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IMPROVEMENT OF SLUDGE STABILIZATION TECHNOLOGY ALONG WITH BIOGAS PRODUCTION

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Studying the microbiology of biological fermentation procedure, physical and chemical characteristics of activated sludge of Bortnichy aeration station. Suggestion the possible methods and ways how to increase the rate of biological fermentation procedure.

Key words: alternative energy sources, activated sludge, anaerobic fermentation, biogas, ultrasound, hydrolysis.

Problem Statement. Today one of the main problems for Ukraine is formation and accumulation of lots of organic wastes that need to be utilized in some ways. The average amount of activated sludge that is formed in sewage treatment plants of both city and village can be estimated as 45 mill m3 per year. This problem requires quick solution. In order to solve this task, it is needed to suggest ways and methods for improving of activated sludge stabilization technology and increasing the efficiency of biogas production with less energy inputs. Nowadays there are several ways of activated sludge utilization. It can be used as agricultural fertilizer, can be burned with further energy production or recycled into building materials. On the one hand the implementation of these technologies is perspective ones, but there is the other site of the coin. The disadvantage of the first method is probability of pathogenic microorganisms getting into soil. The second method (burning) causes environmental pollution, and the third technology (recycling into building materials) is expensive enough.

Despite of these disadvantages using activated sludge as a fertilizer is the most promising and perspective one.

It is obvious that for increasing the quality of this fertilizer, it is required to eliminate pathogenic microorganisms. This is an actual task for solution. In order to get rid of them various stabilization technologies are used. The most popular one is anaerobic stabilization.

Analysis of publications. According to literature sources, three main groups of anaerobic fermentation can identified, which imply different kinds of installations.

– group of one-phase technologies representing one-chamber installations;

– group of two-phase technologies representing two-chamber installation;

– group of technologies, that takes into account division of fermentation into stages. This group is mainly represented by multy-chamber facilities [1].

Each of this group takes into account peculiarities of fermentation procedure, and causes production of biogas. Among the disadvantages of the two first groups we can identify long-term proceeding of the process that can last for thirty days, remaining of the pathogenic organisms in final sludge and loose of biogas efficiency. So, the last group of technologies is considered to be prospective one for future usage.

According to the last group of technologies, scientists identify four stages of anaerobic fermentation:

– hydrolysis – the first stage of anaerobic fermentation. Within processing of this stage, such complex organic compounds as proteins, carbohydrates and fats are broken down into simpler ones – molecules that are soluble and transportable within a cell membrane. Hydrolytic enzymes secreted by special groups of bacteria brakes chemical bonds in mentioned above complex compounds [2].

Thus, such polysaccharide as cellulose is hydrolyzed into glucose with the help of cellulose enzyme; mannose – with the help of pectinases and hemicelluloses; hemicelluloses and pectin – to monomers like glucose, pentoses, xylose and etc.; starch is converted to glucose with the help of amylase enzyme.

Extracelularly produced lipases hydrolized by lipolytic bacteria convert lipids to long-chain volatile fatty acids [3].

Proteins are hydrolysed to amino acids with the help of protease enzymes, being secreted by Butyrivibrio, Bacteriodes, Selenomonas and Streptococcus [3].

The next chemical formula shows the hydrolysis reaction of carbohydrates' breaking into simple sugars. For example, equation 1.1 presents the transformation of glucose:

$$C_6H_{12}O_4 + 2H_2O\ C_6H_{12}O_6 + 2H_2 \quad (1.1)$$

(sugar polymer) + (water) • (glucose) + (hydrogen)

The hydrolysis procedure of carbohydrates takes place within a few hours, when hydrolysis of proteins and lipids finishes in a few days. As a result the degradation of cellulose occurs slowly and incompletely. During the hydrolysis, facultative anaerobic microbes consume oxygen, being dissolved in water, and creates favorable low red-ox potential for the obligatory microbes [3, 4].

– acidification/fermentation (acidogenesis) is the second step of anaerobic fermentation process. During this stage the acid forming bacteria break down the products of hydrolysis, and as a result acetic acid (CH3COOH), hydrogen (H2), carbon dioxide (CO2) and alcohols are released. Also such lower weight simple organic acids as propionic and butyric acids, being further converted to acetic acids, can be produced at this stage [5].

Below there are two chemical reactions showing the principle of acidogenesis stage work. The equation 1.2 shows how glucose is converted into ethanol and equation 1.3 presents the formation of propionic acid from glucose.

$$C_6H_{12}O_6 \cdot 2CH_3CH_2OH + 2CO_2 \quad (1.2)$$

(glucose) • (ethanol) + (carbon dioxide)

$$C_6H_{12}O_6 + 2H_2 \cdot 2CH_3CH_2COOH + 2H_2O \quad (1.3)$$

(glucose) + (hydrogen) • (propionic acid) + (water)

– acetogenesis is the third step of anaerobic fermentation, when with the help of hydrogen producing bacteria convertation of fatty acids to acetate (20 %) and hydrogen gas (4 %) occurs. During this stage concentration of biological oxygen demand (BOD) and chemical oxygen demand (COD) is reduced. The amount of hydrogen is critically important for anaerobic digestion process; its concentration ought to be kept in range of 60 – 200 ppm. If the concentration is higher than the established one, then the further chemical reaction will be inhibited [4, 5].

– methanogenesis is the last stage of anaerobic digestion process, when methane and carbon dioxide (biogas) is produced from soluble products of acodogenesis and acetogenesis (acetic acids, carbon dioxide and hydrogen). The methanogenic bacteria, being responsible for conversation are divided into two groups: hydrogen-carbon consumers and acetate consumers. The acetate consumers are represented by Methanosarcina and Methanothrix bacteria, and produce about 70% of methane from acetic acid. Alkali environment is preferable for methanogens [6].

Peculiarity of these stages is that their procedure requires different parameters of environment. So, the *purpose* of this article is to analyze main optimal parameters of each stage; compare these values with the laboratory researches of BSA sludge; and make suggestions how the process can be optimized.

Main Part. It is known that optimal value of parameters for procedure of one stage is not optimal for the other one. After analyzing the scientific literature, two main parameters of anaerobic sludge stabilization were identified. These parameters are: measure of acidity of a solution – pH value and temperature regime [5, 6]. The obtained data are presented in table 1.1.

Table 1.1

Optimal conditions for sludge stabilization technology

	Hydrolysis	Acidogenesis	Acetogenesis	Methanogenesis
pH	6,8-7,4	5,2 – 6,5	6,5 – 7,2	7,8-8,2
T, 0C	35	35	55	55 – 60
Ammonia	1500 mg/L	2000 mg/L	2500 mg/L	3000 mg/L

Laboratory researches were done and main physical and chemical characteristics of activated sludge from Bortnichy station of aeration were determined. The results of experiments are shown in table 1.2.

Table 1.2

Physical and chemical characteristics of BSA sludge

№	Name of index	Value
1	Concentration of hydrogen ion (pH)	pH = 6,9
2	Temperature	T = 10°C
3	Ammonia concentration	C = 1,209 mg/dm^3

As the values are different, it is reasonable to use and create technology with division of various stages in space, provision of optimal parameter values for each stage.

For implementation of this technology it was suggested to use screw methane tank. Its scheme is presented in figure 1.1.

Hydrolysis – is the first and the limited stage in space. Without its ending, the other stages can't begin. One of the main methods of process intensification totally is speeding of fermentation hydrolysis. There are such types if intensification:

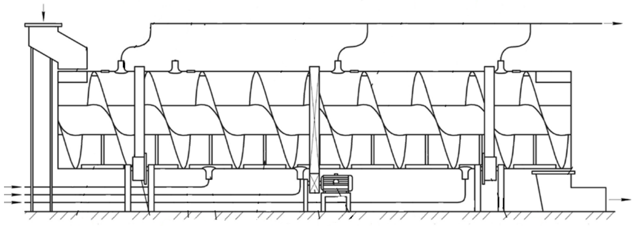

Fig.1.1. Scheme of facility for activated sludge stabilization

– Physical: mixing, ultrasound, vibration, thermal hydrolysis.

– Chemical: enzymes and catalysts; alkaline hydrolysis; acid hydrolysis.

– Mixed: thermal-alkaline hydrolysis.

As a result of hydrolysis intensification methods, ultrasound pre-treatment is considered as perspective one. In order to localize ultrasound impact it is recommended to use hydroxylation facility as separate technological equipment.

And for de-watering of fermented sludge, it is recommended to use additionally device for dehydration – sludge dryer. Suggested technology is shown in figure 1.2:

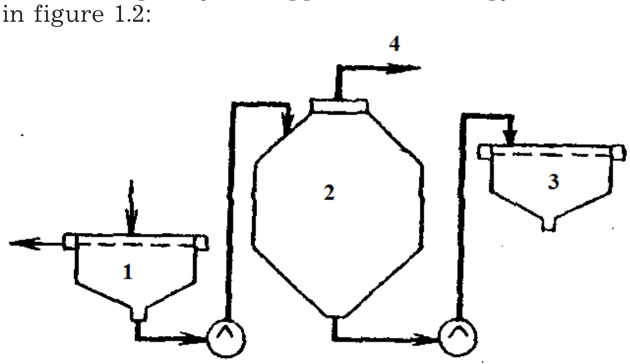

Figure 1.2. Scheme of sludge stabilization technology: 1 – hydrolysation facility; 2 – anaerobic methane tank; 3 – sludge dryer; 4 – biogas

So, from the scheme we see that firstly sludge is pre-treated, then it is delivered to crew methane tank, then to sludge dryer. Finally it can be used as fertilizer, and produced biogas – on technological needs.

Conclusions. The necessity of alternative energy sources forced the scientists and engineers searching for new ways of alternative energy production. One of such methods is anaerobic recycling of activated sludge in sewage treatment plants. Sludge stabilization technology is not the new one, and is already successfully applied in Ukraine. The problem is that it requires to be improved. It was suggested a group of technologies, that takes into account division of fermentation into stages. As the process consists of four stages, a four-phase methanetank construction was presented. Also, laboratory investigations were done. The results were compared with optimal parameters. After analyzing the kinetic of the process, it was identified that the first phase "hydrolysis" is the limiting one. In order to increase its rate, a scheme presented in figure 1.2 was suggested.

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УДОСКОНАЛЕННЯ ТЕХНОЛОГІЇ СТАБІЛІЗАЦІЇ ОСАДУ СТІЧНИХ ВОД З ОТРИМАННЯМ БІОГАЗУ

Анотація
Досліджено мікробіологію анаеробної ферментації, фізико-хімічні характеристики активного мулу Бортницької станції аерації. Розроблено рекомендації щодо можливих шляхів прискорення процесу анаеробної ферментації.
Ключові слова: альтернативна енергетика, активний осад, анаеробна ферментація, біогаз, ультразвук, гідроліз.

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СОВЕРШЕНСТВОВАНИЕ ТЕХНОЛОГИИ СТАБИЛИЗАЦИИ ОСАДКОВ СТОЧНЫХ ВОД С ЦЕЛЬЮ ПОЛУЧЕНИЯ БИОГАЗА

Аннотация
Исследовано микробиологию анаэробной ферментации, физико-химические характеристики активного ила Бортнической станции аэрации. Разработаны рекомендации относительно возможных путей ускорения процесса анаэробной ферментации.
Ключевые слова: альтернативная энергетика, активный осадок, анаэробная ферментация, биогаз, ультразвук, гидролиз.