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Risk Assessment as a Decision-Making Tool in the Field of Public Health and Environment

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ABSTRACT
The article deals with the current issues of interconnection between public health and the quality of water resources. It was proposed to determine environmental safety areas in the basins of small rivers based on environmental morbidity valuation. Four phases are herewith determined: hazard identification, exposure assessment, environmental mortality rate assessment, decision-making regarding the need for implementation and water protection measures. In order to assess the influence of the state of river quality on the health status of the population in the certain administrative region, the impact factor of recreational water use was introduced. The risks related to organoleptic, sanitary and toxicological properties of water; epidemiological water hazard are considered.

Keywords: risk, water resources, morbidity, recreation, management in the sphere of public health and environment.

INTRODUCTION

Ensuring the sustainable society development requires continuous improvement of management decisions. The proper information support is an important component of this process [Kovshun et al. 2021]. The results of field research need to be processed and interpreted to become the basis for the justification of the appropriate projects or measures aimed at improving the quality of the environment.

The deterioration of quality of the environment has a significant impact not only on the health and demographic composition of the population, but also on the living and socio-economic conditions of people's lives, having a negative impact on the social infrastructure and the development of the region's economy. The water factor largely determines the level of development of the national economy [Savina et al. 2021a].

The analysis of a negative impact can be carried out using different approaches. Thus, risk assessment deserves special attention. Risk analysis is seen to be a valuable tool for public health and environmental decision-making. It is important herewith to clearly define the nature, strengths and limitations of the used analytical methods and risk analysis methods in decision-making process [Asante-Duah 2002, Savina et al. 2021b].

The relationship between public health and the quality of water resources is being actively developed. For example, the impact of agricultural activities and domestic pollution on water quality in the river basin was studied by using the Water Quality Index (WQI) and the Hazard Index (HI) to assess trace elements in terms of public health risk.

[Ustaoğlu et al. 2020]. Considerable attention is paid to the assessment of drinking water quality [Li & Wu 2019, Khan et al. 2013, Prasad et al. 2021].

Public health risk assessment is an extremely important task and an effective method for identifying the environmental hazard areas. Determining a potential risk has the advantage of simplicity compared to the traditional method of assessing the risk to public health [Liu et al. 2013, Jena et al], since it is focused on a specific environmental factor (in this case, water body quality) and it is one of the features of a public health disorder. Potential risk assessment allows analyzing the degree of impact of the considered environmental factor on the public health and choosing a set of measures aimed at its minimization.

METHOD

Decision-making in the field of public health and the environment requires the identification of environmental safety areas, in particular, in the small river basins. Therefore, it is expedient to compare the level of environmental morbidity within a certain administrative district, where population's recreation in the small river basins takes place, and the average level of environmental morbidity within the region. This concept is based on the public health risk assessment arising from the impact of anthropogenic factors [Ahmed et al. 2018, McOliver 2009, Yalaletdinova et al. 2021].

Identification of environmental safety areas in the basins of small rivers consists of four phases: hazard identification, exposure assessment, environmental mortality rate assessment, decision-making regarding the need for implementation and water protection measures (Fig. 1)

Hazard identification implies taking into account those factors that can have an adverse effect on human health. Point sources of pollution are the cause of water bodies pollution, namely, wastewater discharges from industrial, municipal and agricultural sources, as well as diffuse, dispersed sources (runoff from urban areas, agricultural land, etc.). Information on point sources of pollution can be obtained from the monitoring network (statistical reporting data in the 2-TP form (air, water supply, wastes)). The calculations results using standard methods enable estimation of diffuse sources of water bodies pollution [Wójcik & Pawłowska 2021, Wójcik et al. 2021, Polishchuk et al. 2021].

Exposure assessment involves identification of the study area, sensitive population groups, exposure route and exposure rates. The water resources of small rivers are most often used for recreation purposes. Therefore, the recreation territories are studied areas. The exposure route is ingestion and skin contact with water while swimming and bathing.

At the third stage of identification of environmental safety areas in the small rivers' basins, a "dose-response" relationship model is formed. To this end, it is necessary to analyze the qualitative state of the water body and determine the substances that exceed the maximum permissible concentrations (MPC). An expert group puts forward a hypothesis about the potential danger emergence or increase of the existing level of environmental morbidity (affected organs and systems, the severity of changes at different exposure rates) [Obertyukh et al. 2021, Gursky et al 2021].

At the fourth stage, public health risk profile in the recreational water use of small rivers is given.

The aim of the article is to develop a risk assessment methodology for the use of small rivers for recreation in quantitative and qualitative terms.

PRACTICAL REALIZATION

To do a comprehensive assessment of the current state of the public health, it is proposed to use a morbidity index related to recreational water use [11, 12].

We consider the assessment of the public health risk when using small rivers for recreation on the example of the administrative division of Ukraine.

To assess the morbidity caused by the use of small rivers for recreation, data on acute intestinal diseases, salmonella infections, dysentery, viral hepatitis and leptospirosis should be studied, since these diseases can occur when swimming in polluted water bodies.

For each type of listed diseases, the calculation of the morbidity index according to formula 2.1 was developed:

$$I_i^r = \frac{Z^r}{N^r} \tag{1}$$

where: I_i^r – index of the *i*-th type of the average level of environmental morbidity in *r* – administrative region;
Z^r – the number of cases of the i-th disease in the r-administrative region;
N^r – the population in *r* – administrative region.

The calculation of the morbidity index for the abovementioned diseases and the index of environmental morbidity rate in the administrative districts of the region is carried out according to the formula:

$$I^r = \frac{\sum_i I^r}{i} \tag{2}$$

where: I^r – index of environmental morbidity rate in r – administrative region;
I^r – index of i-th environmental morbidity rate in r – administrative region;
i – the number of analyzed disease cases that could be caused by the use of water bodies for recreation.

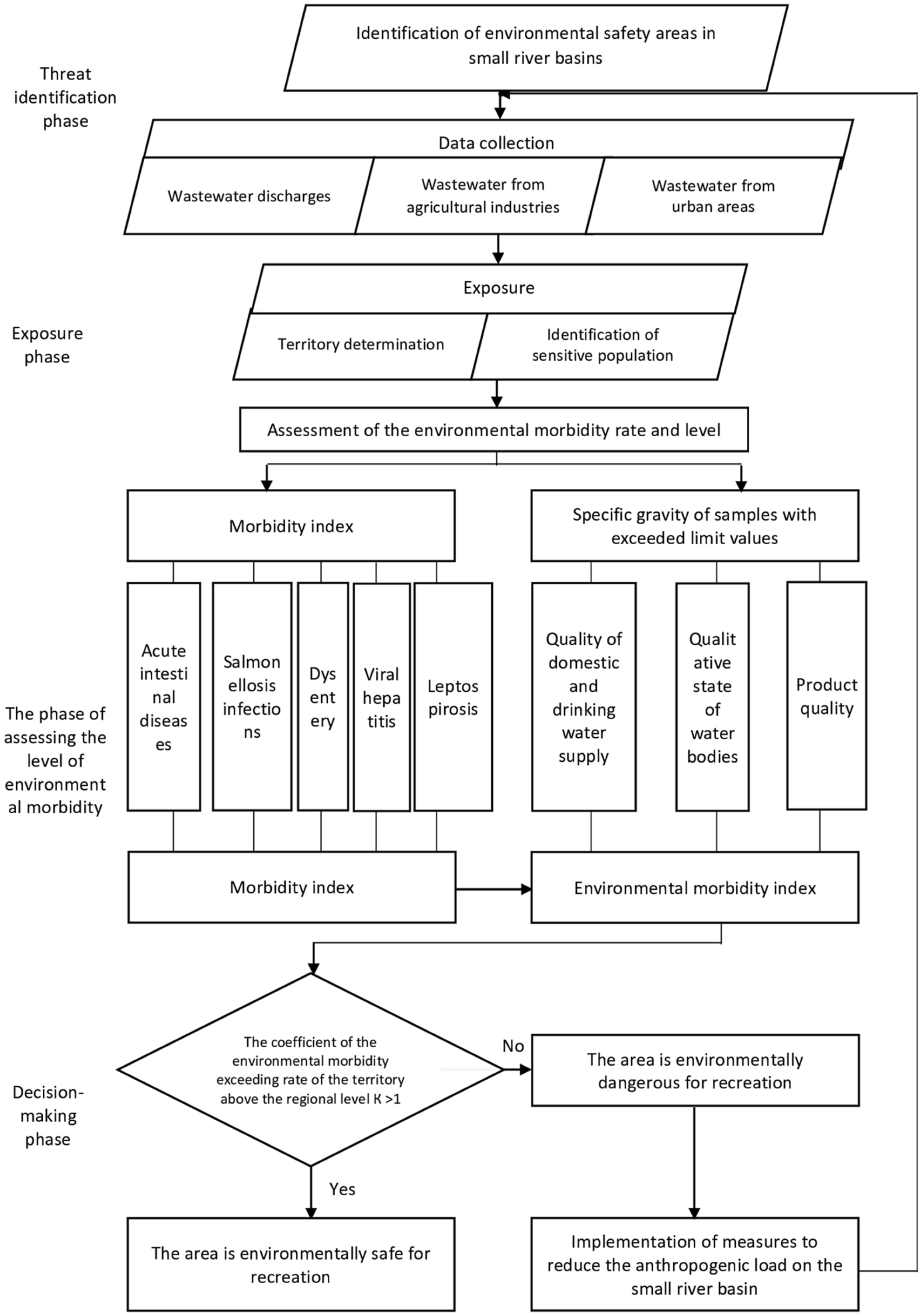

Figure 1. Logical diagram of the process of environmental safety areas identification in the basins of small rivers

In addition to swallowing water or entering harmful substances through the skin when swimming or bathing in water bodies, the cause of infectious diseases may be the consumption of food or water that does not meet sanitary and hygienic standards. Therefore, it is necessary to determine the weighting coefficients in relation to samples exceeding the MPC (K1, K2, K3) to the total number of samples (N1, N2, N3) analyzed by local regional bodies of sanitary-epidemiological service for domestic and drinking water supply (L_r1), the qualitative state of water bodies (L_r2) and food (L_r3) according to formulas 3 and 4:

$$L_r = \frac{K}{N} \tag{3}$$

$$L_r1 + L_r2 + L_r3 = 1 \tag{4}$$

where: L_r1 – the weight coefficient for domestic and drinking water supply in r – administrative region;
L_r2 – the weight coefficient for recreational water use in r – administrative region;
L_r3 – the weighting factor for food products.

It enables to identify the administrative districts with unfavorable sanitary and epidemiological morbidity by calculating the coefficient of the environmental morbidity index exceeding, taking into account the weight coefficients according to formula 5:

$$K_r = \frac{I_r \times L_r2}{I \times L2} \tag{5}$$

where: K_r – the coefficient of the environmental morbidity index exceeding in r – administrative region;
I – denotes the environmental morbidity index in the whole region;
$L2$ – the weight coefficient for recreational water use in the region.

When $K_r > 1$, the state of public health in the r-administrative region raises concerns over the poor condition of water bodies that are used for recreation, and then management decisions are to be made to implement a set of measures in the field of health care and restoring natural value of water bodies.

In order to assess the impact of the qualitative state of the j-th river on the health status of the population in the r-th administrative region, it is proposed to introduce the coefficient of influence of recreational water use (m), which can be calculated by the formula 6:

$$m = \frac{L_j}{L} \tag{6}$$

where: m – the impact coefficient of recreational water use of the j-th small river on the public health;
L_j – is the length of the studied j-th small river in the r-th administrative region, m;
L – the total length of rivers in the r-th administrative region, m.

Then the coefficient of the environmental morbidity index exceeding in the j-th river will be determined as the following:

$$K_j = m_j \times K_r \tag{7}$$

Three components are usually calculated, when assessing risk [13]:
- risk related to the organoleptic properties of water;
- risk related to the sanitary and toxicological properties of water;
- risk related to the epidemiological danger of water.

The risk related to the organoleptic properties of water involves risk assessment in terms of color, hydrogen, smell and taste, and other indicators in accordance with their effect on the organoleptic water properties.

Risk based on the color index is determined according to Equation 8:

$$P_r = -3.33 + \\ + 0.067(C - Background + 20) \tag{8}$$

where: $Background$ denotes the natural color of water, obtained from long-term observations, and is specific for a given season;
C – the current color of water (in degrees of color);
P_r – associated with probability (risk) in accordance with the laws of normal probability distribution.

The following equations can be used to determine the risk by pH factor:

$$P_r = 4 - pH, when\, pH <= 7 \tag{9}$$

$$P_r = -11 + pH, when\, pH > 7 \tag{10}$$

where: K_3 – the safety factor equal to 100 for substances with a pronounced probability of long-term effects and 10 for other substances.

The risk related to the epidemiological water hazard

The epidemiological risk is calculated depending on indicators such as coli index, enterococcus index and coliphage index, using the following risk dependences on the following indicators:

$$Risk = 2.894 - 2.94 \cdot 10^{-5} \cdot \\ \cdot X_1 + 7.93 \cdot 10^{-4} \cdot \\ \cdot X_2 + 2.77 \cdot 10^{-4} X_3 \quad (11)$$

where: X_1 – the number of lactose-positive Escherichia coli in 1 liter of water in a water body;
X_2 – an index of enterococci;
X_3 – an index of coliphages;
$Risk$ – the probability (%) that the water in a water body can be epidemiologically dangerous.

Thus, the health risk related to the organoleptic and sanitary-toxicological properties of water, as well as the risk related to the epidemiological water hazard, is calculated separately, then the total risk is determined according to the rule of probabilities multiplication, where the multiplier is not the values of the health risk, but the values characterizing the probability of its absence:

$$Risk_{sum} = 1 - (1 - Risk1) \times \\ \times (1 - Risk2) \ldots . (1 - Riskn) \quad (12)$$

where: $Risk_{sum}$ – the total potential risk to public health;
$Risk1, \ldots, Riskn$ – the potential risk of exposure to a particular pollutant.

When interpreting the obtained values of the potential risk to public health, it is proposed to use the following rank scale (Table 1):

Since the reaction of the body to environmental pollution may appear after some time, and morbidity rate level is non-linear, one of the most serious problems in assessing the impact of the qualitative state of the environment is to determine the acceptability of the risk to public health, that is, how dangerous its increase is at the existing level of incidence. It is possible to determine risk acceptability in combination with a comprehensive assessment of public health.

The main disadvantage of the public health risk assessment system is its anthropocentric approach, that is, focusing only on maintaining human health, its adaptive capabilities to the natural environment, while the state of ecosystems is not taken into account.

At the same time, dynamic control over the quantitative results of assessing the acceptability of a potential health risk enables risk management authorities (in the field of nature protection and health care) to raise the issue of revising the current permissible exposure levels and develop specific measures to prevent or reduce risk, taking into consideration various factors: environmental, economic, social, political.

Table 1. Dependence of the effects severity on the risk rate to public health

Risk	Severity of effects
0.9–1.0	Very severe effects
0.6–0.89	Severe acute effects
0.5–0.59	Threshold acute effects
0.2–0.49	Severe chronic effects
0.1–0.19	Threshold chronic effects
0.06–0.09	Reactions of supersensitive subgroups
0–0.05	Minimal risk levels and rates

CONCLUSIONS

Having limited funding, decision-making on effective management of natural resources in small river basins is of great importance. Economic activities carried out in the basins of small rivers have a more significant impact on the state of their ecosystems compared to medium and large rivers. The proposed method to identify and rank the problematic situations of water use in small river basins in terms of the acceptability of a potential risk to public health will enable the determination of the priority of environmental and recreational activities.

When developing a strategy for the revival of small rivers, it is necessary, first of all, to identify the environmental hazard areas. Thus, the economic analysis of the recreational water should be based on risk assessment. The appropriate ranking analysis of negative and positive factors makes it possible to give recommendations on the restructuring of the catchment area, taking into account the environmental hazard areas.

The established dependencies of the severity of environmental consequences deepen the study of the properties of the river systems functioning, which is the justification for increasing the rationality of the economic use of water, land, and forest resources within the small river ecosystem.

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