The efficiency improvement of faecal sludge management with rate increase of biodegradation in septic tanks and pit latrines

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Abstract. The article discusses the environmental and economic aspects of faecal sludge management in an individual residential sector, proposes approaches to solving the problem, discusses findings in improving the effectiveness of the biodegradation rate of faecal sludge and domestic wastewater in a septic tank, and evaluates the using adequacy of biological additives for accelerating faecal sludge biodegradation.

1. Introduction
Nowadays the organization of the faecal sludge management is acute socio-economic and environmental problem in most settlements of Russia and in many countries of the world due to the high urbanization level [1, 2]. On the one hand, the development of urban infrastructure, including drainage and sewage systems, is carried out at a fairly modern level. But on the other hand, the situation in non-urban area, where private households predominate, is practically unresolved in relation to faecal sludge management. This problem is especially relevant to regions where the population constantly lives in an individual residential sector, but does not use it for seasonal recreation [3]. The introduction of additives is the most common method of accelerating the biodegradation processes in pit latrines and septic tanks. The process efficiency with adding biological additives depends on many environmental factors and composition of the decomposed substance. Moreover, additives effectiveness can potentially determine effectiveness of septic tank or pit latrine because of increasing operation time of local sewage system and reduce its emptying frequency that leads to significantly cost reduce for operation and maintaining of local sewage system.

2. Research objective
There are several ways of handling sewage and faecal sludge in an individual residential sector. Typically septic tanks is used for collection and treatment of sewage in households. Septic tanks provide partial decomposition of biomass and further soaking of the filtrate with drainage system. The operation technology is provided for regular sludge pumping and removal for subsequent permanent storage. Pumping out the sludge from the septic tank, according to the instructions, should be done once every one or two years as the first tank camera is filled. However, in practice, it is necessary to pump out every three or four months due to the fast filling of all tank camera with highly diluted effluents [4–6]. The pumping cost is about $60 (data are presented for the Moscow region), therefore the cost of a homeowner pumping of septic tank with permanent residence is already $180–240 per year.

The population uses pit latrines in areas with seasonal residence, for instance, in summer communities, as well as in rural settlements. In the pit latrines the substrate decomposition occurs naturally, the filtrate diffuses in the upper soil layer and soaks into the groundwater. The generated
sludge is not pumped out, the charged pit is filled with soil, and a new pit is dug out in the new place. It is common practice that the average filling is 550 liters per person per year. The subsequent filling rate of the pit latrine depends on the income frequency of faecal sludge and on the degradation rate of it. The accumulation rate decreases as the pit is filled [6].

A special feature of pit latrine sludge is a high content of organic matter and ammoniate, as well as pathogenic microorganisms due to the lack of dilution that causes water pollution in wells located near pit latrines, even at great depths. As a result, additional water treatment is required for drinking and domestic purposes, and this fact significantly increases the cost of homeowners. The pollution risk of surface water with feces is relied heavily on land and water use. Moreover, surface watercourse can be contaminated with feces when water and feces come into contact as well as during flooding of settlements that were built below the flood line.

Groundwater is more protected from contaminant sources, as the top soil creates a protective effect. Groundwater pollution usually occurs when such protective barriers are violated, for example, through contaminated or disused wells, or by the impact of pit latrines or septic tanks [7]. Besides, groundwater can be contaminated in case of the artificial groundwater recharge is polluted or the clay layer landfills is damaged due to leaching, which contains the end concentration of Coliforms and potentially pathogens [8].

The contamination rate of groundwater by feces depends heavily on the size and surface properties of viruses and bacteria, the physical properties and chemical composition of the soil above the aquifer, and also the ambient temperature [8].

In some settlements, especially in the developing African and Latin American countries, sewage wastewater is discharged directly into water bodies located near the settlement (swamp lands, rivers, seas). It leads to the growth and spread of intestinal infectious diseases [3,9]. The complexity of the situation is also due to the organizing impossibility of a reliable monitoring system for such water disposal systems.

Thereby, the following aspects of the problem can dwell on the tasks for an effective engineering, economic, and institutional solution:

1. Analysis of composition, conditions and stages of sludge biodegradation in a septic tank in order to increase the process efficiency and reduce pumping frequency;
2. Causes identification of ineffective process in septic tanks and their elimination;
3. Reliable scientific justification for the injunction on the use of pit latrines in conditions of individual residential sector;
4. Development of local regulatory legal acts and instructional guidelines for the effective disposal of septic tank sludge in an individual residential sector;
5. Analysis of the advisability, effectiveness and profitability of the co-utilization of sludge from septic tanks and other organic wastes in a specific region (sewage sludge, cattle dung and poultry dung);
6. Logistic scheme development for organic wastes handling from individual residential sector and their processing.
7. Technological advancement for using resource and energy potential of organic wastes from individual residential sector.

2.1 Formatting the Composition features of faecal sludge
Numerous studies of the faecal sludge composition, including urine, prove that it contains the following nutrients: nitrogen, phosphorus, potassium and sodium [10–13]. In addition to nutrients, it also contains environmentally hostile and dangerous to health components (pathogenic microorganisms and viruses, toxins, detergents, surface active compounds), therefore faecal sludge is not suitable for use as fertilizer or direct plowing into the soil layer. The adverse effects risk of untreated faecal sludge is always high due to the potential presence of pathogens - bacteria (Salmonella, Campylobacter, Salmonella typhi, Vibrio cholera, Shigella), viruses, staphylococci, parasitic one celled protozoa and helminths [8,14,15]. According to Tauxe and Cohen (1995), more
than 120 different types of viruses can be excreted with faeces. The most common among them are intestinal viruses, rotaviruses, intestinal adenoviruses, calcicviruses, noroviruses. Pathogens (Leptospira interrogans, Salmonella typhi, Salmonella paratyphi and Schistosoma haematobium) were also found in urine [8,16].

The parasitic one celled protozoa Cryptosporidium parvum and Giardia lamblia/intestinalis have been intensively studied over the past ten years, partly due to their high resistance to environmental load and low infectious doses. Cryptosporidium is dangerous due to several widespread outbreaks of water-borne infections, Giardia is due to its widespread use as an intestinal pathogen. Entamoeba histolytica is also considered as infection microorganisms that is a problem in developing countries. The general significance of other pathogens, such as Cyclospora and Isospora, is currently under discussion (World Health Organization, 2018).

The life cycle of most pathogens lasts around 100 days, but they do not completely die in a septic tank, since the inflow occurs constantly [8]. This fact must be taken into account when choosing a technology for further sludge processing from septic tanks of individual residential sector.

2.2 Conditions for faecal sludge biodegradation in septic tank

Time and prevailing environmental conditions are characteristics that usually affect the biodegradation degree of sludge and microorganisms survival. Some physico-chemical and biological factors also affect the survival factor of microorganisms, but their influence depends on microorganisms’ types and the prevailing biocenoses.

As applied to use septic tanks, the most significant biodegradation factors are: temperature, acidity (pH), nutrients quantity, the concentration of degradable substances, oxygen concentration, and the presence of other microorganisms. In this case parameters that determine the climate type, such as humidity and the amount of solar radiation, and important for reducing intestinal microorganisms in the top soil do not matter [17]. For a risk assessment, the selection of dominant resistant microorganisms is a generally accepted approach that also takes into consideration more sensitive types of microorganisms.

In the septic tank biodegradation occurs both under aerobic and anaerobic conditions. The composition of the microbiological community will depend on these conditions. Aerobic digestion can reduce the faecal sludge mass by 30%, while anaerobic digestion can just reduce by 70%, but it proceeds more slowly. There are no any biological manipulations that can completely deplete the pit latrine contents, since not all substances can be transformed into gas or liquid [6,13,18].

Recently, various additives have become very popular both for pit latrines and septic tanks, which were initially used to reduce the volume of animal waste. Suppliers take up the position that such additives reduce the content amount and thus prolong service life of pit latrines or septic tanks. They have a chemical nature (nitrate oxidant, ammonium compounds, formaldehydes) and a biological nature (bacterial strains) [6]. In this paper authors investigated biological additives.

It is common practice that additive manufacturers pursue the following objectives [13, 19].

1) Addition of microorganisms to intensify all ongoing biological processes. However, with a natural increase of the bacteria number that are already in the pit, the additive will inhibit the growth process, and the multiplication of added microorganisms can also be inhibited. In addition, some additives contain aerobic microorganisms that can only function on the surface and cannot significantly affect the lower layers contents of the pits or septic tanks.

2) Addition of destructive microorganisms to increase the efficiency of decomposition, in case that certain process stage is limited due to the absence or inhibition of the corresponding bacteria. It would probably happen anyway if a certain bacteria type for reducing the faecal sludge amount could function in a pit or septic tank. Therefore, sometimes only a single additive dose is sufficient.

3) Addition of enzymes to increase the rate of hydrolysis/solubility of complex organic molecules. The cost of such additives is much higher. Enzymes must be added periodically, since they are washed out in pit latrines.
4) Addition of nutrients (for example, phosphorus, nitrogen, carbon) to increase the bacterial activity in the substrate. However, the amount of nutrients in the faecal sludge substrate is sufficient for the biocenoses life, therefore, the excess addition is most often not advisable. The exception is provided by addition after a sustained interruption in the pit latrine use, for example in winter, or after adding chemical reagents, when nutrients go into hard-to-reach sparingly soluble forms.

5) Addition of aerobic (or anaerobic) microorganisms to increase the biodegradation rate. It is a common knowledge that, the aerobicity degree and the prevailing type of biocenosis depends on the oxygen concentration in the upper part of the pit latrine or in the septic tank volume. Addition of aerobic microorganisms does not increase the oxygen concentration. It is advisable to use with forced ventilation and a supply pump.

For biocenosis a disinfectants is also important factor, which have adverse effects on life of the microbial population present in feces [18–20]. Such substances can completely exterminate the microbiological population in the septic tank, and the operation of local treatment facilities will be impossible. In this case, it is also advisable to use additives for recruitment of exterminated population [21].

The use of pit latrines or septic tanks for the disposal of solid waste also increases the emptying frequency, since some kind of wastes do not decompose and make it difficult to decompose the rest of the contents. Such wastes also prevent its power-driven emptying [14].

2.3 Study objects
We carried out investigation studies for two different collection and storage methods for faecal sludge and domestic wastewater: a septic tank of an individual residential household in Troitsky and Novomoskovsky Administrative Districts, Moscow (designed for year-round use), and a pit latrine of private household in Alexandrov, Moscow Region.

Septic tank operates in non-aerated, without ventilation, year-round. Wastewater from the kitchen, shower, toilet, washing machine are combined. The maximum wastewater flow (averaging in winter per month) is 467 m$^3$/day, and the minimum is 265 m$^3$/day. Emptying is carried out three times a year from the first and second cameras (emptying volume - 3 m$^3$).

Schematic design and volume of the septic tank are presented in Figure 1.

![Figure 1. Schematic diagram of the investigated septic tank without aeration [3].](image)

In response to silting of the drainage holes in the second camera, there was no drainage of treated wastewater, so an additional the third camera with concrete rings was constructed a year ago. It is 4 m depth without bottom. At the time of the research, the first and second cameras were completely filled with wastewater. There is no water in the third camera. The thickness of sludge (substrate) at the bottom in the first camera is 2–3 cm; there is no sludge at the bottom in the second camera. Organic suspended solids are in wastewater volume in the first camera, solids size is 2–3 cm. In the second camera, the water is turbid, without visible solid fragments.

The soil at the research site: the top soil is sabulous, depth is 40—45 cm; the second layer is sand, depth is 5 m; the third layer is the continental carbon-bearing layer (limestone). Groundwater is absent, subsurface waters is more than 15 m in the deep.
Along the experiment, biological additives (bioactivators) were studied. They are used to accelerate the aerobic and anaerobic degradation of faecal sludge. Several types of bioactivators from various manufacturers with different manufacturing dates, were selected:

1. "Zelenyy Paket" (produced by Doctor Robik Company, Russia) for the pit latrine and the septic tank. Composition: >30% of wheat bran, sodium bicarbonate, <5% of microorganisms. Production Date: 09.2018.
2. “Bioassenizator” (produced by Biosyntez Company, Russia) is a bioactivator for processing the pit latrines contents. Composition: soil microorganisms, bran. Production Date: 04.2018.
3. “Bioseptic” (produced by Bioseptic Company, Russia) is a bioactivator for cottage septic tanks with a filling container. Composition: dry soil microorganisms, enzymes, filler. Production date not specified.
4. “Biosept” (produced by TM BIOSEPT Company, France) is a bioactivator for septic tanks and pit latrines. Composition: a mixture of intentionally grown aerobic and anaerobic microorganisms, enzymes, an organic matter. Production date not specified.

3. Materials and methods

The use Authors conducted investigation studies according to standard sampling and processing procedures. Parameter measurements were conducted on site using a portable laboratory. Two investigation studies were conducted in the laboratory of Moscow State University (Department of Chemistry) in two temperature modes - at 12 and 24 degrees with preliminary homogenization of the mixture by ultrasound and in the Laboratory of Environmental Biotechnological Protection of RUDN University (Faculty of Ecology). The control sample and samples with the addition of biological additives to accelerate biodegradation were studied.

Sampling for laboratory experiment No.1 was taken from a septic tank. Four samples (1 liter) were taken in October 27, 2018, at 14 hours. Samples have a specific faecal odour and high turbidity. According to the state of aggregation, samples are liquids with inclusions of solid particles: feces, mineral particles of soap and dry detergent and other domestic chemicals.

Sampling for laboratory experiment No.2 was conducted in the Alexandrov city, Moscow Region, from a pit latrine in a private household. 2 liters of faecal sludge was selected for the experiment with a relatively homogenous consistency. It is emphasized that faecal sludge samples were not taken after a defecation. Faecal sludge samples were taken from an open pit latrine intendent for daily use. The environmental temperature was -5°C - -1°C at night, which causes the freezing of substrate at night and slightly thaw out at morning.

3.1 Laboratory experiment No.1

The first laboratory experiment is focused on investigation of the biological additives effectiveness in the septic tank. The main goal of laboratory experiment No.1: to study the effect of biological products on the septic tank substrate under two temperature conditions. From a technical point of view, both aerobic and anaerobic conditions can be provided in a septic tank. General aerobic conditions are on the substrates surface in pit latrines and in septic tanks with forced aeration, and anaerobic conditions are in the thickness and at the bottom. Hence, both aerobic and anaerobic conditions were created for laboratory experiment No.1.

Measurements of the temperature conditions in the septic tank were conducted. The contents temperature in the septic tank was +16°C on the surface, +12°C in the thickness and 10°C at the bottom at ambient temperature of +5°C. Instrumental error is ±1°C. Additionally, pH, Cl₂ (mg/L) and total alkalinity (mg/L by CaCO₃) were measured in the septic tank. All indicators meet regulations: pH is about 7, Cl is 0.5 mg/L, CaCO₃ 80-120 mg/L.

Five samples of biological additives were selected for the laboratory experiment: four are dry and one is liquid. Two temperature conditions (24°C (indoor temperature) and 12°C (the average temperature in the septic tank) were selected. They were based on an experimental study of the substrate temperature in the septic tank.
The experimental design involved the samples distribution of faecal sludge taken from the septic tank into two groups due to implementation of studies under different temperature conditions: 24°C and 12°C. Substrate were divided evenly into 12 samples. Biological additives were added into 10 samples for biodegradation accelerating. Each sample with biological additive, as well as a control sample, had two additional conditions: the presence or absence of additional aeration. Prior to the experiment, the following indicators of faecal sludge are examined: pH, Coliforms number, the dry substance amount. The same measurements were conducted at the end of the experiment. The laboratory experiment time is 3 months.

3.2 Laboratory experiment No.2

To study the effectiveness of biological additives in the pit latrine, the fundamental conditions for recreation were determined in the laboratory experiment No.2. The biological additives effect in the pit latrine was necessary to study operation during the autumn and summer season. Hence, two temperature conditions were selected: 12°C and 20°C. There is no additional oxygen supply to the faecal sludge thickness in the pit latrine. There is also no mixing, ragging into smaller fractions, and natural light [6].

Samples were charged in cone flasks with a gas vent. Faecal sludge (150g) and warm water (200ml) were charged into each flask. Biological additives “Bioassenzizator” and “Veselyy Dachnik” were added in flasks No.1 and No.2 (1g each). Flask No.3 is a control sample. The laboratory experiment time is 30 days.

Tentatively, faecal sludge was analyzed for the dry matter amount. At the end of the experiment, the samples were analyzed for moisture (part by weight), COD (mgO/dm3) and BOD5 (mgO/dm3).

Laboratory experiment of COD was conducted in accordance with GOST 31859-2012 “Teat method of chemical oxygen demand”. The specific indicator study of a pollution by the organic fraction - biochemical oxygen demand (BOD) was conducted in accordance with the environmental regulatory document (ERD F) 14.1:2:3:4.123-97 “Quantitative chemical water analysis. The methodology for measuring biochemical oxygen demand after n-days of incubation (BODfull) in surface fresh, subsurface (ground), drinking, waste and treated waters.” Ammonium ions is the third indicator, analyzed in a laboratory experiment No.2, was conducted in accordance with environmental regulatory document (ERD F) 14.1:2:4.276-2013 “Quantitative chemical analysis water. The methodology for measuring the mass ammonia concentration and ammonium ions in drinking, natural and wastewater using the photometric method with Nessler’s reagent."

The moisture (part by weight) in the sample was determined using thermogravimetric analysis with a device “Weighing Moisture Meter” series ML-50. After sample drying with a halogen lamp, the moisture content (%) was determined, as well as other values, calculated on in terms of the difference between wet and dry weight. The drying temperature range is 50-160°C, the interval is 1°C.

4. Results and discussion

4.1 Laboratory experiment No.1

The experiment was conducted from November 12 till March 7. According to the results of the experiment, it was found that the temperature in the first camera of the septic tank was +18°C on the surface, +12°C in volume and +10°C at the bottom. Water temperature in the second camera is +13°C in winter. The acidity of the substrate is weak-alkaline. pH is 7.0 on the surface, 6.8 at the bottom, 6.8 in volume. The oxygen concentration at the bottom is 2.0 mg/l, in the volume is 2.4 mg/l, on the surface is 2.8 mg/l.

The greatest effectiveness of biological additives use to accelerate the faecal sludge degradation is observed in the temperature range +20-24°C, with additional substrate aeration, since there is a significant change in the substrate acidity, a BOD5 reduction and an increase of bacterial mass. Anaerobic digestion in the temperature range +10-12°C is possible, but the processes are slower.
compared to the septic tank conditions in the summer. Therefore, the additives use is possible in order to accelerate anaerobic processes in such conditions.

In the autumn-winter period (temperature range is +10-12°C), in the septic tank the biological activity of the biological additives is preserved. Dry substance was increased, since the biological additive composition contains bacteria that develop under different temperature conditions. Hence, biological additives No.2 and No.3 under cold and warm temperature conditions have the same value changes.

Tentatively, for all samples of faecal sludge taken from the septic tank, pH was 6.8, Coliforms were 108, and the dry substance was 4 (% by weight). The initial weight of each sample was 180g. Their mass increased by 1-1.5g with the addition of biological additives, except the control sample.

Sample No. 1 "Bioseptic". The smallest mass than other samples mass was observed at the end of experiment (72g) at +24°C, with aeration (Figure 2). The pH increased by 0.8 (from 6.8 to 8.6), Coliforms number reduction from 108 to 102, while the dry substance amount (% by weight) was 8.6 at the end of experiment (the largest among all samples). The same significant weight reduction from 180 to 121g was noted without aeration. The pH of this sample was 7.3 at the end of experiment. Dry weight increased only by 0.6%. The same significant mass reduction (from 180 to 96g) was in the sample with aeration, and moderate mass reduction by 15g in the sample without aeration. The dry substance amount was 6.7%, and pH was 7 for the sample with aeration conditions at +12°C. For the sample without aeration dry substance was 5.6, and pH was 7.2 (Figure 3).

Sample No. 2 "Bioassenizator". The greatest sample mass reduction was observed at +24°C with aeration (from 180 to 86g) (Figure 2). There was significant increase of dry substance amount and the smallest Coliforms number among all samples. In all samples the pH increased by 0.4-0.8 in both temperature conditions, the most alkaline medium is observed at +12°C, without additional aeration. Hence, for sample No.2 "Bioassenizator" the most favorable conditions were temperature +24°C and additional aeration, since there was the sample mass reduction and Coliforms reduction.

Sample No. 3 "Zelenyy Paket". There was a significant mass reduction with aeration (Figure 2). Thereby, a significant increase of dry substance amount was observed only at +24°C. Moreover, under the same conditions, Coliforms reduction was observed. It can be considered as a result of impossibility of microorganisms to survive under aeration conditions and the competition inability with aerobic organisms that presumably contain in biological additive. The sample pH turned into alkaline under all conditions (Figure 2). The most alkaline pH was also observed at +12°C without aeration.

Sample No. 4 "Biosept". Sample No.4 had significant mass reduction (by 2 times) at +24°C with aeration. There was also significant Coliforms reduction and pH turning into the acidity (Figure 3). All samples with biological additive "Biosept" showed almost the same results of mass reduction. The increase of dry substance amount is insignificant (0.5–0.6%), while there was alkaline pH for samples without aeration.

Sample No. 5 "Bioassenizator" liquid. Sample composition is identical to sample No.2 "Bioassenizator" dry. Initially, it was assumed that values for these samples will be almost identical, but at the end of experiment it was revealed that there were different results for sample No.5, although some regularity was reported. For sample No.5 (at +24°C with aeration), the most significant mass reduction (from 180 to 76g) was observed, as well as the most significant pH change to 7.6 (Figure 3). Sample mass increase occurred without aeration by 5g at +24°C (Figure 2). Coliforms reduce was also observed in warm temperature conditions with aeration. The increase of dry substance corresponds to reduction of the sample mass except for the sample at +12°C without aeration.

The control samples of faecal sludge did not interreact with any biological additives described above. Respectively, the destruction processes in substrate should be caused solely by the natural biocenosis activity in the septic tank. For samples under different temperature conditions almost the same acidity is 6.8–6.9 (Figure 3). Only the sample that was at +24°C with aeration is characterized by
Coliforms reduction. That can also account for the most significant increase of the sample mass (Figure 2).

Mass increase was observed for control samples, but the destruction processes in substrate due to the natural biocenosis activity were absent. A significant increase of dry substance was recorded for the sample at +12°C with aeration. There was also a slight Coliforms reduction, which may indicate the initial biocenosis preservation and unfavorable conditions for its vital activity in the sample. This proves the indispensability to keep up thermotolerant conditions in the septic tank (Figure 4).

**Figure 2.** Schematic Diagrams 1 and 2. Mass variation of samples (g) at temperature +24°C and +12°C respectively (1 – 5 samples № 1-5, with forced aeration; 6 – control sample, with forced aeration; 7 –11 samples №1 -5, without aeration; 12 – control sample, without aeration).

**Figure 3.** Diagrams 3 and 4. pH variation of samples at temperature +24°C and +12°C respectively (1 – 5 samples № 1-5, with forced aeration; 6 – control sample, with forced aeration; 7 –11 samples №1 -5, without aeration; 12 – control sample, without aeration).
Figure 4. Diagrams 5 and 6. Dry substance variation of samples (% by weight) at temperature +24°C and +12°C respectively (1 – 5 samples № 1-5, with forced aeration; 6 – control sample, with forced aeration; 7 –11 samples №1-5, without aeration; 12 – control sample, without aeration).

4.2 Laboratory experiment No.2
The experiment was conducted from March 30 till April 15 2019. All samples were under anaerobic conditions, without mixing, without daylight and artificial lighting. The first 15 days of the experiment all samples were hold at +12°C. These temperature conditions correspond to the upper temperature limit in the autumn and spring periods of pit latrine using. On the 10th day, for sample No.2 (biological additive «Veselyy dachnik») the biogas producing was recorded. That proves the active life of the biocenosis in the experiment. At the end of the first temperature phase, there was biogas release of samples No.1 (biological additive “Bioassenizator”) and No.3 (control sample).

The second temperature phase is +20°C. It was expected that, the biocenosis activity will increase and the biogas release ensuing substrate biodegradation will be observed under in the samples these conditions. Current on the 25th day of the experiment, an increase of biogas volume was recorded for all samples. At the final stage, a comparison of biogas yield was made. Thus, for the control sample the biogas yield was 3.8ml, for the sample No.1 is 4.2 ml, for the sample No.2 is 5.12 ml. The analysis of processes in the substrate was carried out according to four indicators: COD, BOD$_5$, the dry substance amount (% by weight) and ammonium ions.

The highest COD (Figure 5) was in the control sample, where the substrate biodegradation occurred solely due to the surviving native biocenosis of faecal sludge. It should be observed that sample No.2 “Veselyy dachnik” has the lowest COD. That is explained by the additive “freshness” (release date - March 2019), and, accordingly, the greater effectiveness of the bacteria activity, which is also confirmed by biogas yield.

BOD$_5$ characterizes oxygen consumption by microorganisms during the oxidation (biodegradation) of an organic substrate. The results (Figure 5) show that the highest BOD$_5$ also corresponds to the control sample, and the smallest - to sample No.2, which confirms the hypothesis of greater effectiveness of this additive, compared with sample No.1 (it was produced a year before the start of laboratory experiment). Thus, an indirect study conclusion: there is a need to indicate the shelf life of biological additives on the package.

The content of ammonium ions is a marker for the anaerobic digestion process of the substrate. Comparison of the control sample with samples No.1 and No.2 (Figure 6) shows that in the control sample ammonium ions is the smallest amount - 89.0. Thus, the intensity of the anaerobic biodegradation process of the substrate is low.
5. Conclusions

To sum up for all samples of faecal sludge from the septic tank (laboratory experiment No.1), a significant pH increase, an increase of dry substance and Coliforms reduction were recorded. For all samples with the biological additives (samples No.1-5) a significant mass reduction was observed at +24°C with aeration. The most significant sample mass reduction (more than 2 times) was observed for the biological additive "Bioseptic" (72 g). For the control sample mass reduction was not observed under these conditions. For these samples, a significant increase of dry substance was observed, which can be explained by the exponential growth of the bacterial population at the end of the experiment.

There was a significant Coliforms reduction (by more than 2 times) with oxygen supply, substrate mixing, as well as favorable temperature conditions for mesothermal organisms. Coliforms reduction explains their existence impossibility in an aerobic environment, which is observed in the control sample. Besides, there was the inability to keep a competitive relationship with aerobic organisms of biological additives.

We can conclude that the biological additives, that added to the septic tank, slightly accelerate (5-10%) the faecal sludge biodegradation at +12°C, both in aerobic and in anaerobic conditions, based on the acidity, the dry substance, mass, and Coliforms amount. The using efficiency of biological additives significantly increases (10-15%) with aeration and mesophilic temperature conditions (at 20-25°C).

In the open pit latrine with daily use at night temperatures below 0°C, the substrate freezes and slightly thaws in the morning, which leads to a partial death of the natural biocenosis of faecal sludge and a complete shutdown of organic matter biodegradation. The pit latrine is also characterized by the
insolation absence (the infrared and visible spectra are catalysts for the nutrient medium oxidation), anaerobic conditions in the substrate thickness and aerobic conditions on the surface. It has been experimentally shown, that the effectiveness of biological additives for accelerating the faecal sludge biodegradation in the pit latrine during the autumn (temperatures of 10-12°C), can increase the biodegradation efficiency. For this temperature range, the biogas yield was observed with adding of biological additive “Veselyy dachnik”. That confirms the biocenosis activity in additive composition and, in particular, the presence of psychrophilic microorganisms for which the temperature optimum for growth and development corresponds to the laboratory temperature conditions of the first phase experiment. COD, BOD₅ ammonium ions and the dry substance also confirmed the expected results. However, it should be noted that, all processes in the pit latrine can proceed only in a thin surface layer of the substrate. Therefore, use of biological additives is ineffective.

Biological additives are introduced to pit latrine or septic tank only to disinfect sludge and reducing odour. The study showed there is a significant reduction in odor. Thus, the study does not provide evidence of additive effects on odor.

Biological additives have potential in reducing and controlling faecal sludge in pit latrine or septic tank. The study showed that use of biological additives can provide simple solution under certain conditions (for example, there are no any cleansing materials or mineral components). However, the study showed that reducing contents of pit latrine or septic tank was not significant with certain biological additives and besides there was significant increase of some samples weight in both aerobic and anaerobic conditions. So we may conclude that only some biological additives have options for reducing the pit emptying frequency.

It must be understood operation of family toilets often depends on income level of the household and on whether it can afford private sludge disposal services. Therefore, the quality and efficiency of sludge disposal can vary greatly depending on the situation. So there is a key problem, because if pit latrines have no regular empting, people can dump out in the open and pollute the environment.

In conclusion, the effectiveness of biological additives is questionable and can be verified empirically only by adding a sample to a specific pit latrine or septic tank with its own conditions. In this regard, the economic benefit from using of these biological additives has not been confirmed, since their use will not reduce maintenance frequency with sewer trucks. But these biological additives reduce Coliforms that leads to impact reducing on the environment. Moreover, in the case of eliminating the odour (which was not part of the study), these additives showed their high efficiency.

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