Purification of fat-containing effluents with probiotic substances

A K Strelkov, A O Bazarova, S Yu Teplykh

Head of the Water Supply and Wastewater Disposal Chair, Academy of Construction and Architecture, Samara State Technical University, 194, Molodogvardeyskaya St, Samara 443001, Russia

E-mail: kafvv@mail.ru

Abstract. The paper focuses upon modern methods of wastewater purification in the oil-and-fat industry. The researchers draw attention to the fact that if wastewater of food production is not properly purified it starts to decompose and extricate highly toxic substances. They further describe intensification methods dividing them into two groups and discuss pros and cons of the reagent method of wastewater treatment. Significant advantages of probiotic agents in contrast to the reagent treatment method are revealed. Probiotic agents for wastewater treatment are then proposed for use. It is stressed that is a relatively new method and it has not yet been widely studied. The article describes probiotic products composition and their action. It also explains the impact of various groups of bacteria at the stages of mechanical wastewater treatment in anaerobiosis and aerobic biological treatment. The researchers examine variants of probiotics addition and consider advantages and disadvantages of this method. To compare the results, it is proposed to use probiotic agents at municipal sewage treatment plants and at the oil-and-fat production enterprises. These experiments of probiotics application show the potential of their use for intensifying wastewater treatment processes, reducing the level of unpleasant odours and improving sanitary safety of sewage facilities.

1. Introduction

Industrial effluents of oil and fat industry enterprises contain high concentrations of organic pollutants and differ significantly in composition from domestic wastewater. If wastewater of food production is not properly purified, it starts to decompose and extricates highly toxic substances.

Wastewater consumption and composition of oil and fat industry enterprises are determined by the products volume and range, as well as the production technology. Wastewater consumption and composition depend on water supply system. Plants water supply is carried out from city or plant water pipes. The water used for technological needs of the enterprise is to correspond to drinking water quality. Technical water is used for cooling of vacuum equipment and compressors of refrigerating installations, as well as for external car washing and territory watering.

The absence of local sewage treatment facilities at regional oil and fat industry enterprises is the main reason for multiple wastewater discharges into the household sewer network or into a water body, which is even worse. In both cases, production wastewater does not meet the established standards for several indicators.
2. Research objective
The purpose of this study is to analyse existing probiotic substances and their composition and determine the effectiveness of wastewater pre-treatment as a result of the use of probiotics.

3. Main Body

3.1. Research background
Recently, some production facilities started to produce probiotics intended for use in the field of water supply and sanitation [1]. The use of probiotics for wastewater treatment is a new purification method which has certain advantages over other technologies.

Intensification methods can be divided into two main groups: technologies related to the reconstruction of treatment facilities and technologies based on the use of various reagents (coagulants or flocculants) [2,3]. The reagent method does not require significant reconstruction of treatment facilities, so this method is more preferable from the point of view that it requires only a system for reagents delivery and supply. However, the use of reagents leads to the formation of precipitation and excess active sludge with an increased content of polluting elements, which makes it difficult to further dispose of precipitation. Besides, the use of reagents is a one-way process. Reagents are intended specifically for a single purpose: for example, to increase the effect of mechanical or biological purification.

3.2. Probiotic products characteristics
Probiotic products differ from reagents as they contain cultures of probiotic bacteria, which by definition should be non-pathogenic and non-toxic [4,5], so their use is safe, environmentally friendly and does not lead to contamination of the resulting precipitation. When they probiotics enter the nutrient medium, they quickly absorb the substrate in the form of organic substances, leaving pathogenic microorganisms no opportunity for development [6,7]. The complex impact of probiotics and their environmental friendliness make their use highly promising.

Probiotic products (probiotics) consist of probiotic bacteria and enzymes and do not contain chemical or mineral pollutants [8]. The mechanism of probiotics action is based on the fact that probiotic bacteria and enzymes contained in probiotics are able to quickly destroy organic substances in wastewater and significantly slow usual anaerobic processes, which are accompanied by the release of unpleasant odours and toxic gases (ammonia, hydrogen sulfide, methane). Besides, probiotic microorganisms suppress the activity of pathogenic microflora. When they enter the nutrient medium, they quickly absorb the substrate and do not leave pathogenic microorganisms’ opportunities for development.

According to the method of their application, probiotics can be attributed to the class of reagents, with the correction that due to their environmental friendliness, they do not have a negative impact on the quality of precipitation. Probiotic bacteria are divided into non-pathogenic, non-toxic, and have a high adhesive and antagonistic ability to pathogenic and opportunistic microorganisms. Most probiotics contain, as a rule, facultatively anaerobic bacteria (mainly genera Bifidobacterium and Lactobacillus) and spore-forming aerobic bacteria of the genus Bacillus (Bacillus subtilis, Bacillus subtilis var. amyloliquefaciens, Bacillus licheniformis, Bacillus pumilus, Bacillus megaterium, etc.) [9,10].

The first group of bacteria affects the stages of mechanical wastewater treatment in anaerobiosis, the second group does it during the process of aerobic biological treatment [11,12]. The production of organic acids by lactic acid bacteria Bifidobacterium and Lactobacillus, as well as a large number of biologically active components (antibiotics, bacteriocins, lysozyme, hydrogen peroxide), as well as the competition for nutritional ingredients and adhesion sites, inhibits growth and displaces pathogenic microorganisms and putrefactive bacteria from the nutritional niche, which leads to inhibition of anaerobic rot [13,14]. Therefore, when probiotics are added to the scheme of biological wastewater treatment, it results in the reduction of toxic "stinking" gases release before the wastewater primary
settling in strainer chambers. This process is accompanied by partial disinfection of the environment from pathogens. Reduction of gas formation in strainer chambers improves the mode of impurities precipitation and intensifies the purification process, as well as leads to a decrease in the humidity of raw sediment.

The vital activity of Lactobacillus bacteria leads to the formation of hydrogen peroxide in the working environment. It is accumulated in the process of primary settling and then it enters the aeration tanks. Under aerobic conditions, hydrogen peroxide is decomposed into water and oxygen under the action of enzymes (catalase and peroxidase), typical for aerobic and facultatively anaerobic bacteria, and is further used for the oxidation of the organic substrate. These processes lead to an increase in the concentration of dissolved oxygen in the sludge mixture of aeration tanks.

Intensification of the process of biological wastewater treatment is carried out due to the activity of aerobic bacteria, as well as to the activity of ready-made enzymes contained in the preparations. Aerobic Bacillus bacteria produce a large range of enzymes: oxidoreductase, transferase, hydrolase (lipase, protease, amylase, cellulase, phytase, pectinase, lysozyme), and lyase. A large number of produced enzymes determines the ability of probiotics to quickly destroy organic substances, including high-molecular-weight and decomposition-resistant substances [15-17]. The ability of Bacillus bacteria to produce vitamins, amino acids and biologically active substances that stimulates the activity of active sludge bacteria, as well as the fact that probiotics oxidize decomposition-resistant organic substances, facilitating the work and reducing the load on active sludge, lead to the intensification of biological purification processes.

3.3. Probiotic addition options

There are three main options for probiotic addition: before wastewater enters sand catchers, before it enters primary strainer chambers and before it enters aeration tanks.

Probiotics addition prior to wastewater entering the sand traps will lead to the deposition of some probiotic bacteria along with mineral impurities, which is undesirable. Probiotics addition before wastewater enters aeration tanks will intensify biological cleaning but will not affect the process of primary settling. The most promising is to add probiotics before waste water primary settling, as in this case there is an impact not only on the biological cleaning, but also on mechanical purification because the process of primary settling is intensified, the volume of raw sediment is reduced, and the rotting processes in the primary strainer chambers are reduced [18-20].

However, probiotic products are not used widely as they have not yet been thoroughly examined. Moreover, there is no scientific or scientific-practical basis for their use.

The following companies that produce probiotic products for wastewater and natural water treatment from pollution are currently represented on the market: (Belgium), Agranco Corp. (USA), SCD Probiotics (USA).

4. Experiment

To compare purification efficiency, let's consider the next two experiments conducted while using two different probiotic agents, "Oxidol" [7] (Agranco Corp., USA) and Chrisal (Belgium), for municipal sewage facilities and for a fat-and-oil enterprise with a capacity of 800 m³/day.

Table 1. Study of concentrations of pollutants when adding probiotic agent "Oxidol".

| Indicators | Unit of Measurement | Source wastewater | Concentration of contaminating substances after probiotic addition |
|------------|---------------------|-------------------|------------------------------------------------------------------|
| COD        | mg/dm³              | 514               | 48                                                               |
| NH₄⁺       | mg/dm³              | 51                | 1.8                                                              |
| NO₃⁻       | mg/dm³              | -                 | 91                                                               |
| PO₄³⁻      | mg/dm³              | 14.5              | 9                                                               |
In the first experiment, a municipal treatment plant consists of lattices, sand traps, primary vertical strainer chambers, aeration tanks, secondary vertical settling tanks, and contact basins. Probiotic agent "Oxidol" was added before wastewater entered the primary strainer chamber. The obtained results are given in Table 1.

The results (see Table 1) demonstrate that the addition of probiotic agent "Oxidol" significantly increases the efficiency of primary sedimentation, that is by 91% for COD and by 96.1% for ammonium nitrogen. There was no effect on phosphates reduction when introducing probiotic agent "Oxidol".

In the second experiment, oil-and-fat treatment facilities consist of grease traps, a flow-equalization basin, an aerotank, and a strainer chamber. Probiotic "PIP WATER PLUS" was added before wastewater entered the aeration tank. The obtained results are given in Table 1.

Table 2. Study of concentrations of pollutants when adding probiotic "PIP WATER PLUS".

| Indicators | Unit of Measurement | Source wastewater | Concentration of contaminating substances after probiotic addition |
|------------|---------------------|-------------------|---------------------------------------------------------------|
| COD        | mg/dm³              | 5260              | 770                                                           |
| NH₄⁺       | mg/dm³              | 10.09             | 5.70                                                          |
| NO₃⁻       | mg/dm³              | 6.79              | 2.64                                                          |
| PO₄³⁻      | mg/dm³              | 92.49             | 35.16                                                         |

The results (see Table 2) demonstrate that the addition of probiotic agent "PIP WATER PLUS" reduces the indicators in the following way: by 86 % for COD, by 44% for ammonium nitrogen, by 61% for nitrates, and by 62% phosphates, respectively.

According to the main indicators, the wastewater corresponded to the level of biologically completely purified water after 24 hours of biological treatment. The only exception was suspended substances. Such a long time required for complete cleaning is associated with increased concentrations of pollutants in the wastewater coming to sewage treatment facilities.

The high content of nitrites in the final stages of experiments indicates a prolonged process of nitrification, or rather its second stage which means the oxidation of nitrites into nitrates. The long nitrification process in this case is associated with a high value of ammonium nitrogen in the source water, that is 68 mg/dm³.

The temperature in both tanks was the same. It remained 18-19°C throughout the process. The intensity of aeration was also the same. The silt dose was at the level of 2.0-2.3 g/dm³. The pH factor in both tanks was 8.2-8.3 at the initial stage and then it decreased to 8.0-8.1 at the final stage of experiments.

Both tanks were in equal conditions, except for the addition of a probiotic agent to one of the containers at the beginning of the experiment. Hydrobiological analyses of active silts in both tanks during the experiments did not reveal significant differences between the composition, number and mobility of microbiocenoses. The species composition of active silts consisted of only about 12-14 species of microorganisms, including: attached and free-floating infusoria (Vorticella, Opercularia, Epistulis, Paramecium, Euplotes, Aspidisca), shell amoebae (Arcella, Euqlypha), round and bristly worms, several species of rotifers. In general, the species composition of microbiocenoses of silts from both reservoirs corresponded to a well-functioning active silt.

Thus, the experiments proved that probiotic microorganisms did not have a damaging effect on the microbiocenosis of activated sludge.

5. Conclusions
The research yielded the following conclusions:
Even this limited experience of using probiotic agents in the field of wastewater treatment has shown their prospects for achieving the following goals: intensifying purification processes, reducing the level of toxic gases released from the waste liquid and, accordingly, reducing the level of smell, reducing the volume of precipitation, as well as increasing the content of dissolved oxygen in the sludge mixture of aeration tanks, which makes it possible to reduce air consumption for aeration.

It is theoretically established that the optimal scheme for probiotics addition is adding them before waste water primary settling, which leads to a complex effect: intensification of primary settling and biological purification, reduction of raw sediment volumes and decrease in the level of odors near the primary strainer chambers.

References
[1] Blinov V A, Burlina S N and Kovalev S V 2011 Probiotics in food industry and agriculture (Saratov: Science Research Center) p 171
[2] Voronov Yu V 1990 Reconstruction and intensification of sewage treatment plants Vol 2 (Moscow: Stroizdat ) p 224
[3] Sinev O P, Mantsev A I and Ignatenko A P 1981 Expansion and reconstruction of treatment facilities (Kiev: Budivelnik) p 44
[4] Grishel A I and Kishkurno E P 2009 Probiotics and their role in modern medicine Bulletin of Pharmacy 1(43) 90–93
[5] Khavkin A I 2009 Probiotic food products and the body's natural defenses Russian medical journal 17(4) 241–245
[6] Microbiological results of treatment with probiotics in a hospital: research report 2007 Crisal Company p 27
[7] Dongarra M L, Rizzello V, Muccio L et al 2013 Mucosal immunology and probiotics Curr Allergy Asthma Rep 13(1) 19–26. DOI:101007s11882 01203130
[8] Aleshkin V A, Afanasiev S S Pospelova V V et al 2005 Formation of probiotic therapy in Russia Vestnik RAMS 12 3–13
[9] Bondarenko V M and Gracheva N M 2005Dysbiotic conditions and respective therapeutic measures Vestnik RAMS 2 24–29
[10] Sorokulova I B 1996 Prospects for the use of bacteria of the genus Bacillus for the construction of new biologics Antibiotics and chemotherapy 41(10) 13–15
[11] Karaeva I V 2011 Modern anaerobic devices for treatment of concentrated wastewater Water Supply Sewage Construction Systems for Protection of Water Resources 2 179–184
[12] Hoffmann D E, Fraser C M, Palumbo F B et al 2013 Science and regulation Probiotics: finding the right regulatory balance Science 342(6156) 314–315. DOI:101126science1244656
[13] Vorobyov A A, Bondarenko V M, Lykova E A er al 2004 Correcting microecological disorders in clinical pathology with bifidcontaining probiotics Vestnik RAMS 2 13–17
[14] Landy J and Hart A 2013 Commentary: the effects of probiotics on barrier function and mucosal pouch microbiota during maintenance treatment for severe pouchitis in patients with ulcerative colitis Aliment Pharmacol Ther 38(1112) 1405–1406. DOI:101111apt12517
[15] Melentyev A I 2007Aerobic sporeforming bacteria Bacillus Cohn in agroecosystems (Moscow: Nauka) p 149
[16] Smirnov V V, Reznik S R and Vasilevskaya I A 1982 Sporeforming aerobic bacteria as producers of biologically active substances (Kiev: Naukova Dumka) p 279
[17] Drisko J A, Giles Ch K and Bischoff B J 2003 Probiotics in health maintenance and disease prevention Alternative Medicine Review 8(2) 143–155
[18] Report on the application of "Oxydol" bioregenerator at sewerage treatment facilities of MUP "Vodokanal" 2011 (Ekaterinburg Cherepovets). http:wodoswetruindexphp?option=com_content&view=article&id=37:per&catid=19:pers&Itemid=43
[19] Klaenhammer T R 2000 Probiotic bacteria: today and tomorrow *J Nutr* **130** 415–416
[20] *Oxidol as a product for improving the efficiency of sewage treatment plants and reducing energy consumption* Website of the company Agranco. http://wwwagrancocomr_information_for_water_utilities.html