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Simple biogas desulfurization by microaeration — Full scale experience

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ABSTRACT

Hydrogen sulfide in biogas is common problem during anaerobic treatment of wastewater with high sulfate concentration (breweries, distilleries, etc.) and needs to be removed before biogas utilization. Physico-chemical desulfurization methods are energetically demanding and expensive compare to biochemical methods. Microaeration, i.e. dosing of small amount of air, is suitable and cost effective biochemical method of sulfide oxidation to elemental sulfur. It has been widely used in biogas plants, but its application in anaerobic reactors for wastewater treatment has been rarely studied or tested. The lack of full-scale experience with microaeration in wastewater treatment plants has been overcome by evaluating the results of seven microaerobic digesters in central Europe. The desulfurization efficiency has been more than 90% in most of the cases. Moreover, microaeration improved the degradability of COD and volatile suspended solids.

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1. Introduction

Anaerobic digestion of sludge is the key process for municipal wastewater treatment plants aiming to exploit the energy potential of organic pollution of wastewater through biogas [10,20]. The suitable quality of biogas is the limiting condition for effective power production and also for all other types of biogas utilization. The elevated concentration of hydrogen sulfide is the most frequent problem.

Many physico-chemical methods of biogas desulfurization are available, such as alkali washout, sorption, precipitation, stripping, etc. Operation at high temperature and pressure, as well as the need for additional equipment and chemicals, make physico-chemical methods energetically demanding and expensive [1,16]. In contrast, biological methods based on the biochemical oxidation of sulfide to sulfate, thiosulfate and elemental sulfur involve lower operational costs with lower or no need for chemical addition [2,21]. Among biological methods, microaeration is the simplest one. It can be performed inside the anaerobic reactor without requirements to build a new separate desulfurization unit.

Microaeration has recently proved to be highly efficient biological method of sulfide removal regarding anaerobic digestion of wastewater and sludge [4,9,12,15,22,24]. This process is based on the controlled dosing of a limited amount of air or oxygen into the digester to ensure the oxidation of sulfide into elemental sulfur. Precipitated elemental sulfur is removed from the digester together with the digested sludge. The presence of oxygen does not negatively influence the activity of anaerobic bacteria because it is consumed quickly and almost completely [6].

A variable air/oxygen dosing rate is necessary as the consequence of the feed composition and loading rate variations resulting in the varying production of sulfide. Besides, residual oxygen in the biogas must meet the requirements of the biogas utilization technology that will be employed afterwards. Optimal process control is the key parameter to the successful microaeration in such cases. When the digestion process is stable as regards biogas production and H_2S concentration, the air/oxygen flow rate can be constant for certain period. However, when it is necessary to cope with the changes of H_2S concentration and biogas flow, oxygen supply must be controlled [14].

Until now, the lack of full-scale experience in wastewater treatment plant digesters was reported as a disadvantage of the microaerobic desulfurization [14]. Present work describes the experiences obtained during long-term operation (in the period of

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years 2003–2015) of 7 microaerobic digesters in central Europe in terms of H_2S removal and changes in the quality of sludge and sludge liquor.

2. Material and methods

Microaeration has been applied on seven municipal wastewater treatment plants (WWTPs) in central Europe. Their characterization is described in Table 1. In each of them a desulfurization unit (Fig. 1) has been built to blow air inside of the digester. The desulfurization unit consisted of the source of pressurized air (such as air compressor), and the control unit which was able to monitor and control the air flow. This simple technology does not need changes in the digester construction and can be implemented without interruption of the digestion process. In all evaluated digesters, air has been dosed into the recirculation stream (Fig. 2).

3. Results and discussion

3.1. Start-up

Start-up period of microaerobic digestion took usually 3–12 weeks as shown in Table 2. Nevertheless, our experiences from laboratory and pilot experiments indicated, that the start-up period can be much shorter if necessary (data not shown). Following aims must be fulfilled during start-up period: (1) the optimization of air dose, and (2) the adaptation and growth of sulfide oxidizing bacteria. Fig. 3 shows the start-up of digester U. Microaeration was turned on in the week 29 and the start-up took approx. 12 weeks.

As expected, the dose of air depends strongly on H_2S concentrations in both gaseous and liquid phase. In evaluated digesters the air doses were in the range of hundreds and thousands of litres per hour in general, no cleaning or pretreatment of air was necessary.

At higher air doses nitrogen from air will dilute biogas and decrease the methane concentration. In microaerobic digesters monitored in present work the volumetric dose of air ranged between 1 and 3% of biogas production. In such cases the effect of the remaining N_2 on the biogas composition was negligible – maximum decrease of methane concentration did not exceed 2%. Therefore it was not necessary to consider replacement of air by expensive pure oxygen [4].

3.2. Desulfurization efficiency

The achieved desulfurization efficiency was between 74% and 99% (Table 2). Requested reduction of H_2S concentration was reached in all cases. In addition long-term operation brought usually further decrease of the H_2S concentration.

The typical course of H_2S concentration in biogas when microaeration technology is applied (for digester K) illustrates Fig. 4. The desulfurization efficiency is effective even with strong fluctuation of initial sulfide and/or H_2S concentration which is a common problem at WWTPs. From operational point of view high

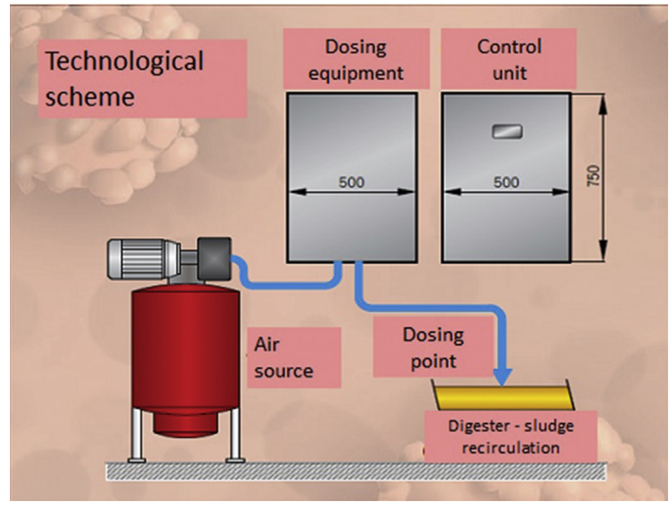

Fig. 1. Technological scheme of full-scale desulfurization unit (designed by K&K Klatovy).

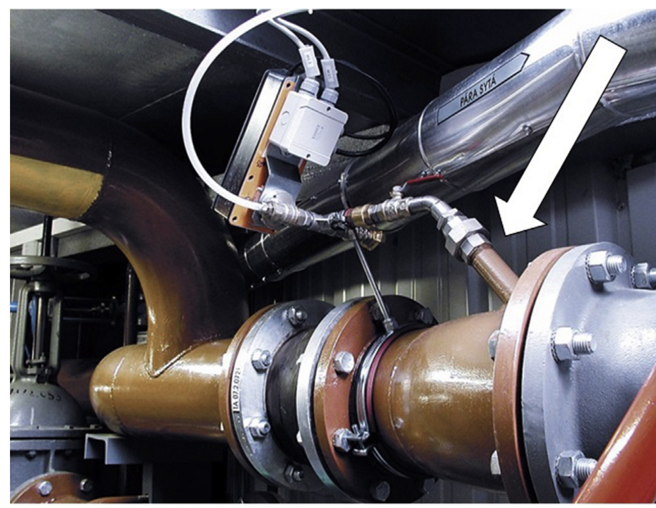

Fig. 2. Air dosing point into the sludge recirculation pipe.

efficiency and stability of desulfurization is important. Hydrogen sulfide compromises the functions of cogenerations unit, causes the corrosion of concrete and steel, and is toxic to humans.

3.3. Quality change of digested sludge and sludge liquor

It was indicated that microaeration is able to improve not only the biogas quality but the quality of digested sludge and sludge liquor as well [7]. The most important changes were found in the

Table 1
Characterization of selected municipal WWTP.

Digester	Population equivalent [–]	Anaerobic reactor volume [m3]	Type of sludge [–]	The start of microaeration [year]
P	19 000	1600	primary + waste activated	2012
M	29 000	2600	primary + waste activated	2012
K	19 000	1900	primary + waste activated	2010
Ko	35 000	3200	primary + waste activated	2010
L	27 000	3000	primary + waste activated	2005
B	350 000	30 000	primary + waste activated	2005
U	36 000	2100	primary + waste activated	2003

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