The mass balance of sewage sludge digestion process

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Abstract: In Romania, in the coming years, the amount of wastewater collected by sewage systems will be constantly growing. NTPA-011 in Government Decision 188/28.02.2002, updated until 19.10.2011, provides that until December 31st. 2018 all agglomerations areas between 2000 and 10000 population equivalent to be provided with sewerage networks [1]..

Many of these human agglomerations are metropolitan areas located near the county capitals. Wastewater collected in these areas are (will be) transported by gravity or by pumping them in municipal wastewater treatment plants already built. Therefore the amount of treated wastewater will increase, causing at the same time, the increase of the processed sludge quantities, and therefore the increase of the specific energy consumption in wastewater and sludge treatment processes.

To compensate this increase of energy consumption, wastewater treatment plants operators must find the best solutions for energy recovery from sewage sludge through anaerobic digestion process with the biogas production and thermal treating with heat and electricity recovery [6; 7; 8; 9; 10].

The purpose of this article is to describe the specific features of an anaerobic digestion process for sludge derived from municipal wastewater. The article presents a calculation summary of mass balance on sludge treatment line.

Keywords: digestion process, biogas, wastewater, sludge, treatment process, mass balance.

1. Introduction

Sewage sludge is a secondary product which is resulted from the treatment of wastewater in the Municipal treatment plants. According with the Ministry of Environmental and Water Management 95/12.02.2005, all treated sewage sludge is classified as non-hazardous waste and are admitted for storage [4].

Considering the Romanian legislation alignment to European regulations, in the coming years, the requirements for the disposal and storage of waste will be tightened. The inappropriately treated sludge may create risk, that it will not be accepted for storage or to be accepted in limited quantities at authorized landfills [2; 3; 4; 5].

The efficiency of sludge treatment is measured by the treatment degree (stabilization) – G_T = SM/SV, where SM represents the quantity of mineral substance and SV represents the quantity of volatile substance of the dry substance contained by the raw sludge. If G_T is ≥ 1, it means that the sludge is sufficiently treated, and if G_T is < 1 the treatment is not proper and the sludge is not stabilized, and there may be negative effects on the environment [5].

2. The description of sludge production process

The sewage sludge is an unwanted product resulting from the wastewater treatment plant process. It consists of the raw primary sludge and the biological activated sludge, secondary or tertiary [6; 7; 8].

The primary sludge results from settling of decanted solids contained in the wastewater, during the mechanical treatment process. Primary sludge has the highest organic load between the all types of sludge, results during wastewater treatment processes in a municipal treatment plant [6; 7; 8].

Secondary and tertiary sludge, where appropriate, is formed in secondary and tertiary settling tanks, through biochemical processes of decomposition for colloidal solids namely inseparable by decantation, as well as the dissolved in wastewater. This sludge is biologically activated in activated sludge tanks and bio filters. This is biological feeding for anaerobic bacteria, which are processes. Most of this sludge is recycled internally and externally and are designed to keep biology processes [6; 7; 8].

Excess sludge which is not required in biological processes is called the activated biological sludge in excess. This together with primary raw sludge and sludge from chemical precipitation of phosphorus, form the sludge of process that is treated by anaerobic fermentation in tanks for fermentation (digestion), being the first treating stage on the sludge line [6; 7; 8].

Sludge production on the line of wastewater treatment plant with tertiary advanced treatment forwastewater with high organic load, is show in process-flow of "Figure 1".

3. The description of anaerobic digestion process

Sludge treatment presupposes the decomposition of organic matter after mechanical and biochemical processes. Anaerobic fermentation is applied in the case of sludge resulted after treatment of wastewater with a high organic contents. Anaerobic processes for sludge treatment determine anaerobic digestion through the action of anaerobic bacteria, which act with the purpose of mineralization of organic matter, resulted after the settlement of wastewater.

To increase energy efficiency, in some treatment plants were designed and built equipment for biogas production, where, addition of sludge from wastewater treatment process, are introduced to ferment and co-substrates derived from the food industry of operating area. These co-substrates have a high organic load, over 75%, and a high dry matter content over 5%.

Between the co-substrates frequently used in the of sewage sludge co-fermentation, can be mentioned:

- Excess sludge, sludge flotation and washing water, derived from the treatment of industrial wastewater from pig and poultry slaughterhouses;
- Milk residues derived from dairy factories;
- Waste and lignin derived from bioethanol factories;
- Wash waters and excess sludge derived from the fruits and vegetables processing in the canning factories.

To ensure the best possible conditions for unfolding of fermentation process, must ensure the co-substrates preheating, before of placing them into fermentation reactors. The station for co-substrates collection and storage must be provided with special chipper pumps, in order to ensure shredding of coarse and larger residues. Heat required for the co-substrates preheating, is supplied from the CHP plants, built inside of the wastewater treatment plant.

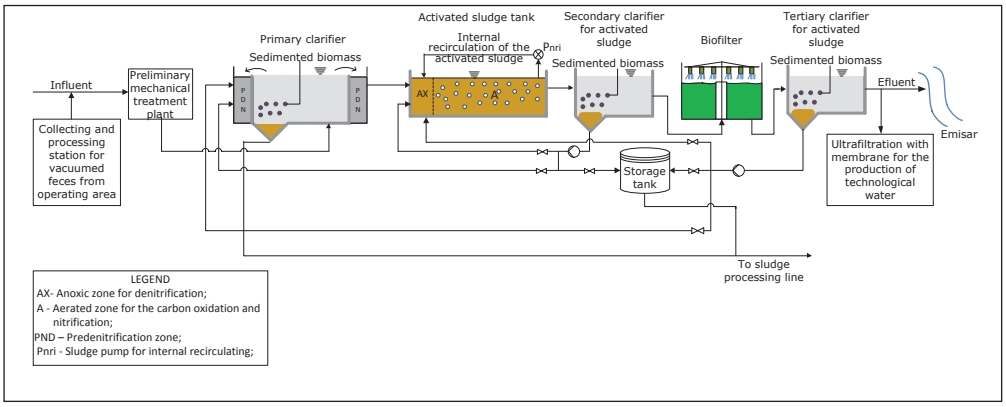

Figure 1. Producing sewage sludge in a plant with advanced tertiary treatment. The drawing was accomplished according with the Straubing city WWTP process, where the first author of this article did an internship of practice in 2013.

The heat and electricity are produced by biogas and dried sludge burning, as products of treatment processes which runs on the sludge line. The biogas production in the co-digestion process of sewage sludge with organic co-substrates is show in process-flow "Figure 2".

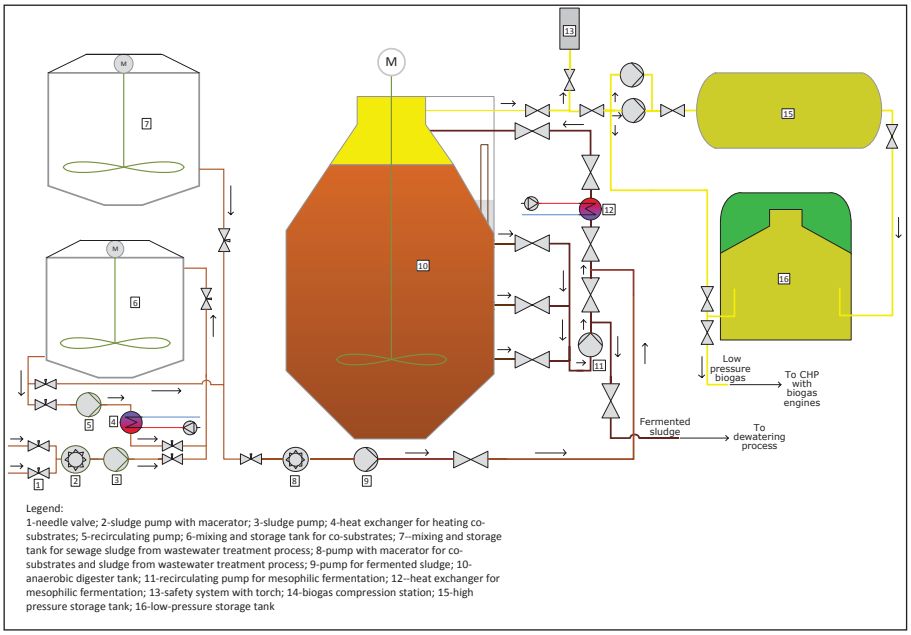

Figure 2. The process-flow of biogas production in the co-digestion process of sewage sludge with organic co-substrates. The drawing was accomplished according with the Straubing city WWTP sludge line, where the first author of this article did an internship of practice in 2013

4. The mass balance of sewage sludge digestion process

Mass and volume-flow of digestion process are show in "Figure 3".

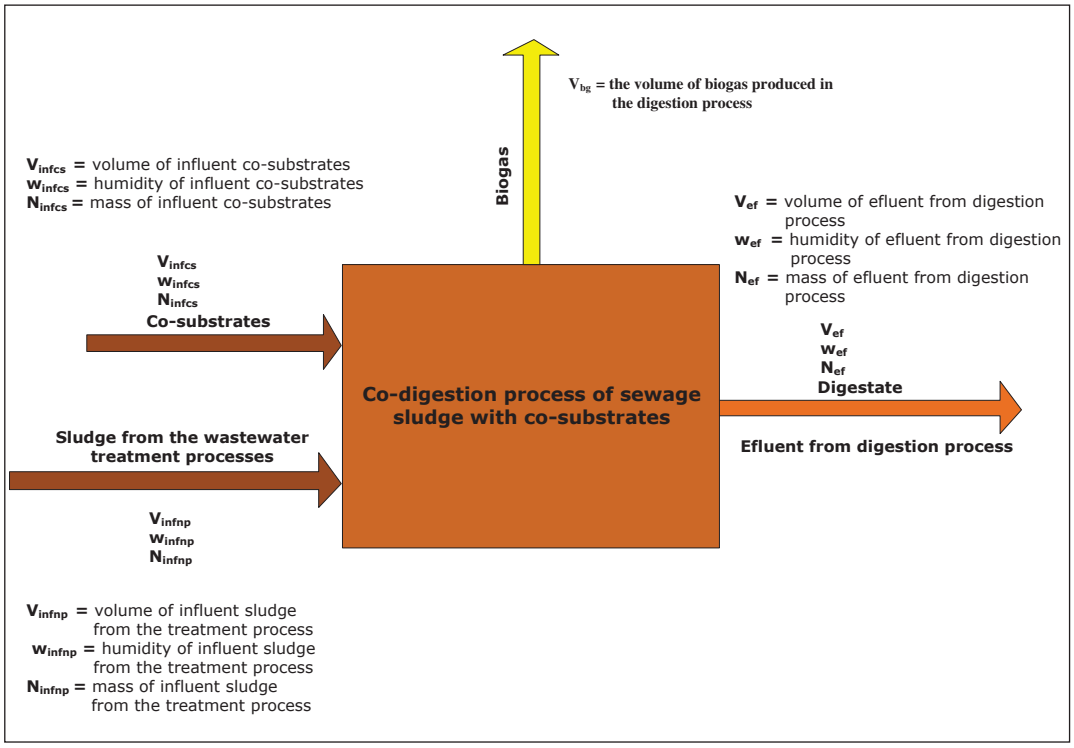

Figure 3. Mass and volume-flow of the digestion process

4.1. Description of process parameters

For mass balance of processes that take place on the line of sludge treatment process in a wastewater treatment plant, should be described and calculated the parameters of influent and effluent for each process [11].

For the digestion process described in Figure 2, the influents are represented by the mixture of sludge resulted from wastewater treatment processes and by the mixture of co-substrates derived from the food industry of operating area. The effluents of digestion process are represented by fermented sludge, the digestat, where appropriate, and the biogas produced in digestion tanks.

Mass balance of fermentation process is necessary for calculating effluent output parameters, namely the volume, humidity and digested sludge mass as well as volume of biogas produced by digestion process. Output parameters of fermentation process represent input parameters for the next process of the sludge treatment line, namely the dehydration process.

4.2. Calculationsummary of mass balance for fermentation process

Process parameters are calculated using MathCAD application, which is a numerical computation mathematical software. The

parameters are calculated using a calculation summary, that can be drafted, considering the input parameters of fermentation process and having as purpose the calculation of parameters at the exit of process.

The input parameters of digestiontion process, actually measured during operation of facilities, or established according to design data of installations that ensure treatment process, are the following:

- The volume of sludge from wastewater treatment process;
- The volume of co-substrates, introduced into the co-digestion process;
- The humidity of sludge from wastewater treatment process and co-substrates, introduced into the co-digestion process;
- The organic loading of sludge from wastewater treatment process and co-substrates, introduced into the co-digestion process;

To calculate the output data of digestion process, in addition to input data mentioned above, in the calculation summary were used some coefficients taken from the technical design standards of wastewater treatment plants, for sludge treatment line. These calculation coefficients are described below:

- Fermentation technique limit: l_f = 40-55% [12];
- Humidity increase by fermentation : Δwf = 1-2% [12];
- Specific biogas production : q_{bg} = 0,5-0,8 m^3 biogas/kg reduced organic matter [12];
- The organic load of anaerobic digestion tank RFN : I_{oRFN}= 1.5...3 kg/m^3day [12].

Calculation summary for mass balance of digestion process is presented in Appendix 1.

5. Conclusion

Calculation summary enables a rapid and accurate calculation of process parameters by using the MathCAD IT application, which is mathematical computation software. The parameters calculated according to the calculation summary presented, allow obtaining a mass or volume balance, for an co-fermentation process that uses besides sewage sludge and co-substrates with high organic loads.

Mass and volume balance of the fermentation process of sludge treatment line offers the possibility to obtain the following parameters of the process:

- Wet sludge quantities introduced in process and removed from process, for a specified period;
- Dried sludge quantities (% TS) introduced in process and removed from process, for a specified period;
- Digested sludge volume, removed from process, for a specified period;
- The volume of biogas produced by digestion in the specified period.

The calculation of the above parameters is based on the premise that all process installations are used to nominal capacity, namely that, the normal operation time is 8,500 hours per year.

Mass balance of the fermentation process on the sludge treatment line is necessary to analyze the process efficiency regarding the following aspects:

- The amount of organic matter, reduced by bacterial biodegradation;
- Specific biogas production;

- The organic load of digestion tanks;
- The degree of wet sludge mass reduction after process digestion;
- The degree of downstream treatment processes charging, namely, the sludge dehydration and sludge drying using heat supplied by CHP with biogas.

By comparing the parameters obtained by the calculation with those actual obtained during operation, the degree of installed capacities utilization, at the nominal design parameters, can be estimated.

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