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## PROSPECTS FOR THE USE OF BIVALVE MOLLUSKS IN BIOINDICATION OF WATER QUALITY IN THE AREA OF THE INGULETS IRRIGATION SYSTEM WATER INTAKE

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The article substantiates the feasibility of using bivalve mollusks for bioindication-based water quality monitoring at the intake facility of the Ingulets Irrigation System under conditions of anthropogenic pressure and a variable hydrochemical regime of the Ingulets River. It was established that the deterioration of irrigation water quality, caused by the influence of highly mineralized mine and industrial waters, seasonal fluctuations in mineralization, and changes in water management regimes, creates risks for irrigation, soil reclamation status, and the efficiency of agricultural production, thereby necessitating more timely monitoring of the aquatic environment.

Current approaches to water quality monitoring were analyzed, and the limitations of conventional hydrochemical control were identified. Since this control is based mainly on periodic sampling followed by laboratory analysis, it does not always ensure sufficiently timely detection of undesirable changes in water quality within the water intake zone. The use of bivalve mollusks as an additional bioindication component of the monitoring system is substantiated, as they are capable of reflecting the integrated response of a living organism to changes in physicochemical water parameters and the presence of toxic impurities.

Based on the analysis, a structural and functional scheme of bioindication-based water quality monitoring at the intake facility of the Ingulets Irrigation System is proposed. This scheme involves the placement of a bioindication station within the water intake zone, registration of the behavioral responses of mollusks, processing of the obtained signal, and transmission of information to the operator for prompt response. It was established that the use of this approach makes it possible to improve the timeliness of detecting potentially hazardous changes in the aquatic environment, provide early warning of irrigation water quality deterioration, and complement conventional laboratory monitoring.

It was determined that the bioindication system cannot be regarded as a self-sufficient tool for identifying the causes of deviations and should be applied in combination with physicochemical and laboratory monitoring methods. The practical significance of the study lies in improving the efficiency of real-time irrigation water quality monitoring through the use of the bioindication approach.

**Key words:** bivalve mollusks; bioindication; water quality; Ingulets Irrigation System; water intake; irrigation water; real-time monitoring; early warning; hydrochemical monitoring; irrigation.

### **Коваленко Р. Ю. Перспективи використання двостулкових молюсків для біоіндикації якості води в районі водозабору Інгулецької зрошувальної системи**

У статті обґрунтовано доцільність використання двостулкових молюсків для біоіндикаційного контролю якості води на водозаборі Інгулецької зрошувальної системи в умовах техногенного навантаження та мінливого гідрохімічного режиму р. Інгулець. Встановлено, що погіршення якості поливної води, зумовлене впливом високомінералізованих шахтних і промислових вод, сезонними коливаннями мінералізації та змінами водогосподарського режиму, створює ризики для зрошення, меліоративного стану ґрунтів і ефективності агропромисловості, що потребує підвищення оперативності контролю водного середовища.

Аналізовано сучасні підходи до моніторингу якості води та визначено обмеження стандартності європейського, який, ґрунтуючись переважно на періодичній лабораторній аналізі, не завжди забезпечує належну



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*оперативність виявлення небажаних змін якості води у зоні водозабору. Обґрунтовано застосування двостулкових молюсків як додаткового біоіндикаційного елемента системи спостереження, здатного фіксувати інтегральну реакцію живого організму на зміну фізико-хімічних характеристик води та наявність токсичних домішок.*

*На основі проведеного аналізу запропоновано структурно-функціональну схему біоіндикаційного контролю якості води на водозаборі Інгулецької зрошувальної системи, яка передбачає розміщення біоіндикаційного поста в зоні забору води, реєстрацію поведінкової реакції молюсків, обробку отриманого сигналу та передачу інформації оператору для оперативного реагування. Встановлено, що використання такого підходу дає змогу підвищити оперативність виявлення потенційно небезпечних змін стану водного середовища, забезпечити ранню сигналізацію про погіршення якості поливної води та доповнити традиційний лабораторний контроль.*

*Визначено, що біоіндикаційна система не може розглядатися як самодостатній інструмент встановлення причин відхилень, а має застосовуватися у поєднанні з фізико-хімічними та лабораторними методами моніторингу. Практичне значення роботи полягає у підвищенні ефективності оперативного контролю якості поливної води за рахунок використання біоіндикаційного підходу.*

**Ключові слова:** двостулкові молюски, біоіндикація, якість води, Інгулецька зрошувальна система, водозабір, поливна вода, оперативний моніторинг, раннє попередження, гідрохімічний контроль, зрошення.

**Introduction.** Irrigation water quality significantly affects soil conditions, the development of agricultural crops, and the efficiency of irrigation systems [1]. In the southern regions of Ukraine, where irrigation plays an important role, timely monitoring of irrigation water quality is of particular relevance.

The Ingulets River is an important source of irrigation water; however, its water quality is formed under complex hydrochemical conditions influenced by highly mineralized mine waters, industrial discharges, and changes in water management regimes [2, 3]. Therefore, the water supplied to the Ingulets Irrigation System requires continuous monitoring [2].

Traditional monitoring methods do not always ensure the timely detection of undesirable changes in water quality [4]. For this reason, increasing attention is being paid to bioindication methods, particularly the use of bivalve mollusks, which are capable of responding to changes in physicochemical water parameters and the presence of pollutants [5, 6]. This determines the relevance of substantiating their use for bioindication-based water quality monitoring at the intake facility of the Ingulets Irrigation System.

**Analysis of Recent Research and Publications.** For the Ingulets Irrigation System, the issue of water quality is particularly relevant due to the prolonged impact of mine and industrial discharges [2, 3]. Scientific studies have emphasized the need for continuous monitoring of this water source, as well as the influence of highly mineralized waters from the Kryvbas region, the operating regime of pumping stations, and water management regulation on the formation of its quality [2–4].

Alongside conventional laboratory monitoring, which does not always provide sufficient timeliness of observation [4], biological early warning systems for aquatic pollution are being actively developed [5]. It has been shown that the use of living organisms makes it possible to continuously detect changes in water conditions and to identify pollutants in a timely manner [5, 7].

Of particular interest in this context are bivalve mollusks as promising bioindicators of aquatic environmental conditions [6, 8]. Their responses can be used for continuous water quality monitoring, timely detection of toxic effects, and monitoring of multipurpose water sources [7, 9–11].

Thus, the issues of Ingulets River water quality have been sufficiently covered in the scientific literature [2–4]. However, the adaptation of bioindication using bivalve

mollusks to the conditions of the Ingulets Irrigation System water intake remains insufficiently explored.

**The aim of this study** is to substantiate and develop an approach to bioindication-based water quality monitoring at the intake facility of the Ingulets Irrigation System using bivalve mollusks as an element of real-time monitoring.

**Materials and Methods.** The study materials included scientific publications devoted to the bioindication of water quality and the use of bivalve mollusks in biological early warning systems for aquatic pollution [5–12], as well as studies addressing the hydrochemical regime of the Ingulets River and the formation of water quality supplied to the Ingulets Irrigation System [2–4]. In addition, regulatory, methodological, and water management documents were used [1, 4, 13, 14].

The study employed bibliographic, analytical, comparative, and generalization methods. Their application made it possible to identify the main directions of using bivalve mollusks in aquatic bioindication [5–12], to compare conventional hydrochemical monitoring with the bioindication approach according to the criteria of timeliness, sensitivity, and applicability under water intake conditions [1, 5, 6, 10, 11], and to substantiate the feasibility of adapting this approach to the conditions of the Ingulets Irrigation System, taking into account the anthropogenic formation of water quality and fluctuations in mineralization [2–4].

The obtained results were processed through content generalization, logical analysis, and scientific interpretation based on the analyzed sources.

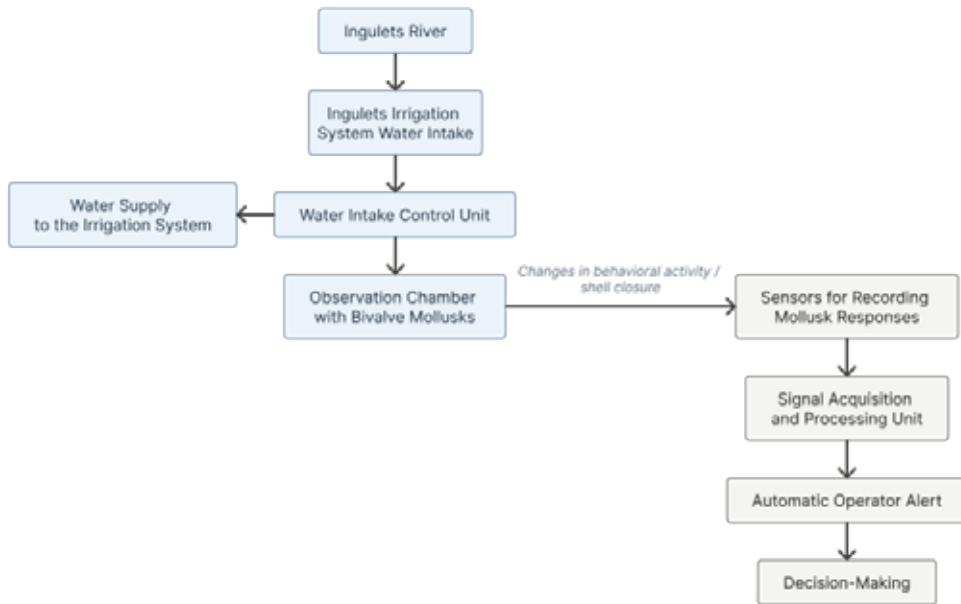
**Results.** The analysis of the reviewed sources made it possible to establish that bivalve mollusks can be used as a sensitive bioindication component of real-time monitoring systems for the aquatic environment [6–8]. Their practical value lies in their ability to respond in an integrated manner to changes in the hydrochemical characteristics of water and the presence of toxic impurities, thereby ensuring continuous detection of changes in the state of the aquatic environment [5, 6, 9]. Such an integrated response makes it possible to assess not only individual water quality parameters but also the cumulative influence of a set of factors, which is particularly important under conditions of a variable hydrochemical regime.

Under the conditions of the Ingulets Irrigation System water intake, where water quality is shaped by anthropogenic factors and is characterized by considerable variability [2–4], the application of this approach makes it possible to improve the timeliness of detecting undesirable changes in irrigation water quality, which is important for ensuring irrigation efficiency [1]. Under these conditions, conventional hydrochemical monitoring does not always allow short-term or abrupt changes in water composition to be detected in a timely manner, which further supports the use of bioindication methods as an element of real-time monitoring.

The obtained results provide grounds for considering bivalve mollusks as a functional component of a combined water quality monitoring system that complements conventional hydrochemical monitoring and ensures early indication of undesirable changes in the aquatic environment. Within this approach, the bioindication component performs the function of a primary signaling tool, making it possible to respond promptly to deviations in water quality parameters and to initiate detailed laboratory analysis in a timely manner. Comparative analysis indicates that the proposed approach can reduce the response time to changes in water quality compared to conventional hydrochemical monitoring methods.

Taking into account the specific features of the study object, a structural and functional scheme for the use of bivalve mollusks in bioindication-based water quality

monitoring at the Ingulets Irrigation System water intake is proposed. The scheme includes a bioindication station, an observation chamber, a signal registration and processing unit, and a channel for transmitting information to the operator. The structural and functional scheme of the system is presented in Figure 1. The proposed scheme provides for continuous monitoring of the behavioral activity of mollusks and automated transmission of signals indicating changes in that activity, thereby creating the preconditions for integrating the bioindication station into existing monitoring systems.



*Fig. 1. Structural and functional scheme for the use of bivalve mollusks in bioindication-based water quality monitoring at the Ingulets Irrigation System water intake*

As shown in Figure 1, changes in the behavioral activity of the mollusks generate a signal indicating possible deterioration in water quality. This scheme does not replace laboratory confirmation of the causes of deviations; however, it ensures timely warning [7, 10]. The implementation of such an approach makes it possible to reduce the time interval between the occurrence of pollution and its detection, which is important for managerial decision-making in water use systems.

The main advantages of this approach include continuity of observation, the relative simplicity of organizing a bioindication station, and the possibility of promptly detecting adverse changes in the aquatic environment [6, 9]. At the same time, mollusk responses may depend on a combination of parameters; therefore, the bioindication system should be regarded as a tool for the early detection of potentially hazardous changes that requires subsequent instrumental and laboratory verification [6, 8]. In addition, the effectiveness of this approach depends on the correct selection of the mollusk species, the conditions of their maintenance, and the stable functioning of the signal registration system.

For the conditions of the Ingulets Irrigation System, the most promising option is a combined approach in which bioindication-based observation operates together with

conventional hydrochemical monitoring [4, 12, 13]. This confirms the feasibility of using bivalve mollusks to improve real-time irrigation water monitoring and to enhance the efficiency of water resources management.

**Conclusions.** The study substantiates the feasibility of using bivalve mollusks as an element of real-time bioindication-based water quality monitoring at the intake facility of the Ingulets Irrigation System.

A structural and functional scheme of bioindication-based monitoring is proposed, providing continuous observation of the aquatic environment and early warning of its deterioration.

It was established that the most effective option is a combined approach in which bioindication-based observation operates together with conventional hydrochemical and laboratory monitoring methods.

Further research should focus on refining the criteria for mollusk responses and developing practical solutions for the implementation of a bioindication station.

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