Ministry of Education and Science of Ukraine
Black Sea Universities Network

ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2022

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Proceedings of International Competition of Student Scientific Works «Black Sea Science 2022» contain the works of winners of the competition.

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Odesa National University of Technology, 2022.

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INTRODUCTION

International Competition of Student Scientific Works “Black Sea Science” has been held annually since 2018 at the initiative of Odesa National University of Technology (formerly Odesa National Academy of Food Technologies) with the support of the Ministry of Education and Science of Ukraine. It has been supported by Black Sea Universities Network (the Association of 110 higher education institutions from 12 countries of the Black Sea Region) since 2019, and by Iseki-FOOD Association (European Integrating Food Science and Engineering Knowledge into the Food Chain Association) since 2020.

The goal of the competition is to expand international relations and attract students to research activities. It is held in the following fields:

- Food science and technologies
- Economics and administration
- Information technologies, automation and robotics
- Power engineering and energy efficiency
- Ecology and environmental protection

The jury includes both Ukrainian and foreign scientists. In the 4 years that the competition has been held, the jury included scientists from universities of 24 countries: Angola, Azerbaijan, Benin, Bulgaria, China, Czech Republic, France, Georgia, Germany, Greece, Israel, Italy, Kazakhstan, Latvia, Lithuania, Moldova, Pakistan, Poland, Romania, Serbia, Slovakia, Switzerland, Turkey, USA.

At the same time, every year the geography has expanded and the number of foreign jury members has increased: from 46 jury members representing 25 universities from 12 countries in 2018, to 73 jury members of the 46 universities from 19 countries in 2022.

More than a thousand student research papers have been submitted to the competition from both Ukrainian and foreign institutions from 25 countries: China, Poland, Mexico, USA, France, Greece, Germany, Canada, Costa Rica, Brazil, India, Pakistan, Israel, Macedonia, Lithuania, Latvia, Slovakia, Romania, Kyrgyzstan, Kazakhstan, Bulgaria, Moldova, Georgia, Turkey, Serbia.

The interest of foreign students in the competition grew every year. In 2018, the students representing 15 institutions from 7 countries have submitted 33 works. In 2021 the number of submitted works increased to 73, authored by the students of 40 institutions from 18 countries.

The competition is held in two stages. In the first stage, student research papers are reviewed by members of the jury who are experts in the relevant fields. In the second stage of the competition, the winners of the first stage have the opportunity to present their work to a wide audience in person or online.

All participants of the competition and their scientific supervisors are awarded appropriate certificates, and the scientific works of the winners are included in the electronic proceedings of the competition. Every year the competition receives a large number of positive responses from Ukrainian and foreign colleagues with the desire to participate in the coming years.

5. ECOLOGY AND ENVIRONMENTAL PROTECTION

WASTEWATER TREATMENT BY BIOLOGICAL METHODS

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Abstract. *Purpose of the work is to analyze existing wetland systems, biotechnologies on using hydrobionts and aerated lagoons in wastewater treatment systems. Task of the work is to elaborate experimental wastewater plant unites based on its function characteristics for suggesting improved models. Relevancy of the work is the increasing environmental pollution caused by wastewaters and urgent need for improved implemented wastewater treatment systems. Study methods used in the work included general scientific methods as system analysis, induction, deduction. Obtained results of experimental studied concluded the following: the efficiency of different pollutants removal is higher in hybrid constructed wetlands than in one-stage systems; hybrid constructed wetlands not only resolve ecological problems about wastewater management but can also provide landscape and educational profits because of their interesting shapes and innovative methods used; long term research on the operation of constructed wetland systems in Poland indicate that these systems can be used with great success on rural areas, especially in protected areas and valuable landscapes in Ukraine; cyanobacteria biomass, released from cultural medium, can be used for production of small tonnage valuable products with unique properties, large tonnage biomass of natural origin can be used for fuel production (biomethane, bioethanol, biodiesel); suggested two-stage purification scheme of landfill infiltrates enables to purify infiltrates effectively with primary purification under conditions of aerobic lagoon on the territory of landfill, transporting of infiltrate with the help of pipeline «landfill – municipal PCF», dissolving it with municipal sewerage effluents and pretreatment on municipal PCF.*

Keywords: *wetlands, aerated lagoons, wastewater treatment, biofuel production, cyanobacteria, hydrobionts, biomass.*

I. PERSPECTIVE OF USING WETLAND SYSTEM IN POLAND

Recent solutions for wastewater treatment in Poland are household wastewater treatment plants that in Poland can be defined as objects that support up to 50 people and their maximum capacity is 5 $m^3 \cdot d^{-1}$ [Water Law 2017, Poland]. There can be enumerated many different types of them and the most important ones are the facilities with drainage pipes, with active sludge, with biofilter, hybrid systems (active sludge+biofiter) and constructed wetlands [Jóźwiakowski et al. 2012]. The first one-stage constructed wetland in Poland was built during 1994-1996 and the scheme of such a facility can be seen on the Appendix 1. Constructed wetland wastewater treatment method involves the use of sorption processes of pollutants, chemical redox reactions and biological activity of selected plants that inhabit the marsh ecosystems. Wastewater treatment using wetlands can take place in natural or artificial conditions, then called "wetland" and "constructed wetland" respectively. Such wastewater treatment is widely applied in many countries (Austria, Czech Republic, Denmark, Germany, Italy, Poland, Portugal, Korea, Japan, Australia etc.) Pollution removal in constructed weltand systems occurs due to the functioning of a biofilm which is formed during the flow of wastewater through the bed. Plants play an auxiliary role in the sewage treatment process. In the rhizosphere (around plant roots) oxygen is produced, while other parts of the bed are anaerobic zone and they are poorly oxygenated. Plants in the constructed wetland systems can be assessed as elements which enable constant oxygen supply from the atmosphere to the bed. Due to the aerenchyma diffusion of oxygen from the atmosphere through the leaves and reed stems allows oxygen to flow into the root zone and then into the ground bed ecosystem, where oxygen can be additionally transferred through molecular diffusion resulting from the chaotic movement of gas particles [Brix 1993]. Plants in constructed wetland systems can have the following functions: stabilizating the surface of beds and protecting them from erosive wind, excellent habitat for fauna (especially birds), excellent thermal insulation, protecting the filter material from freezing in winter, excellent conditions for the development of heterotrophic microorganisms responsible for the organic matter rotting.

In recent years there has been observed a tendency to build hybrid CWs consisting of two or three beds with vertical and horizontal wastewater flow [Gajewska and Obarska-Pempkowiak, 2009; Dębska et al., 2015; Jóźwiakowski et al., 2016]. According to many authors, hybrid CWs provide better conditions for biological wastewater treatment [Gajewska et al., 2004; Gajewska and Obarska- Pempkowiak, 2009; Vymazal, 2005; Masi and Martinuzzi, 2007]. There can be different types of hybrid CWs, we can combine not only different plant species but also different types of sewage flow can be implemented – with vertical and horizontal flow (Appendix 2).

So far there has been built a lot of constructed wetlands in Poland. Many researchers test different equipment and combinations of plant species in order to obtain the best efficiency of domestic wastewater treatment. One of such scientific groups which concentrate on CW systems is the Department of Environmental Engineering and Geodesy from the University of Life Sciences in Lublin. The scientists design and make studies especially on the objects located in south-eastern part of Poland, in Lublin voivodeship. The most common ones are recently the hybrid CWs located in the Roztocze National Park and in the Polesie National Park. A very interesting aspect that should be mentioned is the unique shape of these CWs. For instance in Kosobudy (Appendix 3) the ground and plant beds are designed in the shape of a christmas tree, while in Stare Załucze (Appendix 4) we can observe a turtle shape wastewater treatment plant. The application of constructed wetlands in the areas of nature protection proves that this is a great solution of wastewater treatment which enables not only reliable operation and environmental care of endangered places but can also provide landscape and educational profits because of their interesting shapes and innovative methods used. A multicriterial analysis which takes the above-mentioned criteria into account shows that the use of CWs is consistent with the idea of sustainable development [Jóźwiakowski et al. 2015]. These systems fulfil all of the sustainability criteria, in particular the ecological criterion, as they ensure high efficiency of wastewater treatment with relatively small energy demand [Jóźwiakowski et al. 2019].

It has been observed by many researchers that constructed wetland enable not only high efficiency of wastewater treatment but also a reliable operation for many years. According to many authors CW systems can be a great solution for domestic wastewater treatment as they enable the elimination of many different pollutants such as: TSS, BOD_5, COD, total nitrogen, total phosphorus, heavy metals and pathogens.

The basic element of every constructed wetland system should be an initial septic tank which ensures the elimination of the biggest pollutants during sedimentation, flotation and fermentation. Then sewage after initial purification can be easily treated while biological purification processes occurring in the ground and plant beds. About 25 years of research on the CWs in south-eastern Poland has shown that the discussed systems provide especially high efficiency (over 80%) of biological pollutants removal, which has been expressed by the decrease of BOD_5, COD and TSS values [Jóźwiakowski et al. 2019]. The changes in the state of wastewater treated in the CW system are easily visible which is presented in the Appendix 6. Long term observations have shown that the efficiency of different pollutants removal in the hybrid constructed wetlands is bigger than in the case of one stage CW systems which can be seen in the Appendix 7. For this reason the discussed systems are suggested to be implemented not only on rural areas with dispersed housing, but especially on the protected areas, where the demands of pollutants removal are extremely tight.

On the basis of the polish experiences it can be stated that the efficiency of different pollutants removal is higher in hybrid constructed wetlands than in one-stage systems. Hybrid constructed wetlands not only resolve ecological problems about wastewater management but can also provide landscape and educational profits because of their interesting shapes and innovative methods used. Long term research on the operation of constructed wetland systems in Poland indicate that these systems can be used with great success on rural areas, especially in protected areas and valuable landscapes in Ukraine.

II. PERSPECTIVES FROM USING HYDROBIONTS AND AERATED LAGOONS

Very promising and perspective biotechnology resource for wastewater treatment are such hydrobionts as cyanobacteria. Cyanobacteria play significant role for balanced development of hydro-ecosystems, since they are the main, and sometimes the only, producers of primary organic substance in them. It is estimated today, that from 20 to 30 % of oxygen, obtained from photosynthesis in our planet, is owed to cyanobacteria. This is exactly why they played central role in alteration of air content and atmosphere structure. Cyanobacteria fix oxygen not only in soils, but in coral reefs as well as in other marine ecotopes, making nitrogen available to other organisms under conditions of different ecosystems. Cyanobacteria don't need vitamins for existence and development. They can use nitrates or ammonia as source of nitrogen and also phosphorus compounds and microadditives of such elements as ferrum, sulphur, zinc, copper, manganum, cobaltum, molybdenum etc. Most of their species are phototrophs, but some filamentous types can grow in darkness, using some carbohydrates (glucose or saccharose) as source of energy. Optimum conditions for cyanobacteria growth lay in complex of interconnected, mostly abiotic factors. The method of thickening of the aqueous suspensions of *Microcystis aeruginosa* using the coagulation-flocculation pretreatment was studied using the industrial coagulants and flocculants produced by P.P.H.U. WĘGLO-STAL (Poland). In the investigated suspension of *Microcystis aeruginosa* (without cavitational treatment, or after cavitational treatment), an appropriate reagent composition was added. Content of additives in different samples of suspension are given in Appendix 14. In order to improve the techno-economic indicators of the method researches were done using the very diluted suspensions Appendix 14. The mass contents of PAX-18 and PAX-XL19H coagulants in different suspensions were equal 10 ppm or 1 ppm, and the mass content of flocculant A100 was 10 ppm or 1 ppm, if it used separately, and only 1 ppm if it used in combination with coagulants.

The results of microalgae suspensions thickening by sedimentation with preliminary coagulation and flocculation treatment with the PAX-18 and PAX-XL19H polymer coagulants, as well as the A100 flocculant are shown in Appendix 15. The numbers of the measuring cylinders correspond to the type and concentrations of the additives indicated above in the Appendix 14. Cyanobacteria biomass contains many target products that are valuable for different fields of modern bioeconomics: food, pharmaceutical and perfumery industry. Under natural conditions these bacteria massively grow for centuries as primary source of organic compounds. In our time much effort has been put in field of genetic engineering for modification of phototrophic microorganisms, especially cyanobacteria, − producers of new useful compounds (target products) that aren't synthesized in natural way. Actual direction of modern studies is also environmental biotechnology and bioenergetics that anticipate direct application of cyanobacteria large-tonnage biomass and other massive forms of hydrobionts as raw material for biofuel production (biomethane, bioethanol and biodiesel) and mineralorganic fertilizer. Production of another fuel type − biogas (biomethane) using method of anaerobic digestion of cyanobacteria (biomethanogenesis), that uncontrollably grew during summer period in reservoir water area of Dnieper waterfall. Experiments have shown, that although no universal method for harvesting and concentration of microalgae exists (it is still productive field for studies), for every particular algae species, optimal economic ways and methods can be made. After concentration, in majority of cases it was used a biomass dehydration, resulting increase its maximum term of residence. For microalgae, such ways of dehydration are used as drum, pulverizer, sublimation or solar desiccation. Extraction of lipids and pendent fatty acids from biomass is conducted directly from lyophilization biomass. For extraction can be used such dissolvents as hexane, ethanol or mixture of both hexane and ethanol, which allows to extract up to 98 % purified lipids and fatty acids. Studies have shown, that in case of damage of cellular wall of algae with help of ultrasound procession, extraction of target product increases from 4,8 % to 25,9 %. From obtained feedstock, biodiesel can be produced using traditional technology– repeated esterification of plant oils. Lipid feedstock consists from 90–98 % (weight) triglyceride and small amount of mono- and diglyceride, contains free fatty acids (1–5 %) and small amounts of phospholipids, phosphatides, carotenes, tocopherols, sulphur compounds and remnants of water.

The most popular wastewater technologies in Ukraine are the following: reverse osmosis technology; technology of chemical and biological oxidation; infiltrate knotting technology; technology of biological purification in anaerobic and aerobic medium.

Aerobic methods of biological purification of filtrates have row of undeniable advantages over anaerobic: they are flexible in using, fast include in stationary regime of work, fast accommodate to changeable composition and expanses of filtrates. Aerobic reactors are far more simpler in construction and far more cheaper than anaerobic, they are also much easier automatized and easier in exploitation.
From analysis of existing natural studies it is possible to make conclusion, that purification of infiltrates in aerobic lagoon (or simultaneously connected lagoons) is simply, low-budget and enough efficient method of pretreatment of infiltrates.

Study of the aerobic purification was conducted at plant (Appendix 16).
The plant contained from 5-litter bulb, that with volume of 4 l was filled with infiltrate. Infiltrate for studies was chosen from pound-accumulator of Lviv MSW For aeration the air was supplied to bulb with the help of laboratory compressor. With the help of regulation compressor, set on air flow tube, it was regulated air expanses on aeration and supported constant significance of this expanse throughout the whole experimental time. Experimental work was conducted in two stages.

At first stage (static) was set alteration of COD, concentrations of ammonium nitrogen, pH and concentration of dissolved oxygen under conditions of continuous aeration without allotment of pretreated infiltrate and accordingly without addition into volume `fresh`, untreated infiltrate.

At second stage (dynamic) that was conducted after obtaining maximum possible level of purification under static regime, it was modeled continuous regime of purification, that is planned to be implemented at industrial pollution control facility. Once in 24 hours from bulk it was taken certain amount of infiltrate and was poured same amount of `fresh` unpurified infiltrate. For certain proportion significance of the sample the researches were conducted for obtaining constant concentrations of ammonium nitrogen and COD. After that, the daily volume of purified and `fresh` infiltrate was substituted, that accordingly was collected and poured into aeration plant, and it was studied a process of aerobic purification in dynamic regime for another time significance of infiltrate delay in aeration zone. Once in a day an infiltrate sample from bulk for analysis and sample for addition of infiltrate were taken.

Methodology of tertiary infiltrate treatment research at PCF.

For experiments in static regime for research place a mixture of effluents with active sludge was taken. Infiltrate in quantity of 1 m^3 was selected from pound-accumulator №5 in MSW Hrybovytske landfill. In experimental aeration plant was poured mixture of effluents and active sludge and was added calculated quantity for obtaining mixtures, that met the following dissolving criteria: 10; 500; 1000; 1250; 1500. In reactor it was added mixture of effluents with active sludge till obtaining general volume in 1,64 m^3. After that samples were taken for chemical experiments and the plant was launched. Every study cycle in static regime lasted 6 hours. After finishing of air supply a sample was taken for conducting chemical experiments.

Experiments in dynamic regime were conducted at the same plant (Appendix 17) The plant contained primary settlers: primary model settler for mixture of effluents with infiltrate and primary model settler for effluents without infiltrate. During 8 daily experiments the mixture from effluents and infiltrate as equally carried to aeration plant 1. Regulations of expanses were carried with the help of circulation pump and valve. Homogeneity of the mixture was obtained with the help of aerator. After 8 hours of mixture supply from effluents with infiltrate it was modeled working process of aerotank during 16 hours without adding infiltrate.

General strategy for two-stage cultivation of landfill infiltrates

Analyzing research data it is recommended principal scheme for implementation of landfill infiltrates pretreatment technology that is illustrated in Appendix 18. According to this scheme, infiltrates are accumulated in pound-accumulator that simultaneously serves as aerobic lagoon.

For this it is equipped with aeration system. Pound-accumulator is being screened with protective display by using well known technologies. In aerobic lagoon biological aerobic oxidation is taking place of organic contaminants and of ammonium nitrogen. Constant inflow is being realized and harvesting of infiltrates under conditions of supplement with necessary period of infiltrate residence in reactor. Infiltrate collection is being done with the help of pump station throughout set pipeline «landfill – municipal PCF» infiltrate is transferred into mixing block PCF where at given proportion it is mixed with municipal effluents and in mixture is directed to tertiary treatment at municipal PCF. For every particular case for technology implementation it is necessary to make balance calculation.

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