Influence of anaerobic digestion process parameters on the amount of volatile fatty acids formed in wastewater

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Abstract. The limiting indicator for the course of biological wastewater treatment is easily obtainable organic matter. If the wastewater entering the sewage treatment plant is depleted in terms of the content of easily accessible organic matter, then a set of measures aimed at their enrichment is required. Prefermentation of raw sludge was considered as a method of increasing the proportion of readily available organic matter. The influence of the main technological parameters of anaerobic digestion on the amount of volatile fatty acids formed was studied.

Keywords: prefermentation, acidification, easily obtainable organic matter, phosphorus removal, wastewater treatment

Introduction

The inflow of nutrients with wastewater into water bodies leads to an increase in the content of biogenic and organic compounds, a decrease in oxygen content, the appearance of anaerobic zones, an increase in water turbidity, a change in color, and contamination with microorganisms, including pathogens.

Biogenic compounds, such as nitrogen and phosphorus, can get into surface water both naturally (leaching from the top layer of soil, precipitation, various processes in the water body itself) and as a result of human activities through the discharge of wastewater from industrial, domestic and agricultural facilities.

Exceeding the maximum permissible concentrations (MPC) during the discharge of nutrients into water bodies can lead to the emergence of the eutrophication process. This leads to environmental changes, deterioration accompanied by adverse effects on water use for human consumption and other various purposes.

Soluble phosphorus is the main limiting element for the development of algal blooms in a water body, affecting the process to a greater extent. Therefore, in order to reduce the

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intensity of the process of eutrophication of water bodies, it is necessary to effectively remove phosphorus, taking into account the requirements of the MPC [1], [2].

The process of wastewater dephosphoration is directly related to the vital activity of bio-P bacteria or phosphate-accumulating organisms (FAO). Under anaerobic conditions, without access to dissolved and chemically bound oxygen, these bacteria intensively consume volatile fatty acids, converting them into reserve substances, in the form of polymeric saturated hydroxy acids (PNO) (in parallel, glycogen is consumed in cells), using the energy of polyphosphate bonds, while the phosphorus of polyphosphates enters the medium. Further, in the aerobic zone, the stored organic matter is oxidized, and the released energy is used to absorb orthophosphates, while the conversion of orthophosphates into polyphosphates occurs, while glycogen synthesis occurs in the cells. As a result, the polyphosphate stored in the cells is removed from structures with excess activated sludge. Based on this, it can be noted that the quantitative content of readily available organic matter directly affects the stability of the biological percentage [3].

If the wastewater entering the sewage treatment plant is depleted in terms of organic matter, then a set of measures aimed at its enrichment is required. There are several main methods for increasing the content of biologically readily available organic matter – the rejection of primary sedimentation, the addition of an external organic substrate and the pre-fermentation of raw sludge.

The supply of wastewater without preliminary sedimentation leads to an increase in the cost of aeration (an increase in the load associated with the process of oxidation of organic substances and nitrogen compounds), a decrease in the age of activated sludge and its excessive growth.

The addition of an external carbon source to wastewater with low organic matter content increases the cost of the treatment process – higher operating costs. In addition, the creation of a chemical farm associated with the use of an organic substrate creates a potential danger for employees, since acetic acid is a dangerous chemical, methanol is a poison [4] – [9].

In this regard, the most promising method of enriching wastewater with biologically readily available organic matter is the use of metabolic products of the first stage of anaerobic digestion of sludge.

The aim of the work is to study the influence of the technological parameters of the process of the first stage of anaerobic digestion of the studied sludge on the amount of volatile fatty acids formed.

Materials and methods

The study was carried out on a mixture of real wastewater and sludge from sewage treatment plants. The essence of the experiment was as follows: plastic tanks (acidifiers) with a volume of V one liter each were filled with raw sludge taken from the primary settling tank and placed in various temperature conditions ($t = 14 - 35°C$).

The temperature of the fermented sludge was heated and maintained by a cylindrical *AQUAEL* heater, and cooled by placing the tanks in a *TS 608/2-i* thermostat. Temperature conditions above $35°C$ were not considered for economic reasons, since the operation of structures at such temperatures requires high operating costs to maintain working conditions. Mixing of a part of the fermented sludge was carried out with the help of magnetic stirrers *PE-6110*. Closing of the tank from above was not provided due to the design features of the primary settling tanks (no lid / overlap).

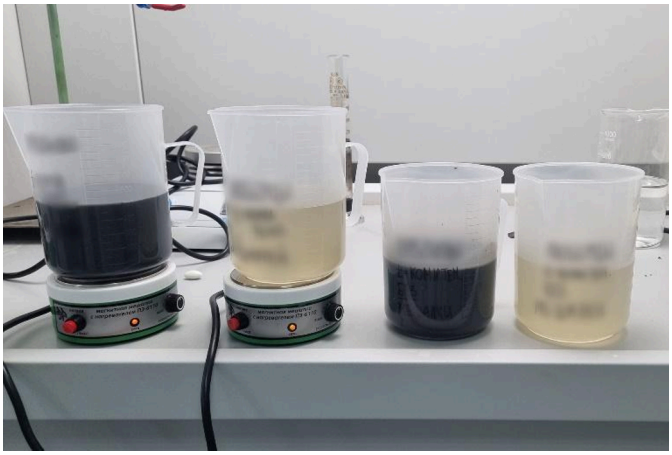

Fig. 1. Tanks with sludge to be tested from primary settling tanks

Results

The main objective of the study was to study the influence of the technological parameters of the process of the first stage of anaerobic digestion of the studied sludge on the amount of volatile fatty acids formed.

The results of the study are presented in the form of graphical dependencies in figures 2 – 5 below.

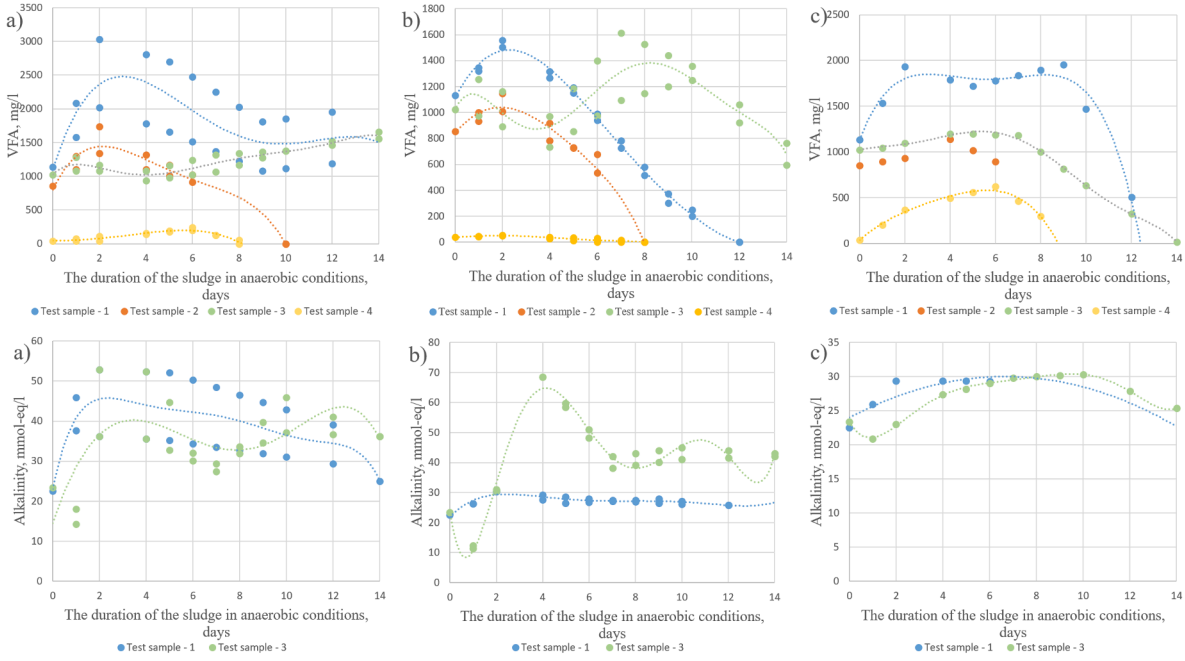

Fig. 2. Effect of the duration of raw sludge residence under anaerobic conditions, at a) $t = 14°C$, b) $t = ambient\ temperature,°C,$ c) $t = 30°C,$

1) on the concentration of VFA formed, *mg/l*; 2) by the amount of alkalinity, *mmol – eq/l.*

Having reached the limit, the process of acid (hydrogen) fermentation of the sludge smoothly turns into alkaline (methane) fermentation – the concentration of volatile fatty acids decreases and reaches the initial values.

As a result of anaerobic digestion, the concentration of carbonates gradually decreases, reaching a minimum value at a certain point. The minimum concentration of HCO_3^- follows from the fact that only complex organic substances are present in the sludge – during this period, the intensive formation of volatile fatty acids occurs. The increase in HCO_3^- content is due to the conversion of acetic acid into energy by organisms that carry out the process of methane fermentation – obligate anaerobes.

Some of the anaerobic digestion samples studied did not show any noticeable change in alkalinity. This is due to the slightly lower concentrations of the formed readily available organic matter in these test samples compared to other samples, for which the nature of the alkalinity change is more pronounced.

The maximum increase in the concentration of volatile fatty acids 16 times higher than the incoming one is observed at a temperature of 30 °*C* from 39 *mg/l* to 625 *mg/l* by 586 *mg/l*. Concentrations of volatile fatty acids at a temperature of 14 °*C* also increased significantly from 39 *mg/l* to 245 *mg/l* at 206 *mg/l* (6.2 times) and from 1134 *mg/l* to 3030 *mg/l* at 1896 *mg/l* (2.67 times).

This indicates that the maximum amount of readily available organic matter is not always associated with an increase in the temperature of the digested sludge, and also depends on the acidification potential of the incoming wastewater and raw sludge of treatment facilities[10].

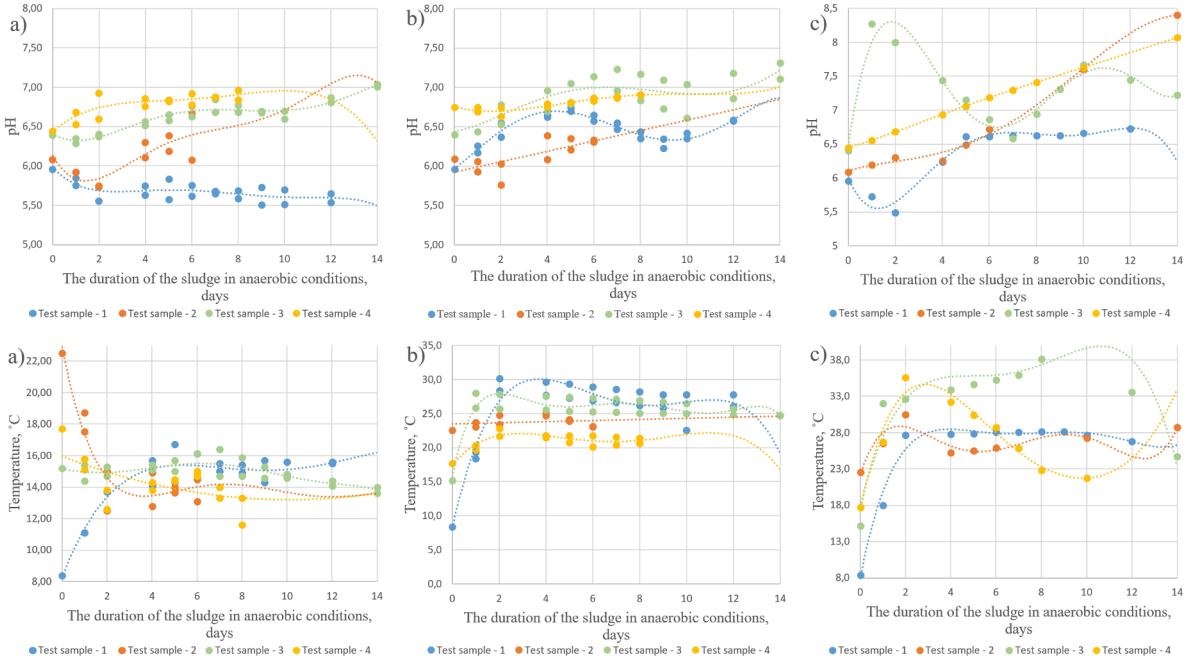

Fig. 3. Effect of the duration of raw sludge residence under anaerobic conditions, at: a) $t = 14°C$, b) $t = ambient\ temperature, °C$, c) $t = 30°C$,
1) pH value; 2) by the value of the temperature, °*C*.

The concentration of hydrogen ions is essential for the vital activity of microorganisms that carry out the fermentation process. In addition, a sharp change in the reaction of the medium has a direct impact on the rate of biochemical processes. The initial pH value is directly related to the nature of the incoming wastewater. The optimal pH value for hydrogen ion activity is between 5.5 and 7 units. The change in pH level during the occurrence of sludge under anaerobic conditions is shown in figure 3 above. The decrease in pH levels can be explained by the formation of volatile fatty acids, i.e. the predominance of H^+ ions.

As the observation shows, in the course of the study, a low background of increase in phosphates in the process of anaerobic digestion is created for the first 1-5 days, their concentration in the average increases by an average of 1.3-2 times compared to the initial values. A much larger amount of phosphates is subsequently released with a longer period of residence of the sludge in anaerobic conditions.

As for the change in the concentration of nitrogen ammonium salts during pre-fermentation of the sludge, it increases on average by 1.5 – 2 times compared to the initial values.

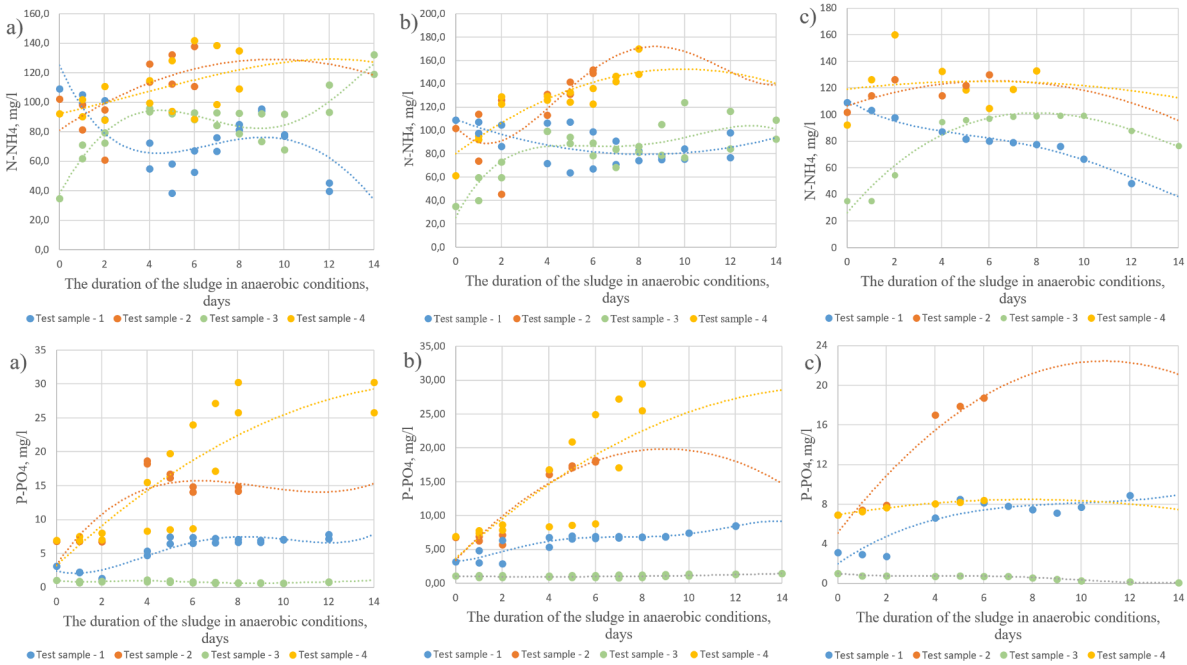

Fig. 4. Effect of the duration of raw sludge residence under anaerobic conditions, at:
a) $t = 14°C$, b) $t = ambient\ temperature, °C$, c) $t = 30°C$.
1) by the amount of ammonium nitrogen; 2) by the amount of phosphorus phosphate.

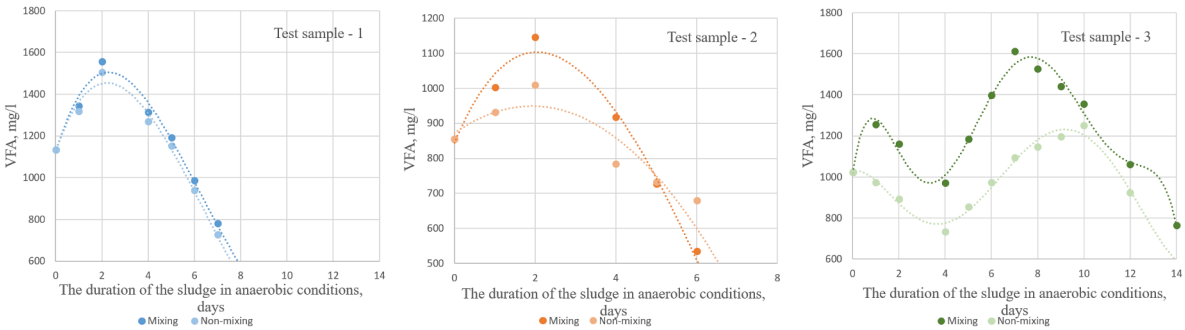

Fig. 5. Effect of agitation on the concentration of volatile fatty acids formed, other things being equal

Another factor influencing the concentration of volatile fatty acids is mixing. Maintaining a stable fermentation process is only possible with constant mixing of the mixture of raw sludge and wastewater, as this allows them to be evenly distributed throughout the volume of the acidifier, to create a homogeneous medium and to prevent the formation of a crust in the upper part of the fermentation mass, which provides the best conditions for the development of bacteria. To achieve this goal, it is possible to use mechanical and gradient agitators, or to recirculate the fermented sludge.

Conclusions

As a result of the study, the nature of changes in the process of digestion of a mixture of raw sludge and wastewater of various sewage treatment facilities is shown of such basic characteristics of the process as the concentration of volatile fatty acids, nitrogen, phosphorus, pH, alkalinity, as well as the influence on them of such technological parameters as the duration of the sludge stay in anaerobic conditions, process temperature, mixing, the purposeful change of which will increase the efficiency of the process digestion and, as a result, improve the quality of wastewater treatment from nutrients.

As a result of the study, there is a positive effect on the amount of volatile fatty acids formed by the presence of mixing, temperature and duration of the sludge in anaerobic conditions.

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