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THE STUDY OF TECHNOGENICALLY TRANSFORMED WATER ECOSYSTEMS WITHIN AVIATION FACILITIES OPERATION AREA

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Abstract

The object of the research is technogenically transformed aquatic ecosystem which helps to develop water protection measures and ensure the ecological safety of technogenically conditioned ecosystems of rivers passing through urban areas within aviation repair facilities. The conceptual model of aquatic ecosystem consists of the Nyvka and Irpin rivers, both aquatic ecosystems belong to the Dnieper basin, and the permanent trophic connection makes it possible to consider them as the conceptual majority of interconnected constituents. ***The aim of the work:*** *to study main features of the formation of technogenically conditioned water ecosystems of small and medium rivers due to anthropogenic influence of the aviation repair facilities.* ***Methods:*** *were used a biotesting method, a method of the complex water quality assessment, a substrate biological transformation model based on the law of non-linear mathematical model of Mono and Michaelis-Menten. The technogenic impact index for every pollutant was calculated.* ***Results:*** *it was found the content of heavy metals, oil products, nitrogen, nitrite nitrogen, nitrate nitrogen in the surface water of the Nyvka and Irpin rivers. Investigated samples of the Nyvka water were of V water quality class and the Irpin water was of I V water quality class. The hydrochemical analyze of the Irpin river has shown that limitation factors affecting the water quality, cause the disturbance of the self-remediation ability of the water ecosystem. Was shown changes of contaminant concentration in the Irpin River current.* ***Discussions****: obtained results of the modeling of the Irpin water self-remediation from contaminants are represented that the constant for contamination agents such as nitrogen, nitrite nitrogen, nitrate nitrogen and* Cu^{2+} *have negative values. The predominating negative values indicate, that in the aquatic environment self-remediation processes have not time to occur, as water is being very active contaminated from the mowings, neighboring agricultural lands.*

Keywords: conceptual model of aquatic ecosystem; Irpin river; technogenic impact index

1. Introduction

The surface waters quality control is a highest priority task for the state to sustain the ecological safety. It is connected with that the problems of the rational waters use; in resent years; are not consistent with the scale and depth of man-made influences; in comparison with the scientific principles of ecologically balanced development of river water ecosystems.

The aviation transportation rapidly develops in the world. Airport operations are an important factor in our economy; for tourism; imports; exports and business. However; these benefits must be weighed against the impact air travel is having on the quality of people's life and on the local and global environment. Despite the positive aspects resulting from the intensive development of aviation; airports and aviation facilities are large-scale polluters of all the components of the environment [1].

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aviation; airports are large-scale polluters of the environment.

In this regard; it is necessary to investigate the aviation influence on environment; particularly; water environment within certain aviation facilities (aviation repair plants); and to improve the environment components quality control near these facilities [2].

2. Analysis of literature and problem definition

According to accessible scientific and technical literature data; aviation facilities affect ecological situation of the water objects; soil; air [1; 3]. In certain articles [3; 4] summarizes information on the analytical methodologies available for the determination of pollutants emitted during airport operations and provides data on the toxicity of runoff containing compounds used in de/anti-icing operations. In most cases aviation facilities do not possess their own effluent treatment plants; so all effluents carrying petroleum compounds; surfactants; the de-icing agents used in winter; and other organic and inorganic pollutants run off together with rain water or snow melt into drainage ditches; where they enter the soil; surface waters (rivers; lakes; ponds); and ultimately ground waters [3].

The contamination of the natural waters; within aviation facilities operation area; is the reason of hazard; conditioned by the worsening of the qualitative indices of the water objects and human health as a result.

The ecological response of the water ecosystems on technogenic impact; is the qualitative depletion of the river waters and formation of technogenically transformed water ecosystems (TTWE) of rivers passing through urban areas within aviation repair.

For study such rivers we propose to use the ecosystem approach and the river basin principle of management. This approach became widespread from all over the world [5] It provides complex research on patterns of their development for the long-term period.

The aim of the work: to study the formation of technogenically conditioned water ecosystems of small and medium rivers due to anthropogenic influence of the aviation repair facilities

The object of the research is structural and functional changes in the technogenically conditioned aquatic ecosystem of rivers. This object helps to develop water protection measures and ensure the ecological safety of technogenically transformed ecosystems of rivers passing through urban areas within aviation repair facilities. The subject of research is to improve the ecological state of technogenically-modified aquatic ecosystems.

3. Materials and methods of research

We propose to study the TTWE with the help of the complex conceptual model of rivers system; which consists of small and medium rivers. This is necessary to ensure the ecological safety of the river ecosystem and to develop water protection measures. Given system may be considered as an example for investigation of the mechanisms of impact of anthropogenic contaminants incoming from small river on ecological condition of the medium river.

In our case; the complex model of the system used for the study of the technogenically determined Irpin River and its right tributaries - the Nyvky River; which are hydrographic structural elements of the Dnipro basin. Thus; TTWE investigation objects constitute the aquatic plot covering the area from aviation repair plant on the Nyvka river; to the place of the Nyvka river entrance into the Irpin river and to mouth of it; i. e. to the Kyiv Reservoir; located above drink water supply of the Kyiv. The length of such complex conceptual system is about 55 km [6].

The main sources of the technogenic impact of rivers ecosystem are: atmospheric precipitation; agricultural wastewater; urban wastewater and surge water from aviation plants.

Nyvka is the first component of the system. It flows within Kyiv city near the aviation repair plant. It's runoff is regulated; the lacinity is about 2.2 %; which is the greatest value for all the small rivers in Kyiv. In this regard; the fishery ponds; which supply the citizens with the fish; were built on the river [3; 6]. Therefore; the quality of the water of the Nyvka river; should meet fishery water body standards. That is why; for the incoming treated wastewaters; more strict standards are applied; in comparison with drink and domestic waters. The violation of these norms and regulations may disturb the water quality; biota condition and even human health as a result.

The Irpin River is the second component of the system. The length of the river is 162 km; the catchment area is 3340 km^2. In the Irpin basin are 14 hydro-amelioration systems (192;73 hectares); 6 reservoirs and 265 ponds (48.4 million m^3). The total length of the regulated riverbed is about 110 km. The river flow is pumped into the Kiev reservoir by the Irpin pump station.

One of the problems of our study was to define the principles of the hazardous water contaminant parameters assessment; concerning formation and functioning of technogenically transformed water ecosystem (TTWE); as well as to determine the ways of its further development improvement under operation as the fishery and recreation source [6; 7].

4. Research results

The Irpin water quality criteria for the water bodies ecological condition assessment; should prevent the use of such water for the fishery and recreation;

because it is hazardous. The basic reasons; which condition the surface water quality worsening; are the organic and inorganic compounds; as well as the substances with damage (toxic) effect on hydroecosystems. These substances potentially may initiate the preconditions of ecological hazard for population. To avoid this phenomenon; ecological condition of the Irpin river in the system “technogenic impact-consequences” should be investigated. The water guard measures to improve the ecological condition of the Nyvka river; as the basic source of the Irpin river technogenic contamination; should be implemented as well.

The initial stage of research was to estimate the probable pollutant hazard for aquatic flora and fauna; biotesting method was applied. This method is the most effective biological method of the experimental assessment of the water toxicity. It is based on indication of the test objects response [8]. During ecotoxicological investigation of the natural waters of the Nyvka river within the aviation engineering repair area; a series of experiments were conducted; with the help of methods; widely applied abroad and developed by Ukrainian (*Daphnia magna S.* biotesting technique) and foreign scientists (*Allium cepa; Z.; Lactuca sativa Z.* biotesting techniques) [8; 9].

Series of samples of the surface water layer; bottom water layer and bottom sediments; were taken. Concerning hydrobiological indices; it is noted that the sample toxicity tends to increase in range: “surface water layer” → “bottom water layer” → “bottom sediments” for all the testing species *Lactuca sativa Z; Allium cepa Z.; Daphnia magma S.* (table 1.).

Table 1

Biotesting of waters and bottom sediments of the Nyvka river

Microorganism	Surface water layer	Bottom water layer	Bottom sediments
Lactuca sativa Z.	55%	60%	82%
Allium cepa Z.	50%	55%	78%
Daphnia magma S.	65%	75%	80%

Thus; it can be concluded that hydrobionts are affected if their environment is of IV class of the water quality (dirty) according to the water contamination index (WCI). To characterize the condition of investigated Irpin river plot; the results of the state monitoring of surface waters of Ukraine in three hydrological section lines; were used: Irpin town; Hostomel urban village; Kozarovychi village [10]; as well as the results of the personal Irpin waters monitoring (above Stoyanka village).

With the use of known indices; the river water composition; the complex assessment of the natural waters quality; was applied [11]. The given method is based on determination of the water contamination index (WCI); as the unique state normative criterion of Ukraine concerning the water quality class definition. Given standard proposes definition of the water quality class according to the following components of environment: salt composition indices; trophic and saprobiological composition indices; indices of specific toxic ingredients [11].

The assessment of the qualitive condition of the surface waters according to the WCI technique; makes it possible to classify the contamination level according to the general ecological approaches (without consideration of the functional changes); to compare the quality of the water of different water objects; and to indicate the tendencies of changes in time.

By the method of the complex Irpin river water quality assessment; following results were obtained:

- in the place of the Nyvka river entrance above Stoyanka village; the water was of V quality class; the water was dirty; the WCI was 4.3-5;
- in hydrological section line of the Irpin town; the most waters (96 %) were of IV quality class; water was contaminated; WCI varied in range of 2.22-2.52; only in 2013 and 2014 water was of III quality class; water was moderately dirty;
- in hydrological section line of Hostomel urban village the water was of 4 quality category; the water was dirty; WCI varied in range of 2.33-2.92 in 90 % IV quality class;
- in hydrological section line of Kozarovychi village the water was of IV quality class; WCI was 2.4-2.67 during entire ten-year period.

Due to fact that the Nyvka river is the right-hand side tributary of the Irpin river; it is the source of the technogenic impacts for given river ecosystem. According to our data; 90 % of investigated samples of the Irpin water were of IV water quality class.

After analyzing the hydrochemical composition of the Irpin river; it should be noted that limitation factors affecting the water quality (oil products; ammonium Nitrogen; ChOD; heavy metal ions); cause the disturbance of the particular property of the water ecosystem – self-remediation ability. This disturbance is reflected on the water contamination level. Mentioned above data show that waters are mostly of IV quality class; i. e. they are dirty.

The fact of anthropogenic transformation of water ecosystems of the Nyvka and Irpin rivers is confirmed by executed analysis; systematization and statistical processing of the ten-year period (2007-2016) ecological monitoring data. Obtained results show that following changes occur in hydroecosystems: disturbances of the matter and energy balance; hydrobionts biodiversity exhaustion; transformation of the biocoenoses associations towards strengthening of β and α-saprobic species; due to technogenic factors pressure increase. Therefore; following examples are considered: summary indices exceeding: ChOD (chemical oxygen demand of hardly oxidation agents) in 1.5 times; ammonium Nitrogen in 3-7 times; significant exceeding of the oil products and heavy metal ions MAC in water samples from the Nyvka river.

The next step of research was the description of the contaminating agents content in the aquatic environment [12; 13]. To describe this process; the substrate biological transformation model was applied. In this model; the dilution processes origin was not considered; according to the law of non-linear mathematical model of Mono and Michaelis-Menten [14]. In Michaelis' and Menten's papers the fundamentals of the enzymatic kinetics were presented. The patterns of the enzymatic kinetics and various factors effecting life activity and growth of the microorganisms; were deduced.

Given law is derived on the base of the chemical kinetic reaction equation and describes the rate of products formation according to the following equation:

$$E + S \rightarrow [ES] \rightarrow E + P.$$

The formula of Michaelis-Menten looks like the first order differential equation:

$$\frac{dS}{dt} = -\frac{V_m \cdot S}{K_S + S} \quad (1)$$

where (dS/dt) is the rate of the enzymatic reaction; important index; which is the measure of the enzymatic activity; S is the substrate concentration; mg dm^{-3} (g m^{-3}); V_m is the maximal speed of the process; achieved at unlimited amount of the substrate; mg (dm^3 hour)$^{-1}$; K is the Michaelis-Menten constant (the constant for contamination agents); mg dm^{-3} (g m^{-3}).

To forecast the behavior of the aquatic environment contamination; the calculative formula was introduced; by solving equation (1) with initial condition t=0; S=S^0. S^0 is the substrate concentration in initial monitoring plot; the section line of Irpin town. The required dependence between S and t looks like:

$$t = \frac{1}{V_m}(S^0 \cdot S + K_S \ln\frac{S^0}{S}) \quad (2)$$

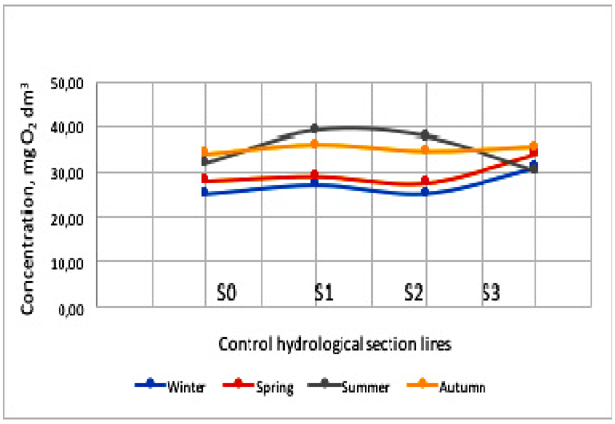
The formula (2) includes two unknown coefficients K_s; V_m. To determine these ones; at least two reliable values of the S concentration at different t_1; t_2 time moments; are required. ChOD; oil products; the simplest Nitrogen compounds; heavy metal ions are supposed to be considered as the substrate. When selection of the primary ecotoxicans of anthropogenic origin; the hazard degree for hydrobionts; structural and functional features of the water body formation; were taken into account.

Consequently; to determine the required coefficients; following formulas are used:

$$K_s = \frac{t_2(S^0 - S_1) - t_1(S^0 - S_2)}{t_2 \ln S_1 - t_1 \ln S_2 - (t_2 - t_1)\ln S_0} \quad (3)$$

$$V_m = \frac{1}{t_1}\left(S^0 - S_1 + \frac{t_1 S_2 - t_2 S_1 + S^0(t_2 - t_1)}{t_2 \ln S_1 - t_1 \ln S_2 - (t_2 - t_1)\ln S^0}\ln\frac{S^0}{S_1}\right) \quad (4)$$

The S concentration values; simultaneously determined due to numerous surveillances; in four different hydrological section lines of the Irpin river; are preferred to be interpreted as the result of the corresponding substrate degradation in the river water at certain time moments – 0; t_1; t_2; t_3. Water temperature is a significant criterion in the carried out calculations because it can affect hydrobionts life activity; and as the result cause the change of the environment-formation function of the water ecosystems due to transformation of the physical and chemical parameters of the water. Water temperature of seasons; i. e. winter; spring; summer and autumn; should be taken into account [15; 16]. If known the river flow speed and distance between hydrological section lines; time of the substrate exposition in water during its motion from one hydrological section line to another; should be considered. Relatively; $t_1=l_1/U$=22;2 hours; $t_2=l_2/U+t_1$=37;2 hours; $t_3=l_3/U+t_2$=60;3 hours. Thus; in such a way; the values for four seasons and eight types of substrate; were obtained.



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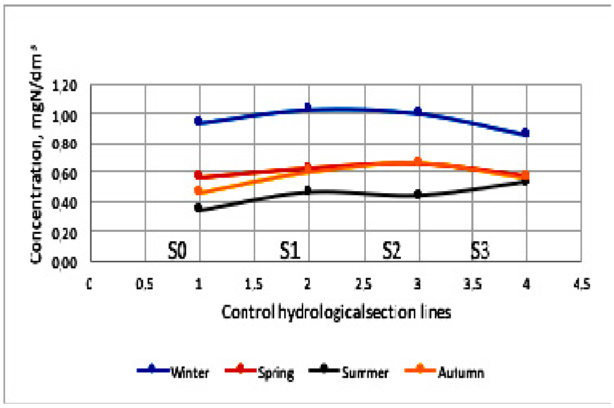

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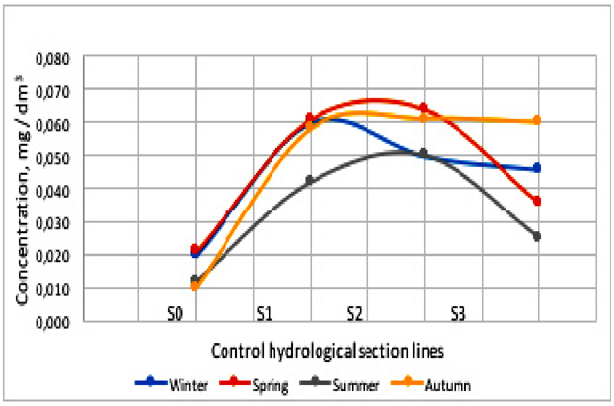

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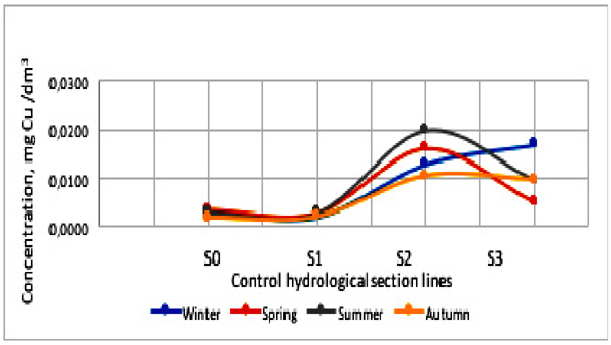

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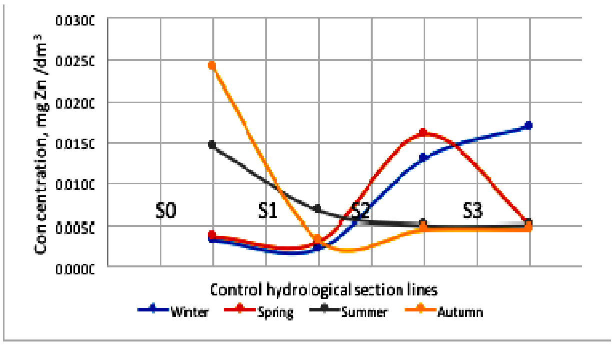

e

Fig. 1. Change of the contaminants concentration in the river current. *a* – ChOD; *b* – Oil products; *c* – Cu^{2+}; *d* – Cr^{6+}. Footnote*: Sampling point S_0 is the hydrological section line of Irpin town; S_1 – Stoyanka village; S_2 – hydrological section line of Hostomel urban village; S_3 – hydrological section line of Kozarovychi village

The coefficients; required for calculation; were determined according to the formulas (3); (4); due to which every curve $S(t)$ passed through four basic experimental points (S_0; 0); (S_1; t_1); (S_2; t_2); (S_3; t_3). The obtained data are represented in the table 2.

From the Michaelis-Menten equation (table 2) it is concluded that at high S value for the substrate and low K_s; the reaction speed is maximal; and at low S the reaction speed is proportional to the substrate concentration at each time moment. Due to $K<0$ in the S interval from K to ∞; $dS/dt \to Vm$ at $S \to 0$; as usual. However; at any final S values in given cases; $dS/dt > Vm$; and if $S \to K$; then $dS/dt \to \infty$ at all.

Table 2

Results of the modelling of the Irpin water self-remediation from contaminants

Index name	ChOD; mg O_2 dm^{-3}	Oil products; mg dm^{-3}	Phenols mg dm^{-3}	Ammonium Nitrogen; mg N dm^{-3}	Nitrite Nitrogen; mg N dm^{-3}	Nitrate Nitrogen; mg N dm^{-3}	Cu^{2+}; mg dm^{-3}	Zn^{2+}; mg dm^{-3}	Cr^{6+}; mg dm^{-3}
Spring									
Vm	0;0128	2;7*10^{-5}	-0;0016	-0;0034	-0;0199	0;5741	-0;0004	0;0003	0;0001
Ks	-30;5605	-0;0013	-0;0429	-0;6068	-0;1941	-1;9449	-0;0095	-0;0097	-0;0030
Summer									
Vm	-0;1441	-0;0048	-0;0015	-0;0025	-0;0018	-0;3114	-0;0006	0;0002	0;0001
Ks	-34;0883	-0;8629	-0;0305	-2;0232	-0;0601	-0;9592	-0;0109	-0;0089	-0;0029
Autumn									
Vm	-0;0163	2;5*10^{-5}	-0;0017	-0;0089	-0;0080	-0;7389	-0;0002	0;0004	0;0001
Ks	-35;6995	-0;0014	-0;0286	-0;5755	-0;1279	-1;0764	-0;0064	-0;0116	-0;0032
Winter									
Vm	-0;0028	0;0002	-0;0010	-0;0089	-0;0074	0;4868	-0;0003	0;0005	0;0001
Ks	-27;9851	-0;0037	-0;0347	-0;5755	-0;1340	-1;9822	-0;0040	-0;0130	-0;0028

The next task of research is to determine the number of residual pollutants in aquatic environment; even after the material cumulation and self-remediation [17]. To do it; we calculated the technogenic impact index for pollutant with the use of approximate values of coefficients of the river water self-remediation from contamination agent.

$$I_{techn.imp.} = \frac{C_{cont}}{MAC_{cont}} \cdot K_{self-rem} \quad (5)$$

where C_{cont} is the contaminant concentration; MAC_{cont} is the maximal allowable concentration of contaminant; $K_{self\text{-}rem}$ is the coefficient of speed of the river water remediation from certain contamination agents. The obtained data are represented in the table 3.

Table 3.

The technogenic impact index

Control hydrol. section lines	$I_{techn.imp.}$			
	Spring	Summer	Autumn	Winter
S_0	0;373	0;427	0;4	0;33
S_1	0;4	0;507	0;453	0;36
S_2	0;364	0;486	0;435	0;347
S_3	0;468	0;543	0;56	0;384

5. Discussions of results

Obtained results of the modelling of the Irpin water self-remediation from contaminants are represented that the constant for contamination agents such as nitrogen; nitrite nitrogen; nitrate nitrogen and Cu^{2+} have negative values. The predominating negative K_s values indicate the non-traditional character of the dependence of the process speed *dS/dt* on concentration *S*; for the microbiological transformation (destruction) of contaminating compounds

The predominating negative values indicate; that in the aquatic environment self-remediation processes have not time to occur; as water is being contaminated from the mowings; neighboring agricultural lands; even after the Nyvka river entrance.

By determining the concentration of residual contaminants of anthropogenic origin; remaining after destruction; we obtained clear picture about ecological condition of the Irpin river. Dealing with these pollutants is problematic for hydrobionts. This confirmed by the technogenic impact index ($I_{techn.imp.}$).

Many dissolved substances of anthropogenic origin affect the structural and functional features of the aquatic ecosystems development. That is why; the necessity of the ecological indices assessment; as well as necessity of assessment of their parameters characterizing the functional features of the aquatic ecosystems development of the small and middle rivers ecosystems; appeared. Given techniques obligatory should be harmonized with the recommendations of the international organizations; which engage in the problems of the water ecosystems guard and restoration. Furthermore; understanding of the process of transformation of substances of anthropogenic origin in the aquatic environment will allow the development and implementation of the most effective water treatment technologies and modern environmental protection measures.

6. Conclusions

1. We investigated the technogenically-modified aquatic ecosystems of small and medium-sized rivers. The ecosystem approach and the river basin principle of management used for study the conceptual model of the system of rivers. The research found that the functioning of technogenically-modified aquatic ecosystems is the result of repair facilities activities.

2. The obtained results of the ecological monitoring of the Irpin River and the Nyvka River aquatic ecosystems during the ten-year period (2008-2017) are analyzed; systematized and the data bank for further research work is formed. The water analysis shows that the Irpin's water quality predominantly are IV quality class (polluted). The Nyvka's class of water quality are V – water (dirty). Biotesting has confirmed the toxicity of water – 50-65% of fatal cases for microorganisms in the surface water layer.

3. The basic principles of the contaminants hazard characteristics assessment; are found. The dynamics of their changes; affecting the self-remediation processes in ecosystems and are the pre-conditions of their transformation; are investigated. The individual and summary subtances are: oil products (concentration 0.5 – 2 MAC); NH_4 (concentration 1;5 – 2;5 MAC); NO_2 (concentration 1;5 – 2;7 MAC).

4. The non-linear mathematical model of Mono and Michaelis-Menten; to describe the self-remediation processes of the Irpin river water ecosystem; were applied at first time. Negative values of contamination agents such as: Cu^{2+} (-0;0040) – (-0;0109); oil products (-0;0013) – (-0;8629); NH_4 (-0;5755) – (-2;0232) indicate the non-traditional character of the dependence of the process and hence the violation of the self-healing processes.

5. The index of technogenic impact of pollutants on water ecosystems; was proposed and calculated. The highest value is noted in summer–autumn period especially in control hydrological section lines Kozarovychi S_3= 0;543 – 0;56; the lowest value is noted in winter period for section lines Irpin S_0= 0;33. These values indicate the ability of the hydroecosystem for self-regulation.

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Дослідження техногенно-змінених водних екосистем в зоні впливу авіапідприємств

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Для розроблення водоохоронних заходів та забезпечення екологічної безпеки техногенно зумовлених гідроекосистем; що протікають вздовж урбанізованих територій з авіапідприємствами; об’єктом дослідження було обрано техногенно змінену гідроекосистему. Концептуальна модель системи річок складається з річок Нивки та Ірпінь; обидві річки належать до басейну Дніпра; а постійний трофічний зв'язок між ними дозволяє розглядати їх як концептуальну сукупність взаємопов'язаних складових у системі. **Основна мета:** вивчення особливостей формування техногенно-зумовлених водних екосистем невеликих річок внаслідок антропогенного впливу ремонтних авіапідприємств. **Методи:** були застосовані методи біотестування та комплексної оцінки класу якості води; модель біологічної трансформації субстрату на основі закону нелінійної математичної моделі Моно та Міхаеліса-Ментена; також було розраховано індекс техногенного впливу кожного полютанта на якість води. **Результати:** виявлено вміст важких металів; нафтопродуктів; азоту амонійного; азоту нітритного; азоту нітратного в поверхневих водах річок Нивка та Ірпінь. Досліджені проби води з р. Нивки відносяться до V класу якості води; а води р. Ірпінь до IV класу якості. Була показана зміна концентрації забруднюючих речовин в потоці річки Ірпінь. Гідрохімічний аналіз річки показав; що обмежувальні фактори; які впливають на якість води; спричиняють порушення самовідновної здатності водної екосистеми. **Обговорення:** отримані результати моделювання самовідновлення вод р. Ірпінь свідчать що константа забруднюючих речовин; таких як азот амонійний; азот нітратний; азот нітритний та Cu^{2+}; має від’ємне значення. Переважання від’ємих значення свідчить про нетрадиційний характер залежності швидкості процесу від концентрації; не встигають відбуватися процеси самоочищення; тому що забруднювачі продовжують досить активно поступати до гідроекосистеми.

Ключові слова: індекс техногенного впливу; концептуальна модель гідроекосистеми; річка Ірпінь

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Исследование техногенно-изменённых водных экосистем в зоне влияния авиапредприятий

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Для разработки водоохранных мероприятий и обеспечения экологической безопасности техногенно-обусловленных гидроекосистем; что протекает вдоль урбанизированных территорий с авиапредприятиями; объектом исследования была выбрана техногенно-трансформированная гидроекосистема. Концептуальная модель гидроэкосистемы состоит из рек Нивка и Ирпень; обе реки относятся к бассейну Днепра; а постоянная трофическая связь между ними позволяет рассматривать их как концептуальную совокупность взаимосвязанных составляющих в системе. **Основная цель:** изучение особенностей формирования техногенно-обусловленных водных экосистем небольших рек в результате антропогенного воздействия ремонтных авиапредприятий. **Методы:** были применены методы биотестирования и комплексной оценки класса качества воды; модель биологической трансформации субстрата на основе закона нелинейной математической модели Моно и Михаэлиса-Ментена; также было рассчитано индекс техногенного воздействия каждого загрязнителя на качество воды. **Результаты:** обнаружено содержание тяжелых металлов; нефтепродуктов; азота аммонийного; азота нитритного; азота нитратного в поверхностных водах рек Нивки и Ирпеня. Исследованы пробы воды с р. Нивки относятся к V классу качества воды; а воды р. Ирпень к IV классу качества. Были показаны изменения концентрации загрязняющих веществ в потоке реки Ирпень. Гидрохимический анализ реки Ирпень показал; что ограничительные факторы; которые влияют на качество воды; вызывают нарушения самовосстановительной способности водной экосистемы. **Обсуждение:** получены результаты моделирования самовосстановления вод р. Ирпень свидетельствуют о том; что константа загрязняющих веществ; таких как азот аммонийный; азот нитратный; азот нитритный и Cu^{2+}; имеет отрицательное значение. Преобладание отрицательных значение свидетельствует о нетрадиционном характере зависимости скорости процесса от концентрации; не успевают происходить процессы самоочищения; так как загрязнители продолжают очень активно поступать у гидроэкосистему.

Ключевые слова: индекс техногенного воздействия; концептуальная модель гидроэкосистемы; река Ирпень

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