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ECONOMIC ASSESSMENT OF THE RISK TO PUBLIC HEALTH CAUSED BY SURFACE WATER POLLUTION

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Abstract

The problem of surface water pollution is very relevant in all countries of the world. The usage of low-quality water bodies for public needs leads to the emergence of microbiological diseases in vacationers, which makes it important to conduct a study to determine the impact of surface water pollution for recreational purposes on the health of Kharkiv residents. The aim of the article is to improve the management of decision-making in the sector of surface water conservation by applying a new method of economic risk assessment for social health as a result of recreational water use. The paper investigates the impact of surface water pollution on public health, analyzes the state of infectious disease in the Kharkiv region. Based on the analysis of modern methodological approaches to socio-economic assessment of the impact of environmental pollution, the paper presents a new method of economic risk assessment for health at the current level of surface water pollution, which represents the scientific novelty of the work. The paper provides an economic assessment of the risk to social health due to surface water pollution for recreational purposes in Kharkiv, which is of practical importance for making management decisions in the field of surface water protection.

Key words: economic assessment, risk, infectious morbidity, recreational water use, Kharkiv, Ukraine.

Introduction

Water pollution is an extremely important problem for many countries in the world, but in Ukraine this problem is exacerbated by insufficient water resources and the impact of hostilities on aquatic ecosystems after the beginning of Russian aggression. The Kharkiv region is a large industrial center with numerous settlements and developed agriculture, which leads to poor water quality. Numerous studies have been devoted to the research of the quality of surface water bodies in the Kharkiv region [1-4]. An analysis of the impact of anthropogenic and natural factors on the state of surface waters is presented in [5,6].

Paper [7] analyzes the impact of natural and man-made emergencies on the degradation of natural water quality in different countries and in Ukraine. Floods, accidents, mining, and military operations are the main factors of emergency situations. A method for the rapid analysis water samples is proposed, which involves analysis the conductivity of the studied aqueous samples and calculating the identification coefficient. The possibility of using the method of rapid identification of natural waters and aqueous solutions to determine emergencies is shown [7]. However, this article does not contain a study of the impact of surface water pollution on the increase in the incidence of morbidity.

The problem of infectious diseases due to the usage of contaminated water bodies for bathing and the outbreak of epidemics is very significant for most countries of the world. Waterborne microbes infect people in various ways: through the skin and membranes, through inhalation of water aerosols, aspiration, and ingestion. The clinical effect of these infections range from superficial skin lesions to fatal systemic infections. The survival of many waterborne pathogens is influenced by climate, season, other environmental conditions, and the level of sanitation. The types and numbers of organisms vary depending on salinity, pH, temperature, and other water characteristics. The risk of infection with waterborne microbes depends on the duration and type of infection, the density of organisms in the water, and the immunity of the individual [8].

The authors of [9] conducted a study of *G. duodenalis* agglomerations, subgroups, locations, and potential ways of infection. Based on the epidemiological data, conclusions were drawn about the consequences for public health in the UK. However, the paper does not provide an assessment of the risk to urban health from the use of water resources for recreation.

Work [10] notes that people often get acute gastroenteritis as a result of contact with water contaminated with pathogenic microorganisms. During the flood season, the risk of infection increases due to more frequent direct contact with highly contaminated water for a long period of time. Microbiological diseases are a major health concern in many flood-prone areas, especially where infectious diseases are already endemic. Outbreaks of infectious diseases of varying magnitude and mortality rates have been reported following major floods in developing countries. There is some evidence from India and Bangladesh that diarrheal diseases increase after flooding.

The authors of [10] characterized and quantified the risks to public health associated with different levels of exposure to pathogenic microbes in water during flooding. Based on the analysis, exposure scenarios were developed by flood levels, which assume direct and indirect contact with contaminated water, and the probability of abdomenal infection was estimated based on discovered dose-response relationships for the major pathogen present in flood water (*E. coli*). However, the paper does not provide estimates of economic losses due to outbreaks of infectious disease.

The authors of [11] stated that the number of outbreaks of waterborne diseases connected with recreational water use in summer time season in the Netherlands similar with the number of days with temperatures above 25°C ($r = 0.8…0.9$). However, to calculate the impact of contaminated water objects used for recreation on the increase in morbidity, it is necessary to make laboratory studies of surface water purity.

Climate change is causing a rise in illness and premature deaths worldwide, including in Europe. The most significant health effects of climate change are linked to extreme weather events, shifts in the prevalence of climate-sensitive diseases, and alterations in environmental and social conditions. Among extreme weather events in Europe between 1991 and 2021, heatwaves were the deadliest, resulting in tens of thousands of premature fatalities [12].

Climate change can lead to increased water scarcity and deterioration of water quality, as well as create additional challenges for sustainable water supply and sanitation [12]. Nearly half of the over 50 infectious diseases that EU Member States are obligated to report can be directly or indirectly linked to climate change. Additionally, other climate-sensitive diseases, including many vector-borne illnesses, are regarded as priority infectious diseases in the context of climate change in Europe [13].

In their study [14], the authors examined climate change in the Kharkiv region and analyzed changes in the hydrological parameters of the Oskil River in Ukraine using the Holt-Winters method. The findings indicated a projected gradual temperature rise of 1.9°C, which could result in reduced precipitation, runoff, and water usage. The increase in air temperature, coupled with a decline in runoff modulus, has a substantial negative impact on surface water quality formation and promotes the spread of invasions, posing risks to recreational water use and drinking water supply.

The unevenness of conditions and factors influencing the quality of water bodies creates the need to conduct research on those factors that have the greatest impact. The relevance of such studies is due to the fact that in the current conditions of climate change and intensive use of water resources, it is necessary to identify the largest sources of surface water pollution and the risk to public health from the impact of pollution in order to develop a set of environmental protection measures [15, 16].

When using contaminated surface waters for recreation, there is a possibility of infectious diseases. These are diseases such as intestinal infections, salmonellosis, dysentery, viral hepatitis A, and leptospirosis.

Article [16] analyzes the dynamics of infectious diseases in the city of Kharkiv due to surface water pollution. The incidence of certain infectious diseases (enteritis, salmonellosis, dysentery, viral hepatitis A, leptospirosis) in the Kharkiv region for the period from 2007 to 2019 was analyzed based on official data from the regional department of state statistics in the Kharkiv region. The study [16] showed that from 2007 to 2019, the number of some infectious diseases decreased (enteritis, salmonellosis, dysentery, leptospirosis), while the incidence of viral hepatitis A increased.

It should be borne in mind that the body's reaction to environmental pollution may take some time to manifest itself, and the level of morbidity growth is non-linear. One of the major problems in assessing the impact of environmental quality is determining the acceptability of the risk to public health, i.e. how dangerous is its increase at the existing level of morbidity.

In most countries, public health risk is considered the primary indicator of danger. The method for assessing public health risks based on surface water quality, in accordance with the methodology of the US Environmental Protection Agency (EPA US) (Integrated Risk Information System (IRIS)) [17], is the most widely used approach.

The paper [18] highlights the primary drawbacks of the American method for assessing public health risks associated with recreational water use:

1) the hazard index is calculated using a simple summation of the multiples of reference dose exceedances without considering the hazard class.

2) the no-threshold risk concept (which assumes that any substance, at any concentration, impacts human health) often results in an overestimation of risk levels.

3) for each pollutant, specific diseases are identified as potentially increasing above background morbidity levels; however, these conclusions can sometimes be highly speculative, particularly when evaluating public health risks during recreational water use.

4) bacteriological contamination of surface waters, a significant factor in the spread of infectious diseases, is not accounted for.

The authors of [18] introduced a new method for assessing potential public health risks associated with recreational water use. Nevertheless, the implementation of environmental management for efficient water resource management necessitates an economic evaluation of the public health risks caused by surface water pollution.

The economic assessment of the impact of environmental pollution on public health is a very complex task. The most common approach to addressing this issue at both the international and national levels is to determine the cost of living, as well as indicators of additional mortality, morbidity, disability, forced disability, premature death, the number of years with a poor quality of life, etc.

Paper [19] assesses the impact of air pollution by determining the cost of lost production due to premature deaths and morbidity associated with air pollution for each state in India using the cost of illness method. For India, the problem of increased morbidity due to air pollution is extremely acute, as the authors of the article

[19] estimate that 1.6 million deaths were related to air pollution in 2019, accounting for 17.8 % of the total number of deaths in the country. As a result of premature deaths and morbidity associated with air pollution, economic losses in India amount to $28.8 billion US dollars.

International studies widely use such integral indicators as the Disability-Adjusted Life Years (DALYs) and Quality-Adjusted Life Years (QALYs) [20].

The Disability-Adjusted Life Years (DALYs) index measures the loss of healthy life years caused by temporary disability, permanent disability, or premature death. This is calculated as the difference between the actual age at death, the life expectancy at that age, and the loss of healthy life years due to temporary or long-term disability [20, 21]. Estimating DALYs involves calculating the expected years of life lost, taking into account discounting [21].

Life expectancy serves as a baseline for further calculations, such as reducing life expectancy and loss of person-years of life. To determine these indicators, it is necessary to establish the value of such a parameter as the "price" of one year of lost life. The use of this indicator to determine the economic losses of society from environmental pollution makes sense in the case of exceeding the standards for carcinogenic substances.

The Quality-Adjusted Life Years (QALYs) index characterizes the number of years of life weighted by their quality. The concept of "quality of life" is subjecttive, so, in our opinion, it has limitations in its use.

In the EU and the USA, the value of statistical life G or the value of one year of lost life g is used to assess economic damage. The US and the EU use the following values for the "value" of a statistical life G – 4.8 million US dollars and 3.1 million euros.

In Ukraine, the absolute number of lost years of potential life amounted to 3.031 million person-years in 2013, which, according to economic estimates, is estimated at UAH 90.4 billion of underproduced national product, of which losses due to mortality in the range of 15…59 years amounted to more than USD 10 billion, which is 7 % of the total. This represents 6.7 % of nominal GDP [22].

Paper [23] estimates the economic losses caused by an increase in the level of risk to the health of the population of Cherkasy from air pollutants.

The paper [24] presents the following classification of thresholds for the development of non-carcinogenic effects (based on the hazard factor): extremely high (more than 10), high (5…10), medium (1…5), low (0.1…1.0), and minimal (less than 0.1). This gradation helps assess the potential consequences of harmful effects to determine appropriate measures.

That is, the calculations in [23] showed that even with exposure to pollutants at the level of the maximum permissible concentration (MPC), the state of the atmospheric air corresponds to class 5 (extremely high risk to public health).

The economic assessment of the risk to public health presented in [23] takes into account only the cost of treating one patient from the city budget, while other state expenditures are not taken into account (hospitalization and products that were not produced as a result of temporary disability).

The analysis of research on the economic risk assessment for public health has highlighted the necessity to refine methodological approaches to support scientifically grounded management decisions regarding the implementation of environmental protection measures.

The purpose of this study is to develop a new method for economically assessing the risk of increased infectious diseases associated with recreational water use and to test it on the beaches of Kharkiv (Ukraine).

Research methodology

The authors of [18] introduced a new method for evaluating the potential risk to public health during recreational water use. In [18], it is suggested to assess the potential public health risk (Risk) by calculating the gap for hydrochemical indicators using formula (1) and for bacteriological indicators using formula (2):

$$Prob = -2 + 3.32 \cdot lg\left(I^h\right), \tag{1}$$

where I^h is the multiplicity of exceedance of sanitary and hygienic standards by hydrochemical indicators of surface water quality, a dimensionless value;

$$Prob = -3 + 2.32 \cdot lg\left(I^b\right), \tag{2}$$

where I^b is the multiplicity of exceedance of sanitary and hygienic standards by bacteriological indicators of surface water quality, a dimensionless value.

The potential risk to public health from the combined impact of environmental pollution is evaluated using the rule of probability multiplication. In this case, the multiplier is not the health risk value itself, but rather the values that characterize the probability of its absence [18, 24]:

$$Risk = 1 - \left(1 - Risk_1\right) \cdot \left(1 - Risk_2\right) \cdot \ldots \cdot \left(1 - Risk_n\right), \tag{3}$$

where $Risk$ represents the potential risk of combined exposure to pollutants; $Risk_1$, ..., $Risk_n$ denotes the potential risk associated with exposure to each individual pollutant; and n is the number of pollutants.

The classification of recreational water use hazard levels by potential risk values is given in [18, 24] in Table 1.

Table 1 – Classification of hazard levels of recreational water use by the value of potential risk to public health [18, 24]

Risk	Danger class	Risk characteristics
<0.1	1	insignificant impact on public health
0.1…0.19	2	low impact on public health
0.2…0.59	3	significant impact on public health
0.6…0.89	4	great impact on public health
0.9…1.0	5	very large impact on public health

It is important to note that the cause of these diseases may not only be swimming in contaminated water bodies but also the consumption of poor-quality food or drinking water, as well as soil contamination in the beach areas.

The paper [25] introduces a new method for determining the integral indicator of the occurrence of infectious diseases associated with recreational water use.

The State Institution "Kharkiv Regional Laboratory Center of the Ministry of Health of Ukraine" annually collects data on epidemiological surveillance of food and food raw materials; drinking water of centralized and non-centralized water supply; water of reservoirs, including the quality of surface water in places of mass recreation; the quality of soil, including in the area of beaches, the state of atmospheric air and the quality of indoor air, etc. Form 40 reports on sanitary-microbiological, sanitary-chemical and parasitological studies contain information on the number of samples examined and the percentage of samples that do not meet the standards.

Exceeding the standards for sanitary and micro-biological indicators is determined by the formula [25]:

$$k_{es}^{m} = \frac{n_{es}^{m}}{n_{st}^{m}}, \tag{4}$$

where k_{es}^{m} is the multiplicity of exceeding the standards for sanitary and microbiological indicators, a dimensionless value; n_{es}^{m} is the number of samples of sanitary and microbiological indicators exceeding the standards; n_{st}^{m} is the number of samples of sanitary and microbiological indicators that were examined.

Exceeding the standards for sanitary and chemical indicators is determined by the formula [25]:

$$k_{es}^{ch} = \frac{n_{es}^{ch}}{n_{st}^{ch}}, \tag{5}$$

where k_{es}^{ch} is the multiplicity of exceedance of the standards for sanitary and chemical indicators, a dimensionless value; n_{es}^{ch} is the number of samples of sanitary and chemical indicators exceeding the standards; n_{st}^{ch} is the number of samples of sanitary and chemical indicators that were examined.

Exceeding the standards for parasitological indicators is determined by the formula [25]:

$$k_{es}^{p} = \frac{n_{es}^{p}}{n_{st}^{p}}, \tag{6}$$

where k_{es}^{p} is the multiplicity of exceeding the standards for parasitological indicators, a dimensionless value; n_{es}^{p} is the number of samples of parasitological indicators exceeding the standards; n_{st}^{p} is the number of samples of parasitological indicators that were tested.

Exceedances of parasitological standards have the greatest impact on the occurrence of infectious diseases, followed by exceedances of sanitary and microbiological standards, and the least impact is caused by exceedances of sanitary and chemical standards.

In [25], it was proposed to determine the weighting factor for the impact of surface water pollution in places of mass recreation using the formula [25]:

$$F_{es}^{wr} = \left(1.2 \cdot k_{es}^{wrm}\right) + \left(1.0 \cdot k_{es}^{wrch}\right) + \left(1.5 \cdot k_{es}^{wrp}\right), \tag{7}$$

where k_{es}^{wrm} is the multiplicity of exceedance of the standards for sanitary and microbiological indicators in the study of surface waters in places of mass recreation, dimensionless value; k_{es}^{wrch} is the multiplicity of exceedance of the standards for sanitary and chemical indicators in the study of surface waters in places of mass recreation, dimensionless value; k_{es}^{wrp} is the multiplicity of exceedance of the standards for parasitological indicators in the study of surface waters in places of mass recreation, dimensionless value.

The main causes of infectious diseases are the consumption of low-quality food or drinking water, pollution of surface water and soil in places of mass recreation. Therefore, it is proposed to calculate a separate weighting factor for the impact on the occurrence of infectious diseases using the formula [25]:

$$F^{sid} = F_{es}^{f} + F_{es}^{dvc} + F_{es}^{dvd} + F_{es}^{wr} + F_{es}^{sb}. \tag{8}$$

The weighting factor of the impact of recreational water use on the development of infectious diseases is proposed to be determined by the formula [25]:

$$F^{wr} = \frac{F_{es}^{wr}}{F^{sid}}. \tag{9}$$

The State Statistics Service of Ukraine annually publishes data on the number of people who have contracted infectious diseases, as well as the integral indicator of infectious diseases per 100 thousand people.

To determine the occurrence of infectious diseases as a result of recreational water use, it was proposed in [25] to use the formula:

$$I_{id}^{wr} = F^{wr} \cdot I_{id}, \tag{10}$$

where I_{id}^{wr} is the integral indicator of the occurrence of infectious diseases due to recreational water use per 100 thousand people; F^{wr} is the weighting factor of the impact of surface water pollution in places of mass recreation, a dimensionless value; I_{id} is the integral indicator of infectious diseases per 100 thousand people.

The application of the proposed methodology for determining the impact of weighting coefficients will make it possible to analyze the causes of infectious diseases in order to minimize sources of pollution and create comfortable living conditions for the population [25].

To determine the economic costs incurred by the state for restoring human health deteriorated due to surface water pollution, we propose using the method for assessing potential public health risks presented in [18]. The authors of [18] suggested evaluating the potential risk to public health (*Risk*) by calculating the gap for hydrochemical indicators using formula (1) and for bacteriological indicators using formula (2).Since infectious morbidity occurs mainly as a result of violation of standards for bacteriological indicators, we propose to calculate the potential risk to public health due to pollution of recreational water bodies (*Risk*) by determining the gap, for bacteriological indicators by formula (2). To determine the Risk value, it is necessary to use a normal probability distribution when the samples and the risk are interrelated.

The main causes of infectious diseases are the consumption of low-quality food or drinking water, pollution of surface water and soil in places of mass recreation. In [25], it is proposed to calculate a separate weighting factor for the impact on the occurrence of infectious diseases using the formula (8). The authors of [25] proposed determining the weighting factor for the impact of recreational water use on the development of infectious diseases using formula (9). To assess the occurrence of infectious diseases due to recreational water use, they suggested calculating an integral indicator of the incidence of infectious diseases per 100,000 people (I_{id}^{wr}) by formula (10).

If we take the value of the integral indicator of the occurrence of infectious diseases due to recreational water use per 100 thousand people (I_{id}^{wr}) as the current state, then we propose to determine the predicted increase in infectious diseases due to contaminated surface water, taking into account the potential risk to public health ($Risk^{wr}$), using the formula:

$$N_i^{wr} = I_{id}^{wr} \cdot \left(1 + Risk^{wr}\right), \tag{11}$$

where N_i^{wr} is the predicted number of people who are likely to get an infectious disease due to pollution of recreational water bodies; I_{id}^{wr} is an integral indicator of the occurrence of infectious diseases due to recreational water use per 100 thousand people; $Risk^{wr}$ is a potential risk to public health due to the impact of surface water pollution in places of mass recreation, a dimensionless value.

We propose to determine the economic assessment of the risk to public health due to pollution of recreational water bodies separately for children, for the working population and for pensioners. In this case, the estimated number of people who are likely to get an infectious disease as a result of pollution of recreational water bodies (N_i^{wr}) will consist of children (N_{ich}^{wr}), adults (N_{iad}^{wr}) and pensioners (N_{ip}^{wr}):

$$N_i^{wr} = N_{ich}^{wr} + N_{iad}^{wr} + N_{ip}^{wr}, \tag{12}$$

For children, the economic assessment of the risk of contracting an infectious disease as a result of pollution of recreational water bodies is proposed to be determined by the formula:

$$ER_{wr}^1 = N_{ich}^{wr} \cdot E_{ch}^t, \tag{13}$$

where ER_{wr}^1 is the economic assessment of the risk to the health of one child due to pollution of recreational water bodies, euros/person; E_{ch}^t – the cost of treating children for infectious diseases caused by pollution of recreational water bodies, euros/person;

For the working population, we propose to determine the economic assessment of the risk to the health of one person using the following formula:

$$ER_{wr}^2 = N_{iad}^{wr} \cdot \left(E_t^2 + E_s + E_{up}\right), \tag{14}$$

where ER_{wr}^2 is the economic assessment of the risk to the health of one working person due to pollution of recreational water bodies, euros /person; E_t^2 is the cost of treatment of the adult population for infectious diseases caused by pollution of recreational water bodies, euros/person; E_s – costs for the period of disability of an employed person as the average salary in the region (if the calculation is made for the region) or for a specific enterprise, euros/person; E_{up} – costs from unreceived products during the period of treatment for the disease, defined as gross domestic product (GDP) per capita, euros/person.

For pensioners, the economic assessment of the risk to the health of one person is proposed to be determined by the following formula:

$$ER_{wr}^3 = N_{ip}^{wr} \cdot E_t^3, \tag{15}$$

where ER_{wr}^3 is an economic assessment of the risk to the health of pensioners due to pollution of recreational water bodies, euros /person; E_t^3 is the cost of treatment of pensioners for infectious diseases caused by pollution of recreational water bodies, euros /person.

We propose to determine the total economic assessment of the risk of infectious diseases in the population as a result of pollution of recreational water bodies using the formula:

$$ER_{wr} = ER_{wr}^1 + ER_{wr}^2 + ER_{wr}^3, \tag{16}$$

where ER_{wr} is the total economic assessment of the risk of infectious diseases in the population due to pollution of recreational water bodies, euros /person.

The next step, after determining the risk to public health and economic costs of surface water pollution, is to develop measures to minimize the risk by improving the state of the environment.

Results and Discussion

The new method for assessing the potential risk to public health during recreational water use offers significant advantages over the traditional international approach of the US EPA (IRIS):

– bacteriological contamination of surface waters is considered when evaluating the potential risk to public health;

– only substances exceeding standard values are included in the determination of potential risk, as it is assumed that only in such cases there is a possibility of contracting an infectious disease.

– probit regression models are used to determine the potential risk to public health, as opposed to simply summing the multiplicity of exceedances of reference doses or maximum permissible concentrations;

– the value of the potential risk reflects the probability of adverse effects on a person, rather than indicating a specific disease;

– a classification of hazard levels for recreational water use has been developed, enabling the prioritization of environmental protection measures [18].

The authors of [25] investigated the quality of surface waters based on hydrochemical and bacteriological indicators during the summer from 2020 to 2022 at six beaches in Kharkiv: Zhuravlivskyi Hydropark (public swimming area); Bezlyudivske Reservoir (paid beach); Zhovtnevyi Hydropark (Udy River, near the bridge over the dam, beach near the bird market); Osnovianske Lake (Komsomolske Island, public beach); Petrenkivskyi Pond (Krasnodarska Street, intersection of Traktorobudivnykiv Avenue, beach); and Udy River Beach (near the pedestrian bridge, Pisochyn Mobile settlement).

The study conducted by the authors of [25] on the qualitative state of surface waters using hydrochemical and bacteriological indicators at these six Kharkiv beaches in the summer of 2020 revealed that the index of lactose-positive *E. coli* exceeded the standard by tenfold. Notably, at the Petrenkivskyi Pond beach, located on Krasnodarska Street in Kharkiv, the lactose-positive *E. coli* index was 136 times higher than the standard (Fig. 1).

Based on the assessment of the potential risk to public health from recreational water use in Kharkiv (Ukraine), it was determined that three beaches fall under the 4th hazard class (high impact on public health), and three beaches are classified under the 5th hazard class (very high impact on public health) [18]. Bacteriological indicators demonstrated the highest potential risk values, as they exceeded the standards by 23, 30, 72, 76, and even 136 times on most beaches (Fig. 2).

Using the method of estimating the weighting coefficients of the impact on the development of infectious diseases, the integral indicator of the occurrence of infectious diseases due to recreational water use per 100 thousand people (I_{id}^{wr}) for the period from 2013 to 2019 was determined. The integral indicator of the occurrence of infectious diseases due to recreational water use per 100 thousand people (I_{id}^{wr}) in 2019 is 20.87, since the greatest impact on the development of infectious diseases was due to poor-quality drinking water from decentralized water supply - 53.06 %, and the quality of surface water in places of mass recreation is 10.63 %. An analysis of data on the exceedance of surface water pollution standards, primarily for bacteriological indicators, suggests an increased likelihood of infectious diseases such as intestinal infections, viral hepatitis A, dysentery, and others.

In accordance with the new method for the economic assessment of public health risks associated with recreational water use, the cost of treatment was calculated separately for children, the working-age population, and pensioners.

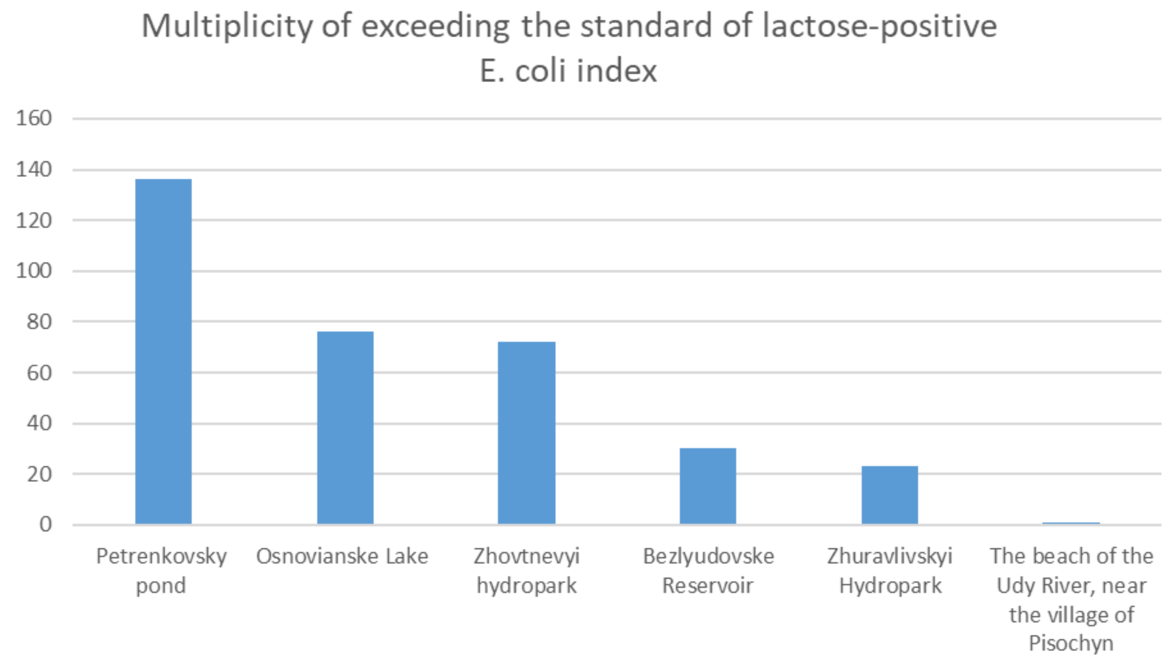

Figure 1 – Exceeding the standards of lactose-positive E. coli index in the water of Kharkiv beaches

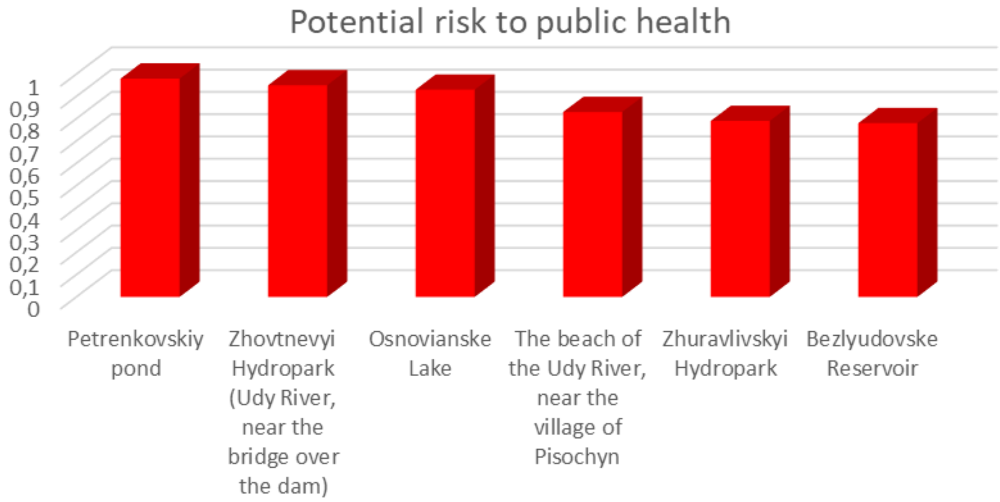

Figure 2 – Potential risk to public health from recreational water use on city beaches in Kharkiv

For the economic assessment of public health risks caused by pollution in recreational water bodies, we utilized statistical reporting data from the Main Department of Statistics in the Kharkiv region [26]. According to the Main Department of Statistics in the Kharkiv region [26], the number of people who contracted infectious diseases is 5258. To determine the number of cases of infectious diseases resulting specifically from recreational water use, we applied formula (10). Additionally, reports from the State Institution "Kharkiv Regional Laboratory Center of the Ministry of Health of Ukraine" provided data on exceedances of sanitary-microbiological, sanitary-chemical, and parasitological standards. The calculation of the weighting factor for the impact of surface water pollution in places of mass recreation (F^{wr}) according to formula (9) took the value of 10.63. Thus, the number of people who contracted infectious diseases as a result of recreational water use is 559 people. The average value of the potential risk to public health ($Risk^{wr}$) is 0.8, which, according to the classification of potential risk (Table 1), corresponds to class 4 (high impact on public health). According to the calculation by formula (11), the estimated number of people who are likely to get an infectious disease as a result of pollution of recreational water bodies (N_i^{wr}) is 1012 people.

In order to determine the number of children, working people, and pensioners who contracted an infectious disease as a result of pollution of recreational water bodies, it is necessary to conduct a detailed examination of patients and study their medical records. For a generalized calculation, we decided to use the percentage of the population of Kharkiv Oblast. According to the information of the Main Department of Statistics in the Kharkiv region [26], 16.68 % of children under the age of 18, 58.63 % of adults under the age of 60, and 24.7 % of the elderly (over 60) live in the city of Kharkiv.

According to the calculation based on formula (12), the estimated number of people who are likely to get an infectious disease as a result of pollution of recreational water bodies (N_i^{wr}) is: children (N_{ich}^{wr}) 169 people, adults (N_{iad}^{wr}) 593 people and pensioners (N_{ip}^{wr}) 250 people.

To determine the cost of treating infectious diseases, data on the cost of medical services were used in accordance with the Draft Resolution of the Cabinet of Ministers of Ukraine of December 27, 2022, No. 1464 "Some issues of improving the implementation of the program of state guarantees of medical care for the population in 2023" [27]. The cost of treating an infectious disease was calculated taking into account weighting factors for children, adults and pensioners.

The total economic assessment of the risk of infectious diseases in the population due to pollution of recreational water bodies is determined by formula (16) and is presented in Table 2.

It should be noted that the economic assessment of the risk of increasing infectious diseases in the population of Kharkiv as a result of pollution of recreational water bodies is indicative, as each case is special and more detailed research is needed, but the determination of the state's costs indicates the need to implement environmental protection measures.

Table 2 – Calculation of the total economic assessment of the risk of increasing infectious diseases of the population of Kharkiv region due to pollution of recreational water bodies

Name of indicator	Economic assessment of the health risk due to recreational water use, euros
Economic assessment of the risk to children's health	142234.22
Economic assessment of the risk to the health of the working population	543825.42
Economic assessment of the risk to the health of pensioners	202966.24
Total economic assessment of the risk of infectious diseases in the population due to recreational water use	889025.87

The assessment of potential public health risks from recreational water use involves evaluating whether hydrochemical and bacteriological indicators exceed established standards, as such exceedances are considered to indicate the possibility of infectious diseases. In Kharkiv, the evaluation of public health risks revealed that three beaches fall under hazard class 4 (high impact on public health), while another three are categorized under hazard class 5 (very high impact on public health). The analysis of weighting coefficients enables an examination of the causes of infectious diseases and facilitates scientifically grounded management decisions aimed at ensuring the health, safety, and comfort of the population.

Methods for assessing potential risks are highly promising because they allow for an accurate evaluation of the impact of adverse environmental factors on public health. This, in turn, helps identify areas with elevated environmental hazards and prioritize necessary measures for environmental protection.

Risk management is based on a set of political, social and economic assessments of the obtained risk values, comparative characteristics of possible harm to human health and society as a whole, possible costs of implementing various options for risk reduction management decisions and the benefits that will be obtained as a result of the implementation of measures.

Conclusion

An analysis of international and national research on the impact of surface water pollution on the development of infectious diseases shows the extreme relevance of this problem for most countries. According to an analysis published by UNICEF, more than 1.42 billion people worldwide, including 450 million children, live in areas with high or extremely high vulnerability to water resources.

In Ukraine, the problem of surface water pollution has become much more acute since the start of the full-scale invasion of Russian troops in 2022. Rocket attacks, destruction of infrastructure, sewage treatment plants, fires, and daily bombardment lead to pollution of all components of the environment. The contamination of water bodies with specific toxic chemicals and infectious agents poses a serious threat to human health, causes a high incidence of intestinal infections and hepatitis, and increases the risk of exposure to carcinogenic and mutagenic factors.

Kharkiv region is a major industrial center of Ukraine and is located on the border with the Russian Federation. Since the first day of Russia's invasion of Ukraine, Kharkiv has been under daily massive shelling, which has led to the loss of life, destruction of public infrastructure, and pollution of surface and groundwater, air, and soil. That is why the study of the impact of surface water pollution on the development of infectious diseases was conducted for the recreational areas of Kharkiv.

Studies of the quality of 6 beaches in Kharkiv were conducted in the summer (from May to August) from 2020 to 2022. The average value of the potential risk to public health due to recreational water use (0.8) corresponds to hazard class 4 (high impact on public health).

Determination of socio-economic losses due to environmental pollution is a very urgent problem. An analysis of existing methods of economic assessment of the risk to urban health due to environmental pollution has shown the need to improve them.

The paper presents a new method of economic assessment of the risk to social health due to pollution of recreational water bodies, which represents a scientific novelty. It is proposed to calculate separately the economic assessment of the risk of increasing infectious morbidity for children, working population and pensioners.

It is proposed to calculate the economic assessment of health risks for the working population by considering the potential public health risk caused by surface water pollution for recreational purposes, the cost of treating infectious diseases, the cost of a working person's disability (based on the average regional wage), and the cost of lost production during the treatment period (defined as per capita gross domestic product, GDP). For children and pensioners, only medical expenses are taken into account.

According to the Main Department of Statistics in Kharkiv Oblast, the number of people who contracted an infectious disease in 2022 was 5258. Taking into account the weighting factor for the impact of surface water pollution in places of mass recreation (10.63), the number of people who contracted infectious diseases as a result of recreational water use is 559 people. The predicted number of people who are likely to get an infectious disease as a result of pollution of recreational water bodies (N_i^{wr}) is 1012 people.

The economic assessment of the risk to public health due to pollution of recreational water bodies was carried out in November 2013 using statistical data from the Main Department of Statistics in Kharkiv Oblast, reports of the State Institution “Kharkiv Regional Laboratory Center of the Ministry of Health of Ukraine” and the cost of treatment of infectious diseases, data on the cost of medical services in accordance with the Draft Resolution of the Cabinet of Ministers of Ukraine of December 27, 2022 No. 1464 “Some issues of improving the implementation of the program of state guarantees of medical care for the population in 2023”.

The economic assessment of the risk of increasing infectious diseases due to pollution of recreational water bodies is calculated. The cost of treating children for an infectious disease is 142234.22 euros; for the working population – 543825.42 euros, for pensioners – 202966.24 euros.

The rise in infectious diseases due to recreational water use is an urgent issue for most countries worldwide. The application of the proposed method for economically assessing the potential public health risk associated with recreational water use will enable the formulation of necessary, scientifically grounded management decisions regarding the prioritization of water protection measures. This is a critical step in ensuring comfortable conditions for recreation and human activity.

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ЕКОНОМІЧНА ОЦІНКА РИЗИКУ ДЛЯ ЗДОРОВ'Я НАСЕЛЕННЯ ВНАСЛІДОК ЗАБРУДНЕННЯ ПОВЕРХНЕВИХ ВОД

Проблема забруднення поверхневих вод є дуже актуальною в усіх країнах світу. Використання неякісних водних об'єктів для суспільних потреб призводить до виникнення захворювань у відпочиваючих, що робить актуальним проведення дослідження з метою визначення впливу забруднення поверхневих вод рекреаційного призначення на здоров'я мешканців м. Харкова. Метою статті є вдосконалення управління прийняттям рішень у сфері охорони поверхневих вод шляхом застосування нового методу оцінки економічного ризику для здоров'я населення в результаті рекреаційного водокористування. Досліджено вплив забруднення поверхневих вод на здоров'я населення, проаналізовано стан інфекційної захворюваності в Харківському регіоні. На основі аналізу сучасних методичних підходів до соціально-економічної оцінки впливу забруднення навколишнього середовища запропоновано новий метод оцінки економічного ризику для здоров'я населення при сучасному рівні забруднення поверхневих вод, що становить наукову новизну роботи. В роботі надано економічну оцінку ризику для здоров'я населення внаслідок забруднення поверхневих вод рекреаційного призначення в м. Харкові, що має практичне значення для прийняття управлінських рішень у сфері охорони поверхневих вод.

Ключові слова: економічна оцінка, ризик, інфекційна захворюваність, рекреаційне водокористування, Харків, Україна.

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