Chapter 11
Environment-Friendly Technology of Airport's Sewerage

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11.1 Introduction

Several types of sewage waters are generated during airport functioning. They can be divided into industrial, domestic, and rain waters. It is known that 1 m^3 of discharged sewages, which have been not sufficiently purified, can result in a situation when from 10 to 50 m^3 of natural clean water becomes unsuitable for many types of usage.

In [17], treatment technologies, employed at treatment plants, depend on sewage water types and their compositions and can differ substantially. Quality of treated waters can also differ depending on technology. Considerable amount of harmful sediments are created during all types of treatment processes. They also require to be utilized. In [2], at the same time, treatment plants are objects, where it is possible to get additional alternative energy sources and other valuable materials.

Therefore, searching for environmentally friendly and energy-efficient ways to organize airport sewage systems is an actual task.

11.2 Research Methods

There was a system approach applied while doing this research. The approach was used to analyze different methods of anaerobic digestion intensification and to form new technological requirements to digestion organization. The approach was also used to analyze highs and lows of conventional methods of microalgae cultivation and to form propositions to organize the cultivation more effectively. There were

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applied deductive methods for studying four different stages of anaerobic digestion and optimum characteristics of the mediums to accomplish them more efficiently. The same methods were applied for researching different techniques of using photobioreactors for microalgae cultivation. There were applied inductive methods to develop new components of the technological process.

11.2.1 Analysis of the Research and Publications

While developing sewerage of an airport and other airline enterprises, it is necessary to take into account several factors, such as amount and composition of sewage waters, which are discharged, possibility and reasonability of treating them on local treatment plants, possibilities of different treatment technologies application, possibility and reasonability of valuable materials extraction out of the sewage water subsequent using of these materials, possibility of obtaining and utilizing additional energy resources at treatment plant, etc.

Quality of treated sewage water determines its subsequent influence on environment. In accordance with the concept of development of the state enterprise “Boryspil International Airport,” when the airport achieves its full handling capacity of 66.5 million passengers per year, quantity of just sanitary sewage water will make up to 18,500 m^3 per day. When discharging this treated water insufficiently, considerable amount of pollution will get into the environment. At such amounts of sewage water treating, about 180 m^3 of sludges will be produced during treatment process. These sludges will need utilization. In the conditions of insufficient supply with freshwater, the question arises about possibility of sewage water recycling and using for technical purposes. Water recycling dictates the necessity of increasing treated water quality. In accordance with the conception, prospective electrical power demand of the airport will go up to more than 88 MW; its thermal power demand on heating and hot water supply will exceed 280 MW. In the conditions of shortage in power resources arises a question about partial power supplying, using own alternative energy sources.

Conventional sewage water treatment facilities usually apply such methods as mechanical treatment, biological treatment, and biochemical treatment. Using these methods, treatment plants are not always able to provide sufficient purification of the water, especially when pollution content in received sewage water substantially varies. It is advisable to apply additional purification facilities for aftertreatment of sewage waters. Methods of nature purification are often used for these purposes. In [8, 12], some of the most popular installations are used: special open oxidation ponds, where different aquatic organisms are cultivated; special agricultural tanks filled with hydroponics, where different aquatic plants are grown; special soil filter systems, where different soil plants can grow; and others [10].

One of the main drawbacks of these methods is that all of them require large areas both for their placement and for sanitary protective zones, which have to be established around them.

One more drawback, which can be named, is that these methods can give little benefits apart from doing final sewage water treatment. On the other hand, sewage water can be directly used as medium for aquatic organism cultivation. Different algae can be used as cultivated organisms. It has many advantages.

Among the algae cultures, which can be cultivated, the most perspective can be microalgae [21]. Some of their types are very rich on lipids. The next culture can be recomended for cultivating, which have percentage of lipids in them:

- *Botryococcus braunii* – 25 ... 85%;
- *Neochloris oleoabundans* – 35 ... 54%;
- *Stichococcus* sp. – 40 ... 59%;
- *Nannochloropsis* sp. – 31 ... 68%;
- *Dunaliella tertiolecta* – 36 ... 42%;
- *Dunaliella salina* – 16 ... 44%;
- *Haematococcus pluvialis* – 25 ... 45%;
- *Scenedesmus dimorphus* – 16 ... 44%;
- *Prymnesium parvum* – 22 ... 38%;
- *Tetraselmis suecica* – 20 ... 30%;
- *Chlorella* sp. – 28 ... 32%;
- *Chlorella vulgaris* – 14 ... 22%;
- *Isochrysis galbana* – 22 ... 38%;
- *Euglena gracilis* – 14 ... 20%.

In [24] due to the high lipid content, these microalgae can be the sources of motor fuel of the third generation.

Conventional facilities for microalgae cultivation, so-called bioreactors, can be divided into two types: the open type and the closed type. The main drawbacks of open-type bioreactors are vulnerability to weather conditions, substantial losses of CO2 during cultivation, and complicacy in providing continuous cultivation and for closed-type bioreactors – complicacy in feeding CO2 inside the reactor and limitedness in productivity because of low CO2 solubility in water.

Integral part of any water treatment process is producing some amount of sludge. At sanitary sewage water treatment plants, the sludge can be of different types. But primarily, it is row sludge from primary settlers and activated sludge from secondary settlers. Altogether, the total volume of them can reach 1% of the volume of treated water. Compositions of these sludges are different. The first one contains from 65% to 75% of organic substances and the second one from 70% to 75%.

In [11], organic part of both sludges contains primarily hydrocarbons, proteins, and fats. Altogether they make up to 85% of all organic part with respect to the mass. The rest is a group of different lignin-humus compounds.

In [3], utilization of these sludges is an actual task. Among the known methods of sludge utilization, it is possible to name these methods:

- Combustion
- Using as material for construction purposes
- Using as food additives for some animals
- Using in agriculture as organic fertilizer and others

Combustion method has become widespread. Burning of sludges is carried out mainly in multiple-bedded furnaces or drum-type furnaces with fluidized bed. This is a quick method to get rid of the sludges. Moreover, ash, which is formed during combustion, has characteristics, which allow using it for different purposes. For example, adding this ash to sludge before dehydration allows accelerating the process with using fewer amounts of other chemicals.

However, it has shortcomings, an economic factor in particular, because efficiency of the process is questionable. It depends on two main characteristics of the sludge: its specific lower heat value and its humidity. Heat value, in turn, depends on percentage and composition of organic part of the sludge. Amount of thermal energy, which can be obtained while burning 1 kg of the sludge, can be calculated by the formula

$$Q_{\text{burn}} = q_{\text{org}} \cdot m_{\text{org}}, \, [\text{MJ/kg}]\,, \tag{11.1}$$

where q_{org} is the law heat value of the sludge's dry organic part in MJ/kg and m_{org} is the mass of the dry organic part in 1 kg of the wet sludge (kg/kg). Mass of the dry organic part, which is included in 1 kg of the sludge, can be defined by the formula

$$m_{\text{org}} = \left(1 - \frac{w}{100}\right) \cdot \frac{c}{100}, \, [\text{kg/kg}]\,, \tag{11.2}$$

where w is the humidity of the sludge (percent of the water in the sludge) and c is the content of organic matter in dry part of the sludge with respect to the mass, in %. Amount of thermal energy, which will be consumed on water evaporation of 1 kg of the sludge, can be calculated by the formula

$$Q_{\text{evapor}} = q_{\text{evapor}} \cdot \frac{w}{100}, \, [\text{MJ/kg}]\,, \tag{11.3}$$

where q_{evapor} is the total consumption of thermal energy on water heating and evaporation, in MJ/kg.

Sanitary sludges usually have specific heat value q_{org} from 16.8 to 27.8 MJ per 1 kg of their dry organic matter. Content of organic matter c makes up from 65% to 75% of the sludge's dry part.

Let us calculate energy balance of raw sludges, which are just out of settlers. Humidity of raw sludges w can vary from 96% to 98%. Mass of its dry organic part, according to the formula 11.2, will be in the range of

$$m_{\text{org}}^{\text{raw}} = \left(1 - \frac{(96 \div 98)}{100}\right) \cdot \frac{(65 \div 75)}{100} = 0,013 \div 0,03, \, (\text{kg/kg})\,.$$

The specific amount of thermal energy, obtained from burning such sludge, according to the formula 11.1, will be in the range

$$Q_{\text{burn}}^{\text{raw}} = (16.8 \div 27.8) \cdot (0.013 \div 0.03) = 0.218 \div 0.822, \, (\text{MJ/kg})\,.$$

In [11], total consumption of thermal energy on heating and evaporating of 1 kg of water, which is in the sludge, is $q_{\text{evapor}} = 4.2$ MJ/kg. So the amount of thermal energy on evaporating, while burning 1 kg of raw sludge, according to the formula 11.3, will be in the range

$$Q_{\text{evapor}}^{\text{raw}} = 4.2 \cdot \frac{(96 \div 98)}{100} = 4.032 \div 4.116, (\text{MJ/kg})\,.$$

As one can see, in the case of burning raw sludge, even in theory, the amount of energy, which is needed for evaporating, is much bigger than the amount of energy obtained from burning. It means that raw sludge cannot be burned independently. It requires a lot of additional fuel to fill the gap in energy balance. After mechanical dewatering, the sludge can have humidity from 75% to 85%. Let us calculate the same energy balance for this sludge. Mass of its dry organic part, according to the formula 11.2, will be in the range of

$$m_{\text{org}}^{\text{dewater}} = \left(1 - \frac{(75 \div 85)}{100}\right) \cdot \frac{(65 \div 75)}{100} = 0,0975 \div 0,1875, (\text{kg/kg})\,.$$

The specific amount of thermal energy, obtained from burning in this case, according to the formula 11.1, will be in the range

$$Q_{\text{burn}}^{\text{dewater}} = (16.8 \div 27.8) \cdot (0.0975 \div 0.1875) = 1.638 \div 5.1375, (\text{MJ/kg})\,.$$

The amount of thermal energy on evaporating in this case, according to the formula 11.3, will be in the range

$$Q_{\text{evapor}}^{\text{dewater}} = 4.2 \cdot \frac{(75 \div 85)}{100} = 3.15 \div 3.57, (\text{MJ/kg})\,.$$

One can see from these calculations that positive energy balance, even in theory, can be achieved only while incinerating dewatered sludge with high specific heat value of its dry organic matter.

Environmental impact of combustion method can also be far from favorable. Burning products are discharged into the atmosphere. If the sludge contains salts of heavy metals, they go into the atmosphere too. To prevent atmospheric pollution, it is necessary to apply costly equipment for burning products purification.

While utilizing sludges for construction purposes, high energy-consuming pretreatment is also needed, in particular drying.

Activated sludge is very rich with proteins and contains a lot of different vitamins, especially vitamin B12. It makes possible to use it as a food additive to some animals' diets.

One of the most promising ways of sludge utilization can be using them as organic fertilizers. The sludges contain also a large amount of nutrients, which are valuable for agricultural fields.

At the same time, the sludges can contain a lot of pathogenic microorganisms and also salts of heavy metals. In addition, raw sludges are inclined to rotting processes, emitting methane into the atmosphere. All of these facts restrain using sludges as fertilizers.

One of the best ways to exterminate pathogens and, at the same time, to stabilize sludges, eliminating possibility of rotting, is anaerobic fermentation of sludges in methane tanks. If the process takes place at thermophilic conditions, it allows exterminating over 98% of pathogens.

In [1, 4], it is understandable that salts of heavy metals have to be removed from the sludges before fermentation and using them as fertilizers [20]. It is because they inhibit the process of fermentation and have very negative effect on agriculture. The presence of heavy metals is unwanted for almost all methods of sludge utilization. For example, after incineration, they can be discharged into the atmosphere along with combustion materials. In [14], there are methods of extracting heavy metals from sludges, but this is not the issue of this research.

Due to the presence of large amounts of organic substances in sludges, it allows obtaining energy-valuable biogas during fermentation. In [5], this biogas can be used for own purposes of a sewage treatment plant or can be sold to other gas consumers.

It may be possible to say that the main shortcoming of anaerobic fermentation is that conventional technologies of fermentation and, consequently, constructions of methane tanks are not perfect.

At conventional technologies, all the fermentation process is organized in the way that raw sludge, which is going to be fermented, goes into the methane tank and is mixed with the sludge, which is being fermented already. Mixing of these two sludges disturbs microflora, which is responsible for fermentation. It causes inhibitory effect on it. It results in slowing down of the fermentation and in decreasing completeness of organic matter decomposition. These, in turn, results in decreasing of biogas yield. In many cases, such technologies are considered to be not efficient.

So, it is a very actual task to develop new technologies of fermentation, which are based on results of latest scientific researches of processes, occurring in a methane tank during fermentation [26].

In [25], there is a large variety of methane tank constructions, which are classified according to different characteristics. There are also very many methods of intensification of fermentation processes in methane tanks. The methods can be combined in the next two groups [13].

The first group can be called biological methods. It includes cultivating and using new more efficient microorganisms, responsible for fermentation, like "Methanobacterium kadomensis St.23," obtained during laboratory research [26]; adding different catalysts to the fermented sludge, which accelerate the process [6]; and providing immobilization of microorganisms, when they are attached to different additional materials, such as fiberglass, pebbles, and so forth, which the inside capacity of a methane tank is filled with. Immobilization prevents efflux of microorganisms along with fermented sludge during unload process [15]; applying common fermentation of different types of wastes, so that they help each other to be fermented easier and others.

The second group can be called technological methods. It includes agitation of the sludge, so that microorganisms were distributed more evenly over the inner space of the methane tank and forming of dead spaces was prevented, where fermentation does not take place due to stagnation; application of different types of sludge pretreatment, such as mechanical destruction of clods in it, acid hydrolysis, alkaline hydrolysis, thermal hydrolysis, ultrasound irradiation, and so forth; and fermentation organized as several-stage process, so that it will be possible to prevent inhibitory effect of different groups of microorganisms on each other.

Some authors consider the last method as very difficult to realize. It is because they believe that designs of methane tanks have to be very complicated and it would be necessary to use additional also complicated devices [25].

In order to form propositions relative to new technology, let us consider technological methods.

The major resulting products of anaerobic fermentation are methane and carbon dioxide. They are formed as a result of decomposition of organic matter, which is present in the sludge. Over 90% of it can be decomposed. Researches, which have been made recently, show that rate of decomposition and percentage of decomposed organic matter at the end of the process depends on initial composition of the sludge and conditions, under which the process of fermentation takes place. The research allows applying new approaches to intensify the process, to make it more efficient and to propose new technology.

In conventional fermentation technologies, the process is usually organized in the next ways [9].

The first one – a methane tank consists of just one capacity, and all fermentation takes place in it. The process is continuous. It means that after equal intervals, portions of the sludge, which is being fermented, are unloaded out of the methane tank, and, at the same time, new portions of raw sludge are loaded inside. After that, raw sludge is mixed with fermented one to be involved in the fermentation process. The obvious drawback of this organization is that raw sludge is constantly mixed with fermented one, and, after regular unloading of the methane tank, in the unloaded portion of fermented sludge, there is always a certain concentration of unfermented (raw) sludge. It reduces biogas yield, because part of organic matter remains not decomposed and allows some pathogenic microorganisms to be carried out from the methane tank and to end up in the final fermented sludge. It raises environmental risks while using this sludge as fertilizer.

The second one – a methane tank consists of two capacities. In this case, intensive fermentation takes place in the first capacity with intensive biogas releasing. The second capacity serves for waning the process and for compacting the sludge, when water is partly separated from it. Such organization allows obtaining more condensed sludge with lower humidity and therefore allows decreasing volumes of sludge concentration tanks, for subsequent sludge dehydration. But the same drawbacks as in the previous way of fermentation are present here. It is because in spite of having two capacities, the main part of the process almost entirely occurs in the first one.

The third one – a methane tank consists of more than two capacities. The process is very similar to the second way of organizing fermentation. Additional capacities are added to the methane tank for better sludge concentration. It allows decreasing volume of fermented sludge due to lower humidity, but it also leads to necessity to create significantly more complicated design of the methane tank. Even so, characteristics of fermentation itself are not substantially improved.

Composition of microorganisms, which are responsible for fermentation, their activity, rate of reproduction, and, as a result, final products of their metabolism not only depend on raw sludge composition but also depend on conditions in the methane tank. Latest researches show that vital functions of microorganisms in anaerobic fermentation differ from the same functions during different aerobic processes substantially. Relationships between aerobic microorganisms are usually established in a way that some of them are predators and some are victims. So they compete with each other. In anaerobic processes, waste products of one type of organisms become nutrients for others. So there is no such competition [9]. All fermentation can be considered as several consecutive, relatively independent metabolic processes, when each of it involves different kinds of microorganisms [27].

It is possible to distinguish the next four groups of anaerobic microorganisms.

The first group provides hydrolysis of organic matter, when complicated compounds are decomposed to more simple organic substances, which are accessible for fermentation. Proteins hydrolyze into soluble peptones; hydrocarbons hydrolyze first into polysaccharides, then to oligosaccharides, and then to monosaccharides. Fats hydrolyze into glycerides, phospholipids, and others.

The second group provides acidogenesis, during which it produces volatile fatty acids, long-chain fatty acids, and alcohols. For this production, they use waste products, which were formed by the first group.

The third group provides acetogenesis. By using volatile fatty acids, long-chain fatty acids, and alcohols, the group produces acetate (acetic acid).

The final fourth group provides methanogenesis. Using acetate, it produces methane, which is the basic component of final biogas.

Among the characteristics of the medium that define activity and production rate of each group of microorganisms are medium temperature, its pH, concentration of oxygen, and others. For some groups of microorganisms, favorable values of these characteristics are different, sometimes substantially [16]. Especially different conditions require the second and the fourth groups of microorganisms, which are responsible for acidogenesis and methanogenesis. At conventional fermentation technologies, when all four parts of the process occur in a single capacity, it is impossible to create favorable conditions for all groups. So they usually try to benefit methanogenic organisms, because they are more susceptible to medium characteristics and grow more slowly. In this case, because of having different favorable conditions, activity of acidogenic microorganisms decelerates, and the amount of created volatile fatty acids, long-chain fatty acids, and alcohols decreases. Having less amount of nutrition, acetogenic organisms produce less amount of acetate. Because acetate serves as part of the nutrition for methanogenic organisms, final biogas yield goes down.

It is possible to create more favorable conditions for acidogenic microorganisms in the capacity. But it also makes no good. In these conditions, vital activity of the second group speeds up. It leads to producing more acids and alcohols that, in turn, causes substantial dropping of medium pH. Low value of medium pH inhibits vital activity of methanogenic microorganisms and also leads to producing less of biogas. It is obvious that the solution should be in searching such conditions, where there is equilibrium between vital activities of acidogens and methanogens.

But there also can be other solutions. According to results of latest research, if acidogenic and methanogenic anaerobic microorganisms are separated in space vital activity, both of them can be increased considerably. It is possible to conclude about favorable parameters of the medium not only for both of these groups of organisms but for the all four of them [18].

So, to intensify the process more effectively, it is necessary to divide all the process into four consecutive stages: hydrolysis, acetogenesis, acidogenesis, and methanogenesis. After dividing, it is necessary to use an individual capacity for each stage. In each capacity, it is necessary to create favorable conditions for microorganisms, responsible for accomplishing the stage.

At the stage of hydrolysis, medium conditions should stimulate decomposition of complicated organic compounds. At this stage, different pretreatments of sludge can be applied, such as mechanical grinding of the sludge, adding acids or alkalis to it, heating and keeping for some time at high temperature, and ultrasound irradiation of the sludge [7].

It is obvious that mechanical grinding can do no good for organic decomposition intensification. It is because sewage water sludges initially consist of very small particles.

Alkalis, while being added to sludges, stimulate decomposition better than acids.

Keeping the sludge for some time at high temperature gives good results; decomposition goes much faster, but it requires a lot of energy on heating process.

Irradiation with ultrasound causes quicker hydrolysis than other methods [7]. Ultrasonic cavitation arises under the influence of ultrasound. The cavitation causes mechanical destruction of organic matter. Intensity of destruction depends on cavitation intensity and, therefore, on intensity of irradiation. Increase of irradiation intensity leads to increase of energy expenditure. Adding barbotage of liquid medium with gas to irradiation allows increasing intensity of the cavitation [19]. It can be explained this way. Gaseous bubbles, which enter the medium, become cavitation nucleus, intensifying the process considerably with less additional expenditure of energy. The rate constant of organic matter destruction increases up to 2.6 times and biological matter up to 4.3 times.

Increase of pressure in the medium on the one hand intensifies bubble collapse and, thereby, increases local pressure rising, which in turn stimulates intensification of hydrolysis; on the other hand, it raises cavitational threshold, hampering appearance of cavitational bubbles themselves. Optimum value of excessive pressure, at which value rate constant of organic matter destruction becomes maximal, is 0.5 · 105 Pa. In comparison with conducting the same process at atmospheric pressure, the constant organic constituent increases up to 1.2 times and the constant of biological constituent up to 1.5 times [19].

Barbotage ought to be carried out with inert gas, which does not contain oxygen, in order to not to disturb medium in a methane tank. It is appropriate to use carbon dioxide, which is obtained during subsequent digestion.

In deeply hydrolyzed sewage water sludge, acidogenesis can be accomplished pretty fast [18]. The main final products, which are created during this stage, are long-chain fatty acids; volatile fatty acids, such as propionic acid, butyric acid, etc.; and alcohols. Along with them, carbon dioxide, small amount of hydrogen, and ammonia are released. It is also possible that hydrogen sulfide is created if sulfur is present in the sludge.

Total composition of final products at the end of this stage depends on partial pressure of hydrogen in the capacity. At high partial pressure, vital activity of microorganisms, responsible for this stage, goes up. They produce more ethanol, propionic and butyric acids, and other volatile fatty acids. Because of this, medium pH can drop from 5.2 to 5.0 [9]. At these conditions and at atmospheric pressure, carbon dioxide, which is produced at this stage, is released easily. But methane is not produced almost at all (no more than 4% of carbon dioxide quantity). It is because low pH of the medium inhibits vital activity of methanogenic microorganisms [27]. So, gaseous products of this stage will consist mostly of carbon dioxide with small amount of hydrogen, methane, and with admixture of ammonia and hydrogen sulfide. They can be withdrawn out from the capacity and will not end up in the final biogas.

At the low partial pressure of hydrogen, vital activity of acidogenic microorganisms is inhibited, and, instead of it, acetogenic microorganisms become more active. It leads to the situation when acids, which could have been created otherwise, are not created and are not processed into methane by methanogenic microorganisms. It results in decreasing final methane output. To conduct acidogenic stage more efficiently, it is necessary to maintain higher partial pressure of hydrogen in the capacity by injecting its additional amount into it.

Research shows that the stage of acidogenesis can be accomplished in 10 h if the conditions in the capacity are favorable [7]. The group of acetogenic microorganisms is divided into two types. The first type makes acetate by decomposing long-chain fatty acids, volatile fatty acids, and alcohols. For example, propionic and butyric acids are decomposed according to the next formulas

$$\mathrm{CH3CH2COOH + 2H2O \rightarrow CH3COOH + CO2 + 3H3} \tag{11.4}$$

$$\mathrm{CH3CH2CH2COOH + 2H2O \rightarrow 2CH3COOH + 3H3} \tag{11.5}$$

The second type makes the same acetate by using carbon dioxide and hydrogen according to the next formula

$$4H2 + 2CO2 \rightarrow CH3COOH + H2O \tag{11.6}$$

The second type of microorganisms cannot use all of the carbon dioxide and all of the hydrogen. So, a lot of carbon dioxide and some amount of hydrogen are released as gases.

Vital activities of both types of microorganisms also depend on partial pressure of hydrogen. At low partial pressure, vital activity of the first type becomes more active and of the second group is inhibited. At high partial pressure, the second group becomes more active and the first one is inhibited. The value of hydrogen's partial pressure, when there is equilibrium between vital activities of these two types, is 10 Pa [9]. The first type of microorganisms is more sensitive to increasing the pressure. So it is necessary to keep the partial pressure in the capacity below 10 Pa.

Acetogenesis is necessary to carry out at atmospheric pressure. Then carbon dioxide easily released. It is also necessary to keep oxidation restoration potential of the sludge in the capacity at the level of 330 mV. If this potential goes down, hydrogen is formed actively, which leads to inhibition of the acetogenesis. But at the lower level of this potential, sulfides appear actively in the sludge, which leads to hydrogen sulfide appearing in the gaseous final products of the stage. The group of methanogenic microorganisms (as well as acetogenic) is also divided into two types. First type decomposes acetate to methane and carbon dioxide; second type reduces methane using carbon dioxide. The processes go according to the next formulas

$$CH3COOH \rightarrow CH4 + CO2 \tag{11.7}$$

$$CO2 + 4H2 \rightarrow CH4 + 2H2O \tag{11.8}$$

The stage of methanogenesis requires very strict stabilization of medium characteristics. It is because methanogenic microorganisms are very sensible to them. To have this stage running efficiently, it is necessary to keep pH variations not more than from 7.5 to 8.0. While carrying out the stage at thermophilic conditions, it is necessary to keep temperature variation no more than ±0.2 °C. Concentration of oxygen must be as low as possible. If it is higher than 0.01 mg per liter, it kills these organisms.

It is possible to improve vital activity of methanogenic microorganisms by adding biostimulants to the sludge. Research shows that adding biostimulant BIOSTIM-SBCH4, which is based on melamine salt of bis(oxymethyl)phosphoric acid, accelerates fermentation process from three to four times and leads to increasing methane concentration in biogas [6, 9].

Methane is produced by two groups of microorganisms in two different ways. The first way is by decomposing acetate (Formula 11.7). At this process, carbon dioxide is produced. It becomes the source of methane production for the second group of microorganisms. They consume carbon dioxide, but for methane producing, they need also hydrogen (Formula 11.8). Research shows that large amount of carbon dioxide remains not consumed because of the lack of hydrogen in the sludge. This is the reason why biogas, obtained using conventional technologies, contains up to 40% of carbon dioxide [13]. To increase the amount of consumed carbon dioxide and consequentially produced methane, it is necessary to add some hydrogen in the sludge at this stage.

Carbon dioxide is soluble in water. Its solubility increases with pressure increasing. Methane, on the other hand, has low solubility, which practically does not depend on pressure. Carbon dioxide, which is produced by the first group of microorganisms and is not consumed by the second group, is usually released as gas. But if the pressure in the capacity is increased, more carbon dioxide dissolves in the water and remains accessible to the second group. Whereas methane continues to be released in gaseous form. So it is necessary to increase the pressure in the capacity, which enables to increase biogas yield and to decrease content of carbon dioxide in the biogas.

11.3 Results and Discussion

The main purpose of the proposed new technology is enhancement of environmental safety and economic efficiency of sewage water treatment processes. The next challenges are met here: diminish harmful impacts of treated sewage waters and their sludges on environment, thereby improving ecology and life conditions, and produce additional alternative energy sources during sewage water treatment and their sludge utilization, thereby enhancing enterprises' energy independence. The proposed sewerage is organized in the way that allows increasing quality of sewage water treatment process and obtaining additional alternative energy sources.

The major idea is that within the bounds of the proposed technology, it is necessary to do the next things. First, it is necessary to organize an additional treatment (posttreatment) of sanitary sewage water, after the water has been treated in conventional treatment facilities, by using it as growth medium for algae cultivation and then producing biofuel out of the algae. Second, it is necessary to organize a process of anaerobic digestion of sanitary sewage water sludges subject to modern scientific concepts, which factors in kinetics of the process.

Technological diagram of the proposed technology is presented on the Fig. 11.1. The technology is functioning in the next way.

Sewage waters from the airport that can be sanitary sewage waters and waters which are close to them by composition go to a conventional sewage water treatment plant. The plant can consist of conventional installations, which apply technology of mechanical, biological, or chemical and biological treatment, depending on sewage water composition. Treated water goes into a photobioreactor for posttreatment. The photobioreactor serves as an installation for using treated in conventional

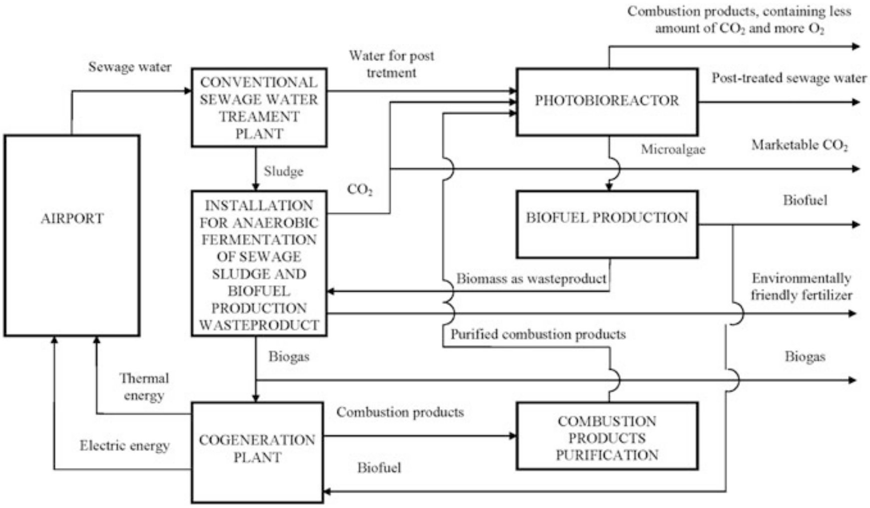

Fig. 11.1 Technological diagram of sewerage organization of an airport

way sewage waters as medium for microalgae cultivation by conversion of solar energy into their biomass. It is proposed to apply microalgae *Botryococcus braunii* for cultivation, as the most suitable culture for motor biofuel production. The installation can be designed as it is described in [22]. It must be placed in an area with enough natural illumination.

To make microalgae cultivation more effective, the following is proposed: using carbon dioxide, obtained during anaerobic digestion of sludge and biomass waste product, conducted according to new technology, and containing carbon dioxide combustion products from cogeneration plant; conducting cultivating process under excessive pressure for increment of carbon dioxide solubility in water; providing possibility to introduce carbon dioxide into the reactor continuously; providing possibility to introduce necessary nutrients for microalgae; and providing continuity of cultivating process. All these are possible while applying the proposed design of installation.

Sewage water, which has been posttreated in the photobioreactor, can be used for technical purposes or can be discharged into a water body.

Cultivated microalgae, unloaded out of the photobioreactor, go to installations for biofuel production. Waste product of the fuel production, which is biomass, is still rich in organic compounds. One of the solutions of utilizing biomass is to ferment it along with sewage water sludge. So the biomass goes to installations for anaerobic fermentation. Produced biofuel can be used at local cogeneration plant or to be sold as marketable product.

Sludges, which are generated during treatment process at conventional treatment facilities, go into installations for anaerobic fermentation. Along with the sludge, biomass as waste product of biofuel production out of microalgae can be placed into the installation and fermented there. The installation can be designed as it is described in [23]. The installation allows obtaining separately biogas with increased methane content and carbon dioxide. Produced biogas can be burned at local cogeneration plant for obtaining heat and electric energy or it can be sold as marketable product. The most reasonable utilization of produced carbon dioxide is using it in the photobioreactor for microalgae cultivation as a source of carbon in photosynthesis. Excessive amount of it, if there is such amount, can also be sold as marketable product. Fermented sludge and biomass can be used as organic fertilizer for agriculture.

11.4 Conclusion

Expected results of organizing sewage water posttreatment in photobioreactors are decreasing of pollutants' amounts, which are released into the environment with sewage waters; obtaining raw materials (microalgae) for producing motor fuel; and reducing amount of carbon dioxide, which is released into the atmosphere.

Expected results of new organization of fermentation process are shortening the process of fermentation approximately from 15 to 3 days, increasing the output of biogas per one volume unit of fermented substance, increasing content of methane in the biogas from 60% to approximately 95%, obtaining marketable carbon dioxide, and obtaining environmentally friendly organic fertilizer, which does not decay and does not contain pathogenic microorganisms.

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