Quest Journals
Journal of Research in Environmental and Earth Sciences
Volume 7 ~ Issue 7 (2021) pp: 01-06
ISSN(Online) :2348-2532
www.questjournals.org

Research Paper

Efficiency of Phytoremediation Method for Surface Runoff Treatment From Urbanized Territories

Olha Rybalova[1], Olena Bryhada[2], Ludmila Melnik [3]
[1,2]*Assistant professor, National University of Civil Defence of Ukraine, Kharkov, Ukraine*
[3]*Researcher, Scientific Research Institution "Ukrainian Scientific Research Institute of Ecological Problems, Kharkiv, Ukraine*

***ABSTRACT**: The effectiveness of the proposed phytoremediation method using industrial waste as a filtration element for surface wastewater treatment, which is a scientific novelty of paper, has been experimentally determined. The paper develops proposals for the introduction of phytoremediation method for surface runoff treatment with low capital and operating costs. The scientific substantiation of the necessity of introduction of phytoremediation facilities with the use of industrial waste as a filter nozzle for surface wastewater treatment in order to improve the ecological condition of water bodies and increase the use of plastic waste, which has practical value, is chosen as the research direction. Carrying out of experimental researches on model installation allows to define efficiency of the phytoremediation method with application of various plants - phytoremediates which represents scientific value of paper.*

***KEYWORDS:** surface wastewater, urbanization, fire, phytoremediation method, waste utilization*

Received 06 July, 2021; Revised: 18 July, 2021; Accepted 20 July, 2021 © The author(s) 2021. Published with open access at www.questjournals.org

I. INTRODUCTION

Discharge of untreated wastewater (rain or snow) is a significant cause of siltation and pollution of water bodies in many countries of the world, including Ukraine. The solution of this problem is complicated due to the specific features of the regime of formation and inflow of surface wastewater into water bodies, which differs significantly from the conditions of formation of domestic and industrial wastewater.

In the context of the current trend towards climate warming, the risk of fires and the ingress of pollutants with surface wastewater into surface and groundwater is increasing.

The development of measures to reduce the ingress of untreated surface water into water bodies with the use of industrial waste is a very important task.

Many studies by both domestic and foreign authors have been devoted to the cleansing properties of higher aquatic vegetation (HAV). The interest that researchers pay to higher aquatic vegetation comes from the function that these plants perform in the ecosystem. Higher aquatic vegetation not only consume substances dissolved in water, but also are a substrate for the development of various microflora, which neutralizes significant proportion of pollutants that come with surface runoff into natural water bodies and thus improve the quality of water [1,2].

Due to the large number of macrophytes, common reed (Phragmites australis (Cav.) Trin ex Stend.), narrow-leaved (Typha angustifolia L.) and broadleaf cattail (Typha latifolia L.), lake reed (Scirpus lacustris L.) and some other species are most commonly used for wastewater treatment. According to researchers, 1 ha of common reed beds during the growing season can extract from water up to 450 kg N, 180 kg P, 220 kg K, 330 kg Cl^- [1-3].

Air-water macrophytes (reeds, cattail, bulrush and others) improve the gas regime of swampy and flooded soils. In the oxygen-enriched environment near the thin roots, rhizosphere microorganisms develop in large numbers, which participate in the processes of aerobic destruction of organic matter that accumulates in silt deposits and promote the conversion of substances into digestible forms. Thus, due to higher aquatic vegetation self-cleaning processes are activated and air circulation in bottom sediments takes place [1].

Studies conducted by the specialists of the Research Institution "Ukrainian Research Institute of Environmental Problems" on the cleaning capacity of higher aquatic vegetation allowed to develop a method of using plants in treatment systems such as Constructed Wetlands (CW) [4]. At present, more than 60 projects of treatment facilities on the territory of Ukraine have been developed on the basis of this methodology.

Constructed Wetlands has been successfully implemented for the treatment of domestic wastewater in the Netherlands, Japan, China, for the treatment of contaminated surface runoff in Norway, Australia, and other countries [5].

In Ukraine, wastewater treatment facilities of the Constructed Wetlands type are used under the name of bioengineering wastewater treatment facilities (BWTF, patent of Ukraine No. 7705, 7708, 1986) [6, 7]. The principle of operation of this type of facility is based on the use of the natural process of self-purification, which takes place in the filter layer and is the substrate for the formation of biogeocenoses of higher aquatic plants [8].

Currently, several types of BWTP have been developed for different purification conditions and different types of bioplateau. Structures with higher aquatic vegetation are effectively used for additional treatment of wastewater after traditional treatment facilities. Bioplateau systems use not only water-air higher aquatic vegetation (reeds, cattail, bulrush, sedge, etc.), but also various types of submerged vegetation - pondweed, parrot's-feather, hornweed, etc.

Design features and differences in the technology of construction and operation of treatment facilities using higher aquatic vegetation of Constructed Wetlands type were the basis for the variety of their terminological definitions: botanical sites (hydrobotanical sites), filter ponds, biological ponds with plantings of higher aquatic plants, filtration devices, artificial wetlands (artificial swamp), bioplateau, bioengineering structures of water quality regulation. Common to all the above facilities and devices is the presence of the biocenosis of higher aquatic vegetation, which directly or indirectly affects the formation of the biological component of the processes of transformation of water quality (its purification) and the engineering characteristics of facilities (individual structural elements, its operational parameters, etc.).

As a rule, water in such systems passes through thickets of higher aquatic vegetation or bog vegetation, partly - through the layer of soils and by means of drainage is removed from the site. The main operational characteristic of artificial wetlands is the length of the filtration path (from 100 to 1500 m) and the speed of water movement (from 6 to 10 days). The effectiveness of their use is characterized by the decrease in concentrations of ammonium nitrogen by 30 - 60%, nitrates - by 10 - 20%, BOC - by 50 - 70% [9].

The economic effect of the introduction of such engineering solutions consists of many factors: the simplicity of the designs of systems with plants, the absence of complex engineering devices for regulating the level or flow of water, the absence of the use of chemicals or other reagents, there is no need for highly qualified operating personnel, etc. [10].

The environmental effect is that such systems are natural areas that are characteristic of river systems and with aquatic vegetation, which organically distributed on the floodplain. The creation of new sites or the expansion of existing ones will help, without harming the natural conditions of the region, to intercept and purify wastewater entering the rivers from such indicators as suspended matter, organic matter, oil products, pathogenic microorganisms, and to reduce mineralization.

II. EVALUATION OF EFFICIENCY OF PHYTOREMEDIATION METHOD FOR SURFACE WASTEWATER TREATMENT

Contamination of surface and groundwater by surface (rain and melt) wastewater is a major problem for many countries [11]. The problem of diffuse sources of pollution entering water bodies is exacerbated by climate change. Climate change negatively affects hydrological, hydrochemical and hydrobiological indicators of surface water status [12,13] and increases the number and volume of fires, which leads to pollution of air, soil, biodiversity loss, destruction of vegetation and animals, and human deaths [14, 15]. Table.1 describes the main purification systems using phytoremediation.

Table.1
Comparative characteristics of treatment systems using phytoremediation

Treatment systems	Location	Application	Water movement	Paper efficiency	Disadvantages
Botanical sites	Shallow waters	Treatment, additional treatment of domestic and industrial wastewater	Horizontal due to thickets of higher aquatic vegetation	Organic substances up to 97%, heavy metals up to 90%	1) Efficiency depends on the season of the year. 2) Insignificant time of liquid contact with higher aquatic vegetation
Phytofiltration devices	Alluvial underwater ridges near the river	Biomelioration of natural waters	Horizontal	Not specified	1) Slight contact of liquid with higher aquatic vegetation, 2) liquid breakthroughs
Bioponds with higher aquatic vegetation landings	Rates with the introduction of higher aquatic vegetation	Treatment, additional treatment of domestic wastewater	Horizontal in the water column	N - 10-80%, COC - up to 90%, suspended solids - up to 98%,	1). Low performance. 2). Alienation of large areas of land. 3). The presence of stagnant

Treatment systems	Location	Application	Water movement	Paper efficiency	Disadvantages
				petroleum products - up to 60%, disinfection up to 90%	zones. 4). Re-contamination.
Artificial natural wetlands	Wetlands with artificial or natural embankments	Treatment, additional treatment of domestic wastewater	Horizontal due to thickets of higher aquatic vegetation	NH_4^{2-} - 30-60%, NO_3^- –0-20%, BOC –50-70%	1). Uncontrolled treatment processes. 2). Efficiency depends on the season of the year
Bioplateau	Canals, rivers, lowlands or upper ponds	Treatment, additional treatment of domestic wastewater	Horizontal due to thickets of higher aquatic vegetation	Ammonium nitrogen -30-60%, NO_3^- -10-20%, BOC -50-70%, disinfection up to 90%	1). Alienation of large areas of land. 2). Efficiency depends on the season of the year

In order to fully realize the possibilities of higher aquatic vegetation, it is necessary to conduct additional research on the choice of the particular phytoremediation method. Therefore, it is necessary to conduct the study to select the best phytoremediation method for surface wastewater treatment.

III. EXPERIMENTATION

In order to determine the efficiency of treatment of rainwater and surface wastewater after fires by phytoremediation, experimental studies were conducted on the model installation. Modeling of the process of phytoremediation and infiltration took place in the laboratory of the Department of Labor Protection and Technogenic and Ecological Safety of the National University of Civil Defense of Ukraine.

The construction was proposed, where the 10-liter PET bottle was used as the base container, with the cut out bottom (Fig.1), filled with soil on top (layer 14-16 cm), below - the layer of plastic waste (shredded parts of PET bottles - deliberated PET container). Next, to keep the fine fraction of the model solution is the layer of sand and synthetic fine filter. The bottom of the bottle is closed with the lid, which is opened for sampling water for analysis.

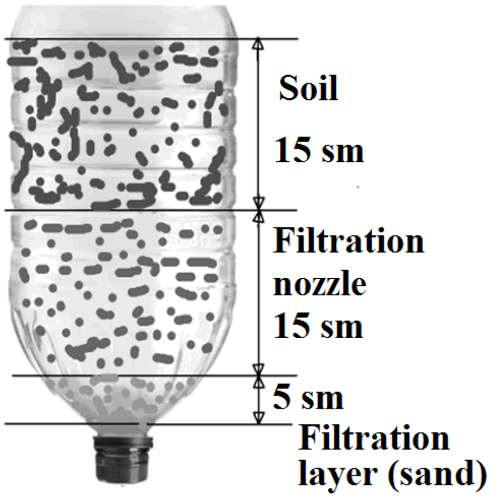

Figure 1. Scheme of the basic capacity of the model installation

To achieve this goal, the model installation was assembled, which consisted of 6 pairs of base tanks with the following filling:

1. soil (without filter nozzle);
2. soil (with filter nozzle)
3. soil (with filter nozzle) with the addition of the solution of microbial culture Aqua Tite Dry Microbes;
4. soil (with filter nozzle) + oats;
5. soil (with filter nozzle) + common reed (Phragmites commnis);
6. soil (with filter nozzle) + beans.

The tanks were installed in pairs side by side. In each pair, the first tank is used to determine the efficiency of surface wastewater treatment, and the second - to assess the effectiveness of surface wastewater treatment after a fire with the addition of foaming agent.

The first pair of tanks was used as the reference for the remaining pairs (2- 6) to determine the effect of the filter nozzle from defibrinated PET containers. The second is reference to the other pairs (3- 6) to determine the effect

of microbial culture supplements and the effect of different types of vegetation on the processes of phytoremediation.
In each pair of tanks before the start of the experiment, the model solution of rainwater runoff (MSRR) was added to complete wetting, which was then used during the experiment. The model solution contained - NH_4Cl - 17 mg / DM^3, KH_2PO_4- 50 mg / DM^3; $NaNO_2$- 10 mg / dm^3 and glucose - 100 mg / dm^3. The 6% solution of the foaming agent used to extinguish fires was used as the model wastewater pollutant.
At the beginning of the experiment, 0.144 dm^3 of 6% foaming solution was added to the tank, based on the foaming agent consumption during firefighting 3.6 dm^3 / m^2, which was intended to simulate the fire extinguishing process.
A day later, the solution of microbial culture Aqua Tite was added to the pair of containers No. 3, which is used to clean waste tanks, pits, reservoirs, etc. from biological pollution.
In the soil of the experimental tanks were previously planted the following for 30 days: No. 4- oat seeds, No. 5 - common reed (Phragmites commnis), whole plants with roots; No. 6 - seeds of bush beans.
At the beginning of the experiment, 3 hours after the addition of the foaming solution, 2 dm^3 MSRR was added to all containers and the solution filtered through the container was collected for analysis. In the same way, samples were taken at 6, 16 and 48 days after the start of the experiment to determine the dynamics of the phytoremediation process in the experimental installation.
All plants developed normally and show the sufficiently developed root system (photo 1).

Photo 1. Sampling for laboratory analysis by the 2nd year student majoring in 101 "Ecology" Zolotariova Sofiia
All water samples were analyzed according to standard methods for determining the quality of surface wastewater.
Table 2 shows the effectiveness of the use of reeds and defibrillated containers of polyethylene terephthalate for the treatment of rainwater.

Table 2
The effectiveness of the use of reeds and defibrillated containers of polyethylene terephthalate for rainwater treatment

Name of identifier	Rainwater before treatment	Rainwater wastewater after treatment with defibrillated containers of polyethylene terephthalate	The efficiency of rainwater treatment with defibrillated containers of polyethylene terephthalate,%	Rainwater wastewater after treatment with defibrillated containers of polyethylene terephthalate and reeds	The efficiency of rainwater treatment with defibrillated containers of polyethylene terephthalate,%
Chemical oxygen consumption (COC), mg O / DM ^{3}	96.0	23.0	76.04	9.6	90.00
Biochemical oxygen consumption (BOC $_5$), mg O $_2$ / DM ^{3}	43.8	10.0	77.17	3.5	92.00
Oil and Oil products, mg / dm^3	0.16	0.04	75.0	0.032	80.0
Suspended substances, mg / dm^3	158.0	5	96.84	3.16	98.00

Experimental studies have shown the high efficiency of the use of reeds and defibrillated containers of polyethylene terephthalate for the treatment of rainwater. The purification efficiency for suspended solids reaches 98.0%, for BOC $_5$ - 92.0%, for petroleum products - 80.0% and for COC - 90.0%.

IV. CONCLUSIONS

1. The scientific work investigated modern methods of wastewater treatment using phytoremediation. Improving surface runoff treatment methods is a very important task, which aims to reduce the negative impact on aquatic ecosystems.
2. The main practical result of scientific paper are proposals for the introduction of low-cost and high-efficiency environmental protection facilities using phytoremediation for surface runoff treatment, taking into account the impact of fire extinguishing.
3. It is experimentally proved that the use of crushed parts of PET bottles (defibrinated PET containers) as the layer (nozzle) under the soil layer increases the efficiency of the process of disinfection of surface wastewater with impurities of anionic surfactants (foaming agent). Analysis of the use of the filter nozzle made of defibrinated PET containers showed the increase in the efficiency of phytoremediation processes.
4. Experimental studies have shown the high efficiency of the use of reeds and defibrillated containers of polyethylene terephthalate for the treatment of rainwater. This method of surface runoff treatment from urban areas provides an inexpensive and easy to operate solution to the problem of reducing the impact of diffuse sources of pollution on the ecological status of surface waters, as well as minimizes the storage of these industrial wastes.
5. It is planned to continue conducting experimental research with the use of other plants - phytoremediates, which are more common in urban ecosystems.

REFERENCES

[1]. Phytoremediation methods for wastewater treatment. Rybalova O., Bryhada O., Ilinskyi O., Bondarenko O., Zolotarova S. Danish Scientific Journal No41, 2020 P. 10-13
[2]. Sustainable livestock wastewater treatment via phytoremediation: Current status and future perspectives. Bioresource Technology. Volume 315, November 2020, 123809. HaoHu, XiangLi, ShaohuaWu, ChunpingYang. https://doi.org/10.1016/j.biortech.2020.123809
[3]. Wenshuo Wei, Juxiu Tong, Bill X. Hu., Study on ecological dynamic model for phytoremediation of farmland drainage water, *Journal of Hydrology*, Vol 578, 2019, 124026
[4]. V.H. Mahmedov, M.A. Zakharchenko. Posibnyk do zastosuvannia vodookhooronnykh bioinzhenernykh sporud (BIS) dlia ochyshchennia nemineralizovanykh zabrudnenykh vod silskohospodarskoho vyrobnytstva Ukrainy, Kharkiv, - 1993
[5]. Anton Matsak, Kateryna Tsytlishvili, Olga Rybalova, Sergey Artemiev, Andrey Romin, Oleksandr Chynchyk. Method of agricultural sewage water purification at troughs and a biosorption bioreactor. Eastern European Journal of Enterprise Technologies, VOL 5, NO 10 (95) (2018), DOI: 10.15587/1729-4061.2018.144138
[6]. Mahmedov B.H., Zakharchenko M.A., Yakovleva L.I, y dr. // Patent Ukrainy N 7705. Cporuda dlia biolohichnoi ochystky stichnykh vod. 1995 r
[7]. Iakovleva L.I, Mahmedov B.H. y dr. // Patent Ukrainy N 7708. Sposib biolohichnoi ochystky stichnykh vod vid spoluk azotu ta sulfativ. 1995r.
[8]. Zakharchenko M.A., Ryzhykova I.A. Perekhoplennia ta ochyshchennia poverkhnevoho stoku za dopomohoiu sporud fitoremediatsii. V Mizhnarodna naukovo-praktychna konferentsiia «Ekolohichna bezpeka: problemy i shliakhy vyrishennia»: Zb. nauk. st. U 2-kh t. T. 2 / UkrNDIEP. – Kh.: Raider, 2008.-s. 298-303

[9]. Treatment of dairy industry wastewater by combined aerated electrocoagulation and phytoremediation process. Chemosphere Volume 253, August 2020, 126652. lJ.Akansha, P.V.Nidheesh, AshithaGopinath, K.V.Anupama, M.Suresh Kumar. https://doi.org/10.1016/j.chemosphere.2020.126652
[10]. Rybalova O.V., Bryhada O.V., Korobkina K.M., Tomchuk N.M. Pryrodni metody ochyshchennia poverkhnevykh stichnykh vod / Abstracts of II International Scientific and Practical Conference, Osaka, Japan, 30-31 October 2019, p. 501-509
[11]. Rybalova O.V., Korobkina K.M., Tomchuk N.M. Otsinka vplyvu dyfuznykh dzherel zabrudnennia vodotokiv na ekolohichnyi stan baseinu r. Oskil / Abstracts of IV International Scientific and Practical Conference Liverpool, United Kingdom 4-6 December 2019, p. 266 – 276
[12]. Rybalova O.V., Korobkina K.M. Vplyv lisovykh pozhezh na stan bioriznomanittia v umovakh zmin klimatu / Materialy Mizhnarodnoi naukovo-praktychnoi konferentsii «Problems of Emergency Situations», NUTsZU, 20 travnia 2020 roku, m.Kharkiv, S. 297-299
[13]. Rybalova O.V., Korobkina K.M. Vplyv lisovykh pozhezh na stan poverkhnevykh vod / Problemy ta perspektyvy zabezpechennia tsyvilnoho zakhystu: materialy mizhnarodnoi naukovopraktychnoi konferentsii molodykh uchenykh. – Kharkiv: NUTsZU, 2020. – S.260
[14]. Vplyv lisovykh pozhezh na yakisnyi stan gruntiv. Rybalova O.V., Bryhada O.V., Korobkina K.M. Krainiukov O.M., Miroshnychenko I.M. / Naukovyi visnyk budivnytstva. – Kharkiv: KhNUBA, PF «Mykhailov», 2019. Vyp. 2(96). Tom 2. S. 413-422
[15]. Korobkina K.M. Vplyv lisovykh pozhezh na stan navkolyshnoho pryrodnoho seredovyshcha / Materialy mizhnarodnoi NPK molodykh uchenykh NUTsZU", 2019- S.385