estimation of the progression on the basis of the measurement results. The amount of feed will be regulated according to the results of the fuzzy control. If an event of fault occurs, which the process controlling unit is not able to remedy, according to the kind of fault a warning signal is given to the service personnel and/or an external expert. This expert will have the facilities to recall the process data and will take proper measures to readjust the optimal processing.
Fig. 3.: Process control system
The interworking of process controlling unit, service personnel and extern expert guarantees an adequate monitoring and controlling of the process.

Conclusion
The aim for the next decade will be the improvement of utilisation of the accruing biological waste. In order to achieve that aim the efficiency of the existing plants has to increase and new plants should be able to react flexible to changing conditions. For that requirement a movable, small reactor will be developed at the Bauhaus University Weimar. In order to enable stable processing and integration of alternating waste amounts with different characteristics in the treatment process an adequate process controlling system will be implemented on that reactor.

References


http://www.biomasse-info.net/Energie_aus_Biomasse/Biogas/wirtschaftlichkeit.htm