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# DEVELOPMENT OF INNOVATIVE MODEL OF REGIONAL MANAGEMENT OF FRESHWATER RESOURCES IN CONDITIONS OF SUSTAINABLE DEVELOPMENT

*In this paper, the object of research is an innovative model of regional management of freshwater resources in the context of achieving environmental goals.*

*The study found that the most problematic issues are the lack of clear criteria and methodological mechanisms in the formation of the basic innovative principles of freshwater resource management in the context of sustainable development.*

*When solving the problems posed in the work, the methods of analysis and synthesis, comparative comparison and logical generalization were used. On their basis, the analysis of the main principles of adaptation of the world experience of regional management of freshwater resources in the context of the implementation of the European Union Water Framework Directive was carried out and the conceptual foundations for the formation of an innovative model for the management of freshwater resources of territories in the context of sustainable development were developed. A cluster model of a regional innovation-information portal of freshwater resources is proposed, which allows uniting the efforts of public authorities, the population, the public, scientific institutions and business in solving problematic issues related to the ecosystem based on smart technologies in the context of sustainable development. It is determined that for the functioning of the cluster model it is necessary to develop institutional, legislative, regulatory, scientific and innovative, investment support. It is substantiated that the functioning of the cluster model of the regional innovation-information portal of freshwater resources will solve the following problems:*

- creation of a unified data bank for monitoring the quality of water resources, the results of scientific and technical activities, business planning and design for the conservation, restoration and purification of water;*
- information services in the field of innovation;*
- attraction of business representatives to co-financing of innovative projects.*

*Thanks to the results of the conducted studies, it is possible to more objectively and balanced assess the possible schemes and tools for managing the territory's freshwater resources. The conceptual approach presented in the paper is a rather flexible tool with a free choice of elements of analysis depending on the goals and objects of management.*

**Keywords:** *regional management, freshwater resources, innovative model, balanced management, environmental protection.*

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## 1. Introduction

An acute shortage of freshwater resources can be experienced by about two-thirds of the world's population for several decades.

There is still a trend in many parts of the world to address water scarcity by:

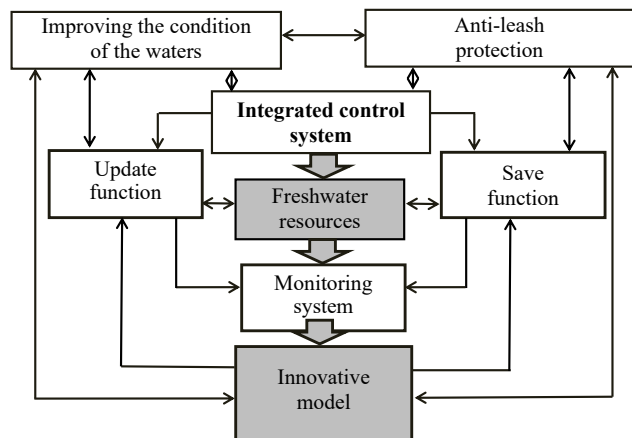
- increase in water supply;
- increasing the storage and distribution of surface and groundwater;
- creation of new infrastructure;

- desalination of salty or brackish water;
- reuse of wastewater or replenishment of aquifers.

This trend today prevails over the focus on reducing the overall demand for the resource. However, water scarcity can be overcome through the use of modern innovative solutions that increase the overall productivity of the use of the resource based on modern innovative management solutions, which makes it possible to significantly modernize the water resource infrastructure. It is the use of innovative principles of freshwater management in the context of sustainable development that should become a prospect for the coming years.

## 2. The object of research and its technological audit

The object of research is an innovative model of regional management of freshwater resources in the context of achieving environmental goals, the technological scheme of which is shown in Fig. 1.



**Fig. 1.** Technological scheme of an innovative model of regional management of freshwater resources in the context of achieving environmental goals

Restoration and purification of freshwater resources remain a very important issue both at the national level and globally.

The strategic goals of sustainable development remain to provide clean water to all miles of the population. Over the years, water pollution occurs, which quite sharply poses new threats to humanity, which is why the search for innovative solutions for the purification, conservation and restoration of freshwater resources is becoming increasingly important. Studies of the current state of the innovative potential of freshwater resources and the prospects for technological development in the context of global trends are quite important.

There are four main cycles in the technological scheme of the innovative model of regional management of freshwater resources:

- the first cycle is associated with the regulation of the improvement of the state of water, grouped and forming an aggregated complex of production factors;
- the second cycle consists of flood protection measures, which are grouped into an appropriate aggregated set of indicators and factors;
- the third cycle with two variations, focused on the regulation of the integrated management system, providing a synergistic effect from the interaction of resource conservation functions and the natural resource function of the sustainable agricultural production model;
- the fourth cycle is connected with the formation and regulation of a modern monitoring system.

## 3. The aim and objectives of research

The aim of research is to develop methodological approaches to the formation of an innovative model of regional management of freshwater resources in the context of sustainable development.

To achieve a certain aim, it is necessary to perform the following objectives:

1. Explore the main innovative principles of freshwater resource management in the context of sustainable development.
2. Conduct an analysis and determine the main principles for adapting the world experience in freshwater management in the context of the implementation of the EU Water Framework Directive.
3. Create a conceptual framework for the formation of an innovative model for the management of freshwater resources of territories in the context of sustainable development.

## 4. Research of existing solution to the problem

In recent years, the range has been significantly expanded and various scientific studies on the issues of sustainable development of freshwater systems related to solving the problems of optimizing nature management and improving the environment have been significantly intensified.

At present, water management and hydroecological problems have become of great importance for all countries of the world. The water factor has become one of the main indicators that limit the regional development of the production sector and an unconditional paradigm of the national security of the vast majority of countries in the world. It is noted that water crises in many countries are caused not so much by a lack of resources as a consequence of a poor and uncoordinated management system in the region [1, 2]. A significant role in the development of crisis phenomena is caused by the lack of comprehensive sound solutions for the integration of ecosystem services into the water resources management system [3].

The authors of [4] note that in 2010–2015, at least 35–45 % of the world's population lived for at least one month under water stress. Moreover, for such regions of the world as India, Pakistan, Bangladesh, Northeast China, this figure reached 80–85 %.

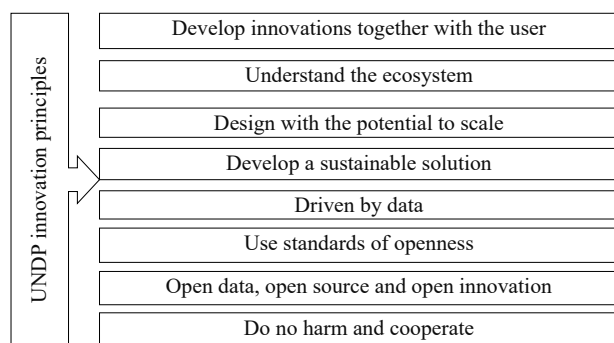
Freshwater ecosystems are among the most threatened in the world while providing essential ecosystem services to humanity. It is emphasized in [1, 3] that, despite its significance and importance, research in the field of freshwater ecosystem services is currently very limited. Studies of the spatially detailed assessment of the global human stress in water supply, the impact of climate change on the reduction of ecosystem services, reveal several features that are unique to freshwater ecosystems [5, 6]. The first problematic feature is, as a rule, a very insufficient and inefficient system for transmitting operational data to all interested parties [3]. It is also necessary to note the insufficient focus on a more dynamic approach of qualitative and quantitative assessment of the resource at the landscape level, the transboundary interconnectedness of freshwater objects and economic entities [5].

The authors of [7] believe that focusing attention requires environmental innovation to exacerbate the problems of our time, including in the field of water supply, especially freshwater safety. This will ensure the sustainable development of the water sector, the preservation of the quality of the environment, the rational use of water resources, and the satisfaction of the needs of future generations in sufficient quantity and the required quality. It is

the processes of irrational use of water that can be stopped through the use of environmental innovations today.

It is necessary to agree with the opinion of the author [8] that «Innovative transformations in the field of water supply and sanitation are a determining factor in improving the efficiency of enterprises, improving the quality of services, raising environmental and social standards, etc. At the same time, the latest technologies (innovations) by themselves cannot carry out reforms in the field of water supply and sanitation, but only as an integral part of state policy (state regulation), which solves a complex of problems in the field of resource management before training professional personnel. The European experience proves the effectiveness of the state policy in the field of water supply and sanitation, which promotes innovation in this area, regardless of the management model and the regulatory model». Consequently, the need to form a state policy in the field of water supply and sanitation based on an innovative model is a challenge for all countries of the world.

Thus, according to the national report «Sustainable Development Goals: Ukraine», «Ukraine belongs to the group of countries with complex environmental problems. They are typical, on the one hand, for developing countries (unbalanced use and emasculation of natural resources), and on the other hand, for industrialized countries (environmental pollution by industrial activities). A specific problem of the transformational period is waste management. The amount of waste generated is growing, and the share of recycled is negligible. Existing land use practices lead to the deterioration of land, and the debilitating use of land, forest and water resources leads to irreversible loss of ecosystem and biological diversity. The share of nature reserves (6.6 % of the total area of the country) is insufficient to prevent such losses. A significant factor in the negative impact on the environment is the armed conflict in Ukraine. Overcoming the consequences of the destruction of landscapes and the destruction of the infrastructure of the country requires significant efforts, resources and recovery time» [9]. Accordingly, the goals of sustainable development should be based on the basic principles of innovation of the United Nations Development Program (UNDP), Fig. 2 [10].



**Fig. 2.** Key principles of UNDP innovation [10]

The author of [11] believes that «production, installation and operation of environmental (treatment) facilities; waste management; development and implementation of environmentally friendly technologies; trade in environmental technologies; eco-audit and eco-expertise are all ecological innovations». Today, however, environmental innovations need to be understood somewhat more than

technologies for cleaning, processing, transporting and burying and eliminating toxic waste. Let's believe that environmental innovation is a comprehensive system of environmental solutions aimed at improving environmental management based on data openness, accessibility, scaling and implementation of innovative technologies.

The authors of the study [12] note that «they consider ecological innovations to be a kind of indicator of sustainable and balanced development in a competitive environment. They are complex and rather complex technologies that allow to effectively solving environmental problems that require not only innovative engineering ideas, but also innovative approaches to the management and organization of society».

A number of researchers of the problem argue that the formation of modern trends in ensuring the optimal operation of the system of balanced functioning of the water management complex encourages the improvement and deepening of approaches to ensuring the gradual development of a system of sustainable water use [13, 14]. At the same time, it is important to define and economically evaluate resources as a basis for the development, development and exploitation of water resources in the context of the implementation of the provisions of the EU Water Framework Directive. Relevant directions for the implementation of the Water Framework Directive in Ukraine have been developed: integrated management of freshwater resources is being introduced based on the basin principle, territories have been zoned, and a draft Water Strategy has been developed.

Article 360 of the Agreement stipulates that strengthening environmental activities will have positive consequences for citizens and businesses in Ukraine and the EU. In particular, by improving the health care system, conserving natural resources, increasing economic and environmental efficiency, integrating environmental policy into other areas of government policy, as well as increasing the level of production thanks to modern technologies [15].

The Ministry of Environmental Protection and Natural Resources of Ukraine notes: «Until now, water resources management in Ukraine was carried out according to the administrative-territorial division, as rivers also have borders between regions and countries. The decision on the ecological state and use of river resources was made by the regional departments of water resources subordinated to the State Water Agency. Each district manages itself, but there is no built-in management. Today, Ukraine is moving to the basin management principle» [16]. Hydrographic zoning of the territories of Ukraine is divided into nine regions of the river basin (Vistula (Western Bug and San), Danube, Dniester, southern Bug, Dnipro, Black Sea, Don, Azov rivers, Crimean rivers).

The author of the work [17] believes that «Innovative directions for improving the mechanisms of state regulation of the systemic use of the water resource potential of Ukraine are:

- all aspects of synergy, quality, harmonization of laws and regulations, ensuring the national security of the state in the field of water resources in connection with the growth of water consumption, total pollution, primarily by surface waters;
- guaranteeing the reliability and safety of hydraulic structures; study of the growth of anthropogenic load on groundwater;

- substantiation of aspects of pricing for drinking water;
- integrated water resources management;
- decrease in the water intensity of the gross domestic product;
- further rationalization of water use;
- construction and reconstruction of water supply and drainage systems; scientific substantiation of the quality of drinking water supply;
- improvement of wastewater treatment and increased responsibility for pollution;
- advancing development of the scientific, technical and regulatory base of the water management complex;
- development of the theory and practice of resolving environmental conflicts;
- improving the efficiency of distribution of water resources;
- wide introduction of developed innovative technologies».

Therefore, for the implementation of the Water Framework Directive, it is necessary to develop and grasp a strategy for the development of water policy. Appropriate strategies should be developed at the macro, meso and micro levels.

In Ukraine, a draft «Strategy for the Development of the Water Policy of Ukraine – Water Strategy» has been developed, the premise of which is defined as «The shortage of fresh water of proper quality is observed in 13 regions of Ukraine. This situation is exacerbated by the consequences of climate change, which has a significant impact on the seasonal distribution of water resources and leads to prolonged dry periods. According to experts from the Institute for Local Development, today only 30.1 % of the rural population, 89.9 % of the population living in urban-type settlements and 99.2 % of the urban population have access to centralized water supply. The rest of the rural population uses water from street standpipes (about 20 %) and uses water from wells and other sources (more than 60 %). The water supply networks of cities are outdated, decrepit and leaky, which is the cause of both significant losses of water that has undergone preliminary water treatment and the ingress of contaminated groundwater into the water supply networks. Poor quality drinking water is one of the reasons for the spread of infectious and non-communicable diseases» [18].

The results of studies [19] show that «Important conditions for improving the organizational and managerial mechanisms for regulating water use are:

- 1) revision of the organizational structure of management with clarification of the rights, duties and capabilities of state, regional and territorial bodies with clarification of their functional responsibilities. Development of effective motivational systems aimed at the development of personnel in the water sector, as well as for users of water resources;
- 2) formation of an effective system for monitoring, coordinating and controlling the state and use of water resources, which will be based on an updated legal framework and modern information systems (in particular, Big Data);
- 3) optimization of systems for planning and forecasting the development of water resources and needs based on an integrated strategic approach that takes into account not only general trends and needs, but also trends in the development of the domestic and world economies, changes in demography, climate, etc.».

According to [20], «The path of innovative development of the ecological and economic system, based on the principles of adaptability, dynamism, self-organization, self-regulation and self-development, should be determined by general trends in economic growth and take into account its administrative and territorial features, natural resource and production and economic potential».

In turn, studies [21] show that «Ukraine's environmental problems can be more realistically solved with the help of international partners, it directs the efforts of national driving forces to harmonize the life of international assistance, attract foreign investment, in particular production, introduce resource-saving technologies, develop a regional system for managing industrial waste management and creation of environmental funds».

The authors of studies [19, 22] believe that «despite the fact that the volumes of current expenditures and capital investments in environmental protection are increasing, investments in ensuring environmental protection in Ukraine are at a low level, the volumes of environmental investments are insufficient. It is necessary to mobilize investment in environmental protection from all possible sources, increase public investment, activate alternative investment, and stimulate the flow of foreign investment in environmental protection. It is advisable to revise the structure of expenditures, namely, to increase the share of capital expenditures in the total volume, gradually reducing current ones».

Despite a significant amount of scientific research, the issues of methodology for the formation of an innovative model of regional management of freshwater resources in the context of sustainable development remain insufficiently studied.

## 5. Methods of research

To solve the problems posed in the work, the following methods were used:

- method of analysis and synthesis in the study of innovative foundations for the management of freshwater resources in the context of sustainable development;
- comparative comparison during the analysis and determination of the main principles of adaptation of the world experience in freshwater resources management in the context of the implementation of the EU Water Framework Directive;
- logical generalization and analogies in the development of conceptual foundations for the formation of an innovative model of regional management of freshwater resources;
- monographic and graphic-analytical methods were applied at all stages of solving this problem.

## 6. Research results

Let's consider the main goals and objectives of sustainable development of the formation of the ecosystem of Ukraine until 2030 (Fig. 2) [23].

Improving the water management system is the main task to achieve the goal. The development of the National Water Strategy should aim to achieve a good state of water resources, the implementation of integrated management of water and other natural resources on the principle of the basin through the development and implementation of river basin management plans.

The Sustainable Development Goals cover the restoration and sustainable use of land and inland freshwater ecosystems.

«The sustainable development goals of Ukraine until 2030 provide for the implementation of the 6th strategic goal through the implementation of the following tasks:

- ensure the availability of quality services for the supply of safe drinking water, the construction and reconstruction of centralized drinking water supply systems using the latest technologies and equipment;
- ensure the availability of modern drainage systems, construction and reconstruction of water intake and sewage treatment facilities using the latest technologies and equipment;
- reduce the volume of untreated wastewater discharges, primarily through the use of innovative water treatment technologies at the state and individual levels;
- increase the efficiency of water use;
- ensure the implementation of integrated management of aquatic resources» [24].

However, it should be noted that virtually every goal of sustainable development involves the tasks of preserving and restoring the ecosystem through the use of innovative technologies. Forecast provision of storage, restoration and sustainable use of terrestrial and inland freshwater ecosystems by 2030 is given in Table 1.

According to [24], in Ukraine, by 2030, it is predicted to increase the share of the area of territories and objects of the natural reserve fund to 15 % of the total territory of the country and the share of the area of the territories of the national ecological network to 41 %.

In the development and further implementation of projects for the use of science and technology in environmental activities to ensure favorable conditions for the safe and balanced development of economic and environmental systems, it is necessary to take into account the presence of risk factors.

Risk sources in this case can be:

- variability of the economic and environmental situation in the country or in certain regions;
- instability of the political situation;
- emergence and development of emergencies;
- occurrence and development of hydrometeorological disasters;
- appearance of radioactive contamination of natural resources;
- emissions of toxic substances into natural spheres;
- terrorist actions, etc. (Fig. 3).

Analysis of the probability of occurrence of economic and environmental risk in the implementation of innovative projects for environmental purposes can significantly increase the quality requirements for the corresponding design, manufacture and further operation of complex technological and organizational schemes. This, in turn, should ensure the introduction of the achievements of science and technology in environmental activities in order to increase the safe development of economic and environmental systems.

It should be taken into account that initially the risks have a latent negative impact on the economic and environmental efficiency of the project, which is hidden in the stochastic fluctuations of certain parameters of the environmental process. To identify the possibility of an economic or environmental risk in the implementation of certain environmental measures, it is necessary to use special methods of probabilistic forecasting of the values of the studied indicator of the environmental process [25, 26].

The measures taken in this case to prevent the impact of possible risks will be the usual measures to prevent negative fluctuations in this indicator. If the changes in this parameter under the influence of developing economic and environmental risks began to exceed the permissible limits, then it is necessary to take special measures to improve the adopted design decisions.

Anti-crisis measures are bringing the complex of environmental measures in line with the internal dynamics of changes in the economic and environmental situation, in line with the changing external situation.

In addition to the above measures, anti-crisis actions are quite effective, consisting in:

- write-off of obsolete fixed capital;
- urgent replacement of obsolete technological and environmental equipment;
- restriction in hiring workers and service personnel;
- implementation of retraining of personnel;
- reduction of non-production costs, etc.

The development of the negative impact of risks in environmental activities largely depends on the timeliness of the adoption of anti-crisis measures.

The practical activity of most industrial and economic enterprises shows that in the implementation of environmental activities to ensure the safe development of economic and environmental systems, it is advisable to use forecasting the possibility of a risk, which is the source of the development of crisis phenomena in this type of activity. This makes it possible to carry out anti-crisis measures in a planned manner [22].

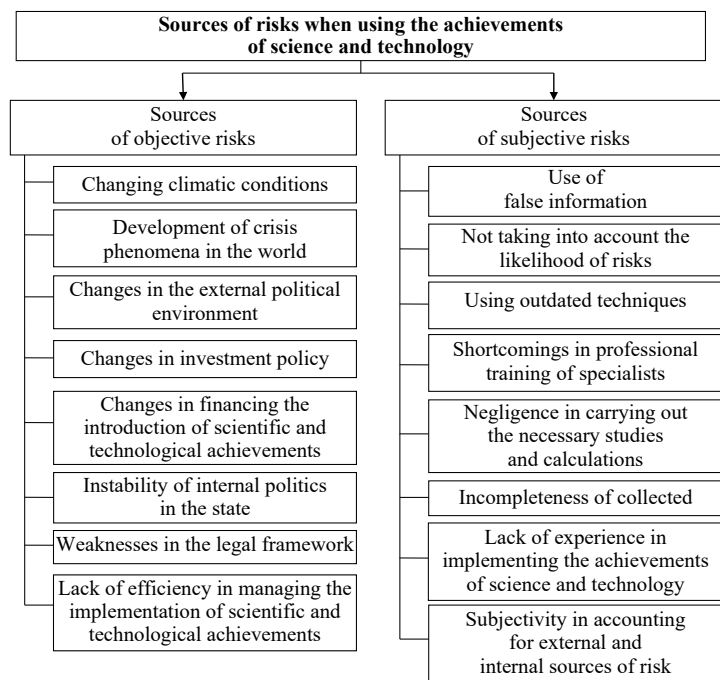
**Table 1**

Ensuring the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems [24]

Indicators	2015	2016	2017	2018	2019	2020 (reference point)	2025 (reference point)	2030 (reference point)
Area of territories and objects of the natural reserve fund, thousand ha	3803.13	3985.60	3985.02	3991.64	4082.20*	6276.90	7545.40	9053.20
Share of the area of territories and objects of the natural reserve fund in the total territory of the country, %	6.30	6.60	6.60	6.61	6.76*	10.40	12.50	15.00
Share of the area of the territories of the national ecological network in the total territory of the country, %	38.16	38.16	38.16	38.16	38.16*	39.00	40.00	41.00

**Note:** excluding the temporarily occupied territory of the Autonomous Republic of Crimea, Sevastopol and part of the temporarily occupied territories in the Donetsk and Luhansk regions;

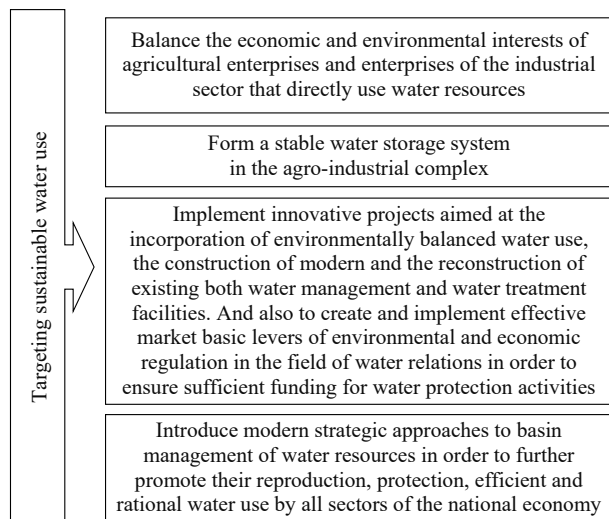
\* – data provided promptly by the body responsible for calculating the indicator within the framework of the system for monitoring the implementation of the Sustainable Development Goals program (according to the order of the Cabinet of Ministers of Ukraine dated 21.08.2019 No. 686-r «The issue of collecting data to monitor the implementation of sustainable development goals»)



**Fig. 3.** Sources of risks arising from the implementation of achievements in science and technology

Fig. 4 shows the main tasks of sustainable water use, among which are identified:

- balanced use of water by agricultural enterprises;
- provision of a water storage system;
- development, implementation and implementation of innovative projects;
- introduction of modern strategic approaches to basin water resources management.



**Fig. 4.** Targeting sustainable water use

That is why, in ensuring the formation of an innovative model of freshwater management, it is necessary to indicate the financial resources for the implementation of innovative projects. Among the main sources of implementation of innovative activities in the field of environmental protection are budget expenditures.

According to the State Treasury Service of Ukraine, expenditures from the state budget for environmental protection over the past ten years have increased by almost 3.2 times, while increasing by an average of 12–17 % annually (Fig. 5) [2].

«In 2020, the national spending on environmental protection (NEEP) of the EU member states amounted to 273 billion EUR. Growing at an average of 2 % annually NEEP has increased by 40 % since 2006» [2]. Remained relatively stable over the past fifteen years (from 1.8 % to 2.0 % of GDP) spending on environmental protection as a percentage of gross domestic product.

At the same time, in Ukraine the share of expenditures from the state budget for environmental protection in total expenditures ranges from 0.57–1.11 %. It should be noted that the largest share of expenditures from the state budget for environmental protection in total expenditures was observed in 2011 – 1.11 %, and the smallest in 2020 – 0.57 %. It should also be noted that in 2020 the volume of environmental protection expenditures has significantly decreased by 675 million UAH compared to the previous year.

The authors of the work [27] note that «The distribution of investments in the areas of environmental protection in the EU countries is dominated by wastewater treatment (especially in Germany and Poland – more than 55 %).

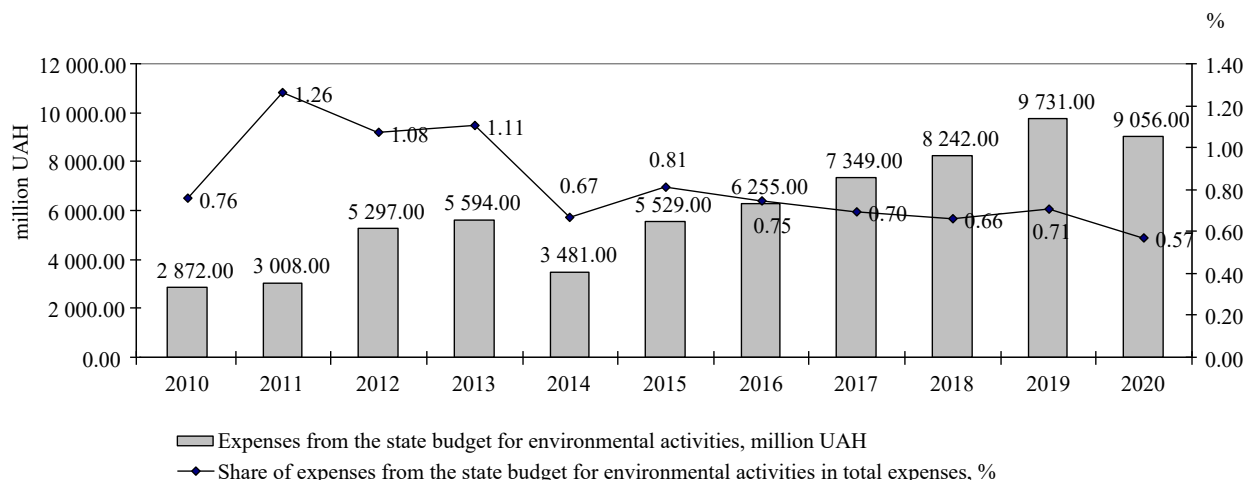
The second most important area of investment is either waste management (in most countries) or the protection of the atmosphere (in particular, in Poland). In contrast, in Ukraine, the main direction of environmental investment is the reduction of emissions into the atmosphere (about 40 %), the second is wastewater treatment (more than 24 %), and the third position is competed by the protection of soils, water bodies and groundwater and waste management.

Differences in investment policy (in areas of investment) reflect the unequal priority (relative relevance) of environmental problems in different states. In the EU countries, the issues of ensuring the quality of atmospheric air, protecting soils and landscapes have been largely resolved, while in Ukraine they have not».

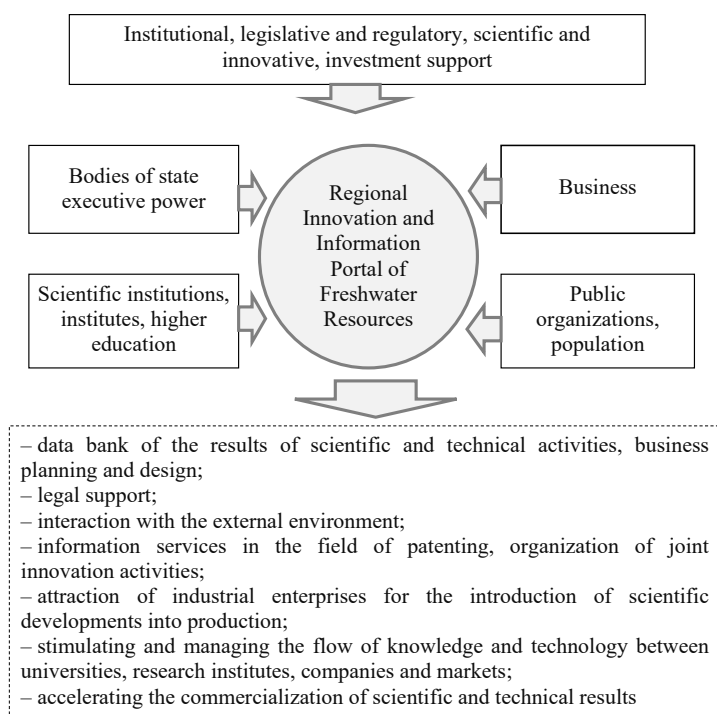
For 2010–2020 the structure of public spending on other activities in the field of environmental protection increased significantly from 11.8 % to 19.5 %. This budget expenditure item is aimed at ensuring environmentally safe living conditions for the population, preventing the occurrence of environmental emergencies, protecting, rationally using and reproducing natural resources, and improving the environmental situation in general.

Ecosystem-related data and monitoring has traditionally focused on the impacts of water use, and interests should shift more towards monitoring ecosystem services that make shorter links between ecosystems and human well-being. That is why let's propose a cluster model of a regional innovation and information portal of freshwater resources based on smart technologies in the context of sustainable development (Fig. 6).

The cluster model of the regional innovation and information portal of freshwater resources will allow uniting the efforts of public authorities, the population, the public, scientific institutions and business in solving problematic issues related to the ecosystem based on smart technologies in the context of sustainable development.



**Fig. 5.** Dynamics of expenses from the state budget for environmental protection and the share of expenditures from the state budget for environmental protection in total expenses for 2010–2020 [2]



**Fig. 6.** Cluster model of a regional innovation and information portal of freshwater resources based on smart technologies in the context of sustainable development

For the functioning of the cluster model, it is necessary to develop institutional, legislative and regulatory, scientific and innovative, and investment support. The functioning of the cluster model of the regional innovation and information portal of freshwater resources solve the following problems:

- creation of a unified data bank for monitoring the quality of water resources, the results of scientific and technical activities, business planning and design for the conservation, restoration and purification of water;
- information services in the field of innovation;
- attracting business representatives to co-finance innovative projects through the placement of relevant project applications;
- involvement of representatives of scientific institutions, institutes, Western Military District in solving

environmental problems, commercialization of proposed projects.

In connection with European integration, Ukraine needs to study the world experience in managing freshwater resources, develop and implement legislative and regulatory documents in accordance with the Water Framework Directive. Accordingly, the adaptation of world experience in freshwater management in the context of the implementation of the Water Framework Directive is among the main objectives of the study.

Issues of international watercourses, parts of which are located on the territory of Ukraine, are resolved as follows. According to experts of the UN International Commission on Strategic Planning and Financing of Sustainable Development at the National and Regional Levels in Ukraine [22], one of the examples of successful implementation of the elements of integrated water resources management is the cooperation of states in the Tisza River basin, a tributary of the Danube. The territories of Ukraine, Romania, Hungary, Slovakia and Serbia belong to this basin. Cooperation in the Tisza basin seems to the UN experts to be successful, first of all, from the point of view of monitoring. The information collected for the Tisza basin is more complex than the information for the Danube basin as a whole.

Since 1995, the transnational monitoring network (TNMM) has been operating – the basin monitoring system of the International Commission for the Protection of the Danube River. The main purpose of the TNSM is to analyze the state and long-term changes in surface water and (where appropriate) the state of groundwater within the entire basin. Particular attention is paid to the level of transboundary pollution, climate change and their impact on the state of water resources.

«According to the World Wide Fund for Nature (WWF), freshwater resources in Ukraine are in very poor condition. According to the WWF Water Risk Filter, freshwater resources are rated «high risk» and are steadily moving towards «very high risk» status. Also, according to the Living Planet report from WWF, the ecosystems of swamps and the steppe zone that suffer most in Ukraine: the area

of the steppes has decreased over the past decades from 40 % of the country's territory to several percent» [18].

The main WWF recommendations for Ukraine on the conservation of natural resources are shown in Fig. 7 [18].

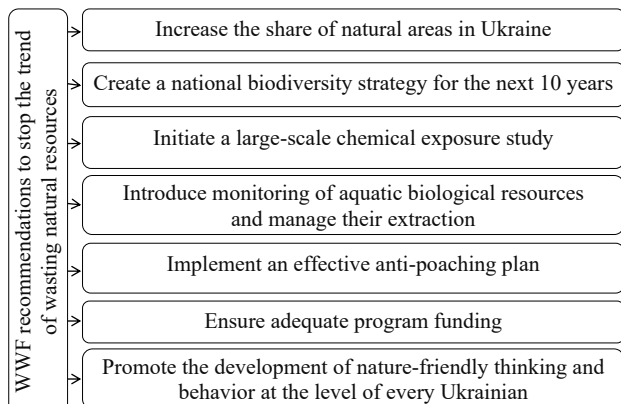


Fig. 7. WWF recommendations for Ukraine on the conservation of natural resources [18]

In connection with the implementation of the Water Framework Directive, it is necessary to improve the mechanism for managing freshwater resources.

An improved mechanism for implementing the integrated basin principle of freshwater management based on the Water Framework Directive 2000/60/EU is shown in Fig. 8.

The mechanism for the implementation of the integrated basin principle of freshwater management based on the Water Framework Directive 2000/60/EU is substantiated, taking into account the main instruments, principles and tasks of the implementation of European legal and environmental standards. The implementation mechanism is based on legislative, regulatory, scientific and innovative, software and hardware, resource and infrastructure support for the tasks of the Water Framework Directive 2000/60/EU. The main objectives of the mechanism for implementing the integrated basin principle of freshwater management are:

- balanced management of freshwater resources based on the basin principle;
- integration of protection and sustainable management of water;
- maintenance and improvement of the aquatic environment;
- stimulation of innovative projects and developments for modernization;
- creation of new water infrastructure;
- development of the community of member states, as well as business and the state on the basis of public-private partnership, fulfillment of the tasks of the Water Framework Directive 2000/60/EU.

Additional financial resources are needed to implement the Water Strategy, sustainable water use, and ecosystem conservation. As noted, state funding for the environmental sector is currently at a low level, and environmental taxes are irrationally distributed.

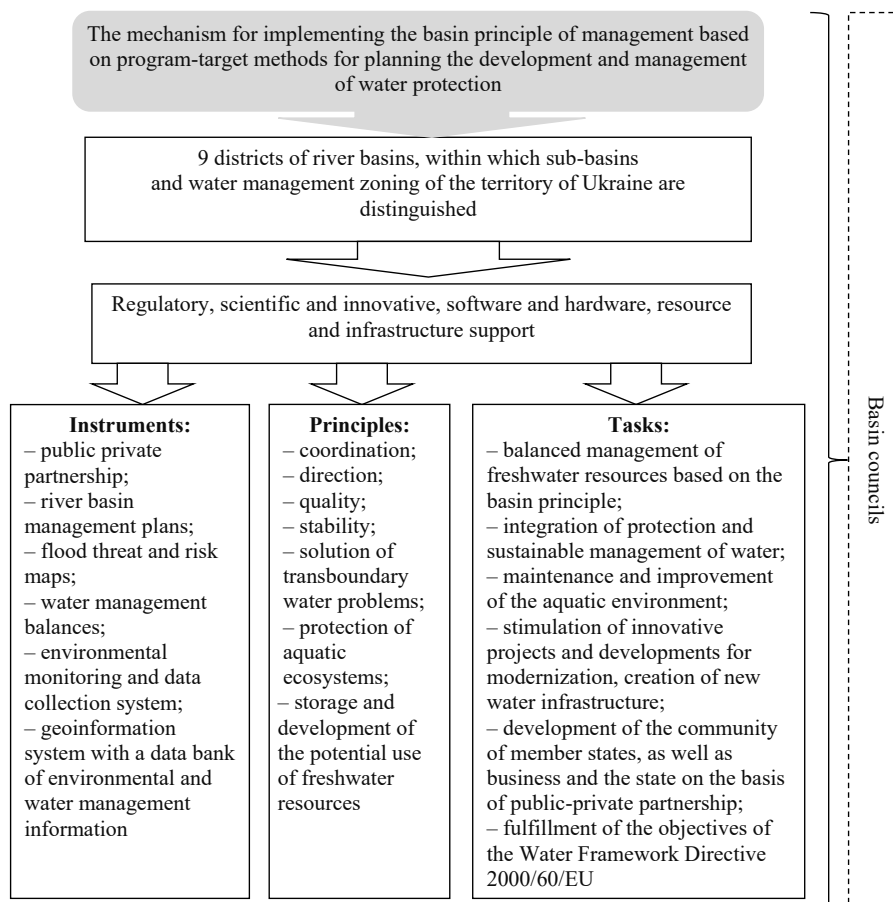


Fig. 8. Mechanism for the implementation of the integrated basin principle of freshwater management based on the Water Framework Directive 2000/60/EU



The performance of the resource saving function requires additional innovative solutions and the introduction of technologies. It is in such conditions that today there is a need to search for additional sources of financing for scientific and technical developments, projects, and innovative solutions. International financial programs can become the main funding for scientific and technical developments, innovative projects in the environmental sector.

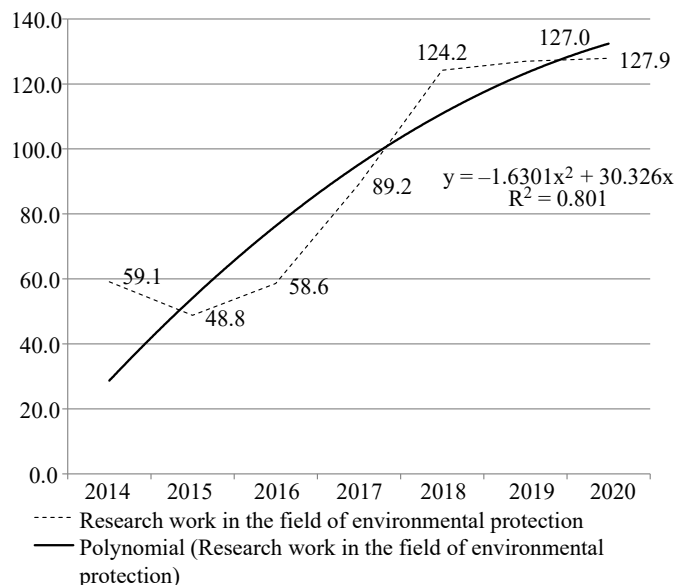
According to the State Statistics Service of Ukraine, the costs of protection and rational use of freshwater resources have been increasing over the years. In 2020, the total amount of environmental protection expenditures by type of environmental protection measures amounted to 41.3 billion UAH. It should be noted that in 2014 the amount of expenditures on environmental protection by types of environmental protection measures amounted to 21.9 billion UAH, which is 1.88 times more [28].

The general structure of expenditures for the protection and rational use of freshwater resources is divided into expenditures for the protection and rehabilitation of soil, groundwater and surface water, treatment of return water and environmental research. The largest share in the structure of expenses in 2020 is occupied by current expenses – 75.02 %, while capital investments – 24.97 %. During the period under study, the structure of expenditures for the protection and rational use of freshwater resources has not changed.

In 2020, the structure of capital investments amounted to 61.83 % for the protection and rehabilitation of soil, groundwater and surface water, 12.80 % for the treatment of return water and 7.67 % for environmental research and development. Thus, the largest amount of capital investments was directed to the protection and rehabilitation of soil, underground and surface waters – 2554224.50 thousand UAH and for the treatment of return water – 1578201.4 thousand UAH.

There is a positive pattern of changes in the dynamics of costs for research work in the field of environmental protection (Fig. 9), which is modeled using second-

order polynomials with an approximation confidence level of  $R^2=0.86$ . Due to the fluctuation of the polynomial, it is possible to foresee an increase in the volume of expenditures for environmental research in Ukraine in the near future.

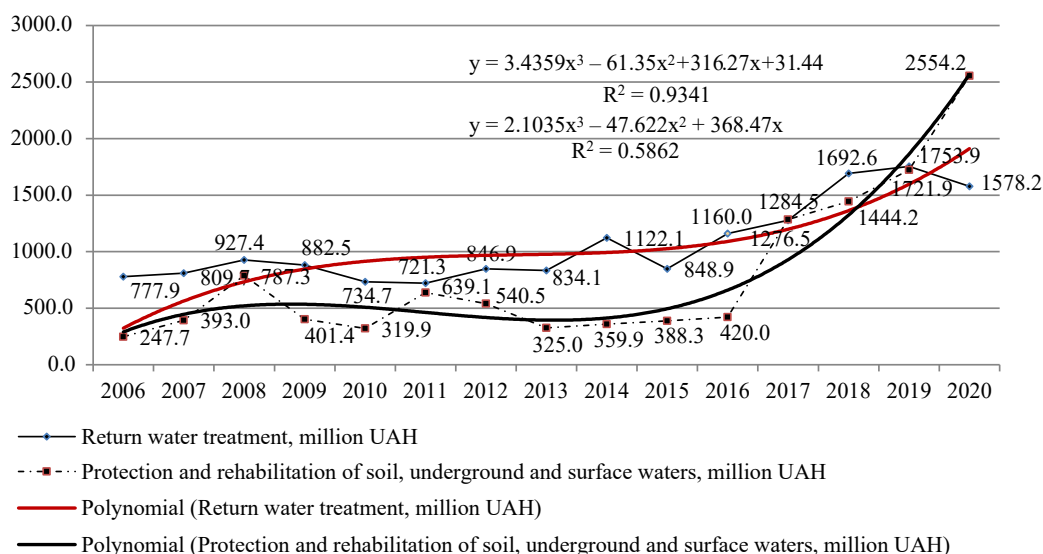


**Fig. 9.** Dynamics of expenditures on environmental research and development for 2014–2020, million UAH [28, 29]

Dynamics of capital investments for treatment of return waters and protection and rehabilitation of ground and surface waters for 2006–2020 shown in Fig. 10.

The polynomial trend of the regularity of changes in the volume of capital investments in the protection and rehabilitation of ground and surface waters with an approximation confidence level of 93.41 % determines by the end of 2020 the estimated value of capital investments at the level of 2554.2 thousand UAH.

This is possible while maintaining the influence of all previously existing factors, balanced in the above dynamic model.



**Fig. 10.** Dynamics of capital investments for treatment of return waters and protection and rehabilitation of ground and surface waters for 2006–2020 [29]

So, in 2020, the cost structure for wastewater treatment was:

- 53 % – purification of return water from pollutants;
- 37 % – sewerage system;
- 9 % – prevention of pollution by making changes to the production process;
- 1 % – elimination of the thermal impact of return waters on water bodies. In the water sector, technologies are used for desalination of salt water and for the treatment of water and wastewater.

Among desalination technologies, sea, brackish and river water reverse osmosis (RO) technology is the leader with a global market share of over 58 % and an expected CAGR of 9.2 % over 2017–2025 thanks to increased efficiency and the ability to consume less energy.

The leading demand regions for desalination technologies are the Middle East and Africa and the Asia-Pacific region with a share of more than 40 % of global demand, and among the countries are Saudi Arabia, the USA and the UAE. The key growth countries in the coming years are Spain, China, Australia, India and South America.

Technological processes of water treatment are divided into primary, secondary and tertiary treatment. In 2018, the tertiary segment was the leader

with a global market share of 43.2 %. The key tertiary treatment technologies are nanofiltration, reverse osmosis, membrane bioreactors, microfiltration and disinfection.

«In 2018, the market leader was the segment of membrane separation equipment with a volume of 6.16 billion UAH. The US is projected to grow due to increased awareness of the importance of nanofiltration and reverse osmosis for wastewater treatment applications. The overwhelming market share (72.8 %) was held by the industrial waste sector and it is expected that by 2025 it will reach 28.13 billion USD. The municipal waste sector will also grow due to strong demand in developing countries, in particular Brazil, China, India, Turkey and Saudi Arabia» [15, 30].

The largest volumes of expenditures on environmental protection in 2020 are observed in the Dnipropetrovsk, Donetsk, Zaporizhzhia and Kharkiv regions, Kyiv. The lowest volumes of expenditures on environmental protection: Ternopil, Kherson and Zhytomyr regions.

The dynamics of capital investments in environmental protection by regions has a positive trend. So, in general, the volume of capital investments increased by 10,478.1 million UAH or 479.44 %. The highest growth rates are observed in the following regions: Khmelnytskyi, Mykolaiv, Chernivtsi, Volyn, Kharkiv. The ranking of regions by the level of capital investment in environmental protection in 2020 is shown in Fig. 11 [28, 30].

The top 5 regions in terms of capital investment in environmental protection in 2020 are occupied by:

- first place – Dnipropetrovsk region;
- second place – Donetsk region;
- third place – Kyiv;
- fourth place – Zaporizhzhia region;
- fifth place – Kharkiv region.

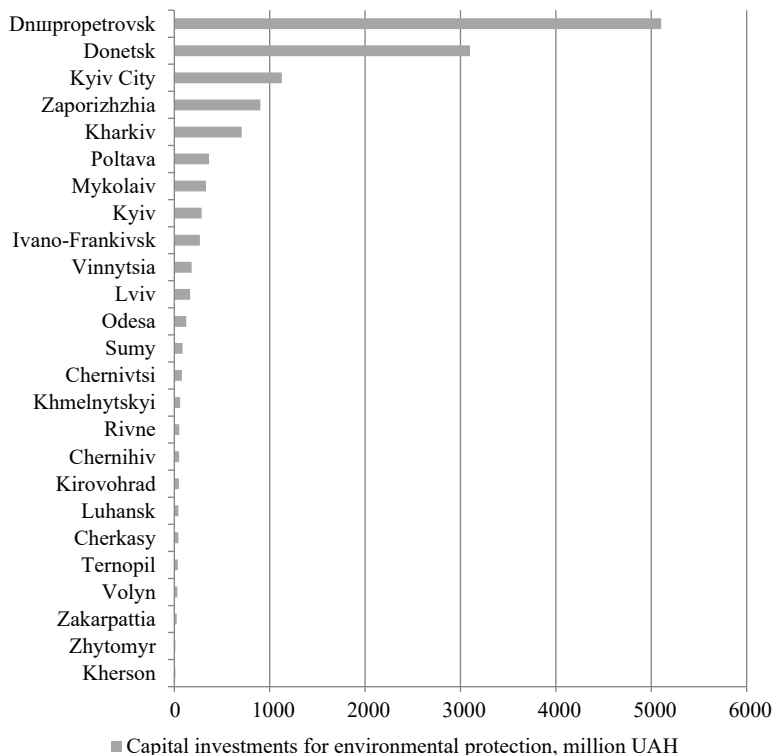


Fig. 11. Rating of regions by the level of capital investments in environmental protection in 2020, million UAH [28, 30]

The lowest expenses are in Kherson, Zhytomyr and Zakarpattia regions.

The author of the work [31] noted that «An analysis of the processes of sustainable development in Ukraine shows that in a significant part the problems of transition to sustainable development turn out to be, first of all, problems of managing socio-economic processes. This management, unlike the current one, should be proactive and based on carefully thought-out long-term programs. A proactive direction should also have a legislative and legal framework, which should be formed both at the national and global levels. According to the concept of sustainable development, the process of civilization development should become more and more manageable, that is, a pre-designed process of interaction between society and the environment».

## 7. SWOT analysis of research results

*Strengths.* The strength of the study is the universality of the proposed methodological approach used for different areas of the economy and management of natural resources. This methodological approach is a fairly flexible tool with a free choice of analysis elements depending on the goals and economic objects.

*Weaknesses.* The weak side of the study is the need to collect data, which today are different objects of nature management in extremely limited volumes, as well as presenting data only in general terms. The development of specific measures to achieve the set goals requires additional research.

*Opportunities.* Opportunities for further research – study of foreign experience to improve the analysis of existing methodological approaches to the assessment of water resources in the implementation of various types of economic activities.

*Threats.* Threats to the results of further research are the need for continuous improvement of methods of economic analysis, taking into account a complex of external factors of influence.

## 8. Conclusions

1. A cluster model of a regional innovation and information portal of freshwater resources is proposed, which allows to combine the efforts of public authorities, the population, the public, scientific institutions and businesses in solving problematic issues related to the ecosystem based on smart technologies in the context of sustainable development. It is determined that for the functioning of the cluster model it is necessary to develop institutional, legislative, regulatory, scientific and innovative, investment support. It is substantiated that the functioning of the cluster model of the regional innovation-information portal of freshwater resources will solve the following problems:

- creation of a unified data bank for monitoring the quality of water resources, the results of scientific and technical activities, business planning and design for the conservation, restoration and purification of water;
- information services in the field of innovation;
- attraction of business representatives to co-financing of innovative projects.

2. The mechanism for the implementation of the integrated basin principle of freshwater resources management based on the Water Framework Directive 2000/60/EU is substantiated, taking into account the main instruments, principles and tasks for the implementation of European legal and environmental standards. It is substantiated that the main tasks of the mechanism for implementing the integrated basin principle of freshwater management are:

- balanced management of freshwater resources based on the basin principle;
- integration of protection and sustainable management of water;
- maintenance and improvement of the aquatic environment;
- stimulation of innovative projects and developments for modernization;
- creation of new water infrastructure;
- development of the community of member states, as well as business and the state on the basis of public-private partnership;
- fulfillment of the objectives of the Water Framework Directive 2000/60/EU.

3. The proposed management system for sustainable water use of a territorial-economic unit, which takes into account the integration mechanism of management of the basin principle and includes the main components (socio-economic, budgetary, tax, organizational, institutional, investment and innovative).

The conceptual scheme of an innovative model of regional management of freshwater resources in the context of achieving environmental goals is substantiated, in which four main cycles are identified. It is proved that the first cycle associated with the settlement of the improvement of the state of water, grouped and forming an aggregated complex of production factors. The second cycle consists of flood protection measures grouped into an appropriate aggregated set of indicators and factors. The third cycle with two variations is focused on the regulation of the

integrated management system, which provides a synergistic effect from the interaction of the resource saving functions and the natural resource function of the sustainable agricultural production model. The fourth cycle is connected with the formation and regulation of a modern monitoring system.

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