EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2023, 24(4), 229–235
https://doi.org/10.12912/27197050/162910
ISSN 2719-7050, License CC-BY 4.0

Received: 2023.02.25
Accepted: 2023.03.30
Published: 2023.04.10

Management of the Environmental Potential of Freshwater Resources in the Conditions of Sustainable Development

Inna Irtyshcheva[1], Nazariy Popadynets[2], Yosyf Sytnyk[3], Uliana Andrusiv[4*], Yosyf Khromyak[2], Iryna Kramarenko[1], Yevheniia Boiko[1], Vasyl Sakharnatskyi[5]

[1] Admiral Makarov National University of Shipbuilding, Heroyiv Ukrayiny Ave., 9, 54000, Mykolayiv, Ukraine

[2] Scientific-Educational Institute of Entrepreneurship and Perspective Technologies of Lviv Polytechnic National University, Horbachevskoho Str. 18, 79044, Lviv, Ukraine

[3] Department of Human Resource Management and Administration, Lviv Politechnic National University, Lviv, Ukraine

[4] Department of Theory of Economics and Management, Ivano-Frankivsk National Technical University oil and gas, Ivano-Frankivsk

[5] Graduate student of Institute of Agroecology and Environment management of NAAS, Kyiv, Ukraine

* Corresponding author's e-mail: andrusivu@ukr.net

ABSTRACT

The article aims to substantiate the methodological approaches to assessing the effectiveness of environmental management of freshwater resources in the implementation of the Sustainable Development Goals. Methodological approaches to assess the effectiveness of environmental management of the regions' freshwater resources are suggested. The ecological and economic model designated to reveal the best options for the development of the water basin is offered. Methodological approaches are formed from the following stages of assessing the efficiency of the environmental potential of freshwater resources: the formation of indicators and indices of the environmental potential of freshwater resources; calculation of efficiency indices of the environmental potential management of freshwater resources of Ukraine and the Black Sea region; calculation of the average value of indices and standardized indicators; calculation of the integrated indicator of the environmental potential of freshwater resources, weighting standardized indicators; implementation of the ecological and economic model for the development of the water basin. The offered approaches help assessing the management of freshwater resources of a particular region and Ukraine as a whole. The model suggested in the article will specify the most negative impact factors while complying with the basin management principle in terms of sustainable development.

Keywords: environmental potential, freshwater resources, sustainable development, management

INTRODUCTION

Today, in the conditions of significant reduction of water resources, there is an urgent need to study the effectiveness of environmental management. Structural shifts of territories negatively affect the formation of the ecological potential of territories. Inefficient public management of territories leads to a deterioration in the use of environmental potential. The poor application of resource-saving technology by economic entities leads to the deterioration of environmental safety. The lack of methodological approaches to assessing the effectiveness of environmental management of territories makes it impossible to determine the criteria that have an impact on it. Appropriate methodological approaches will allow researching the greatest impact of criteria on the effectiveness of territories' environmental management, which will enable the formation of development strategies and programs. The substantiation of approaches to assessing the effectiveness

of environmental management is very important in the context of sustainable development.

It is determined that "the water potential of any region is the natural basis of its economic development and socio-ecological well-being. At the same time, the current degree of development and economic load on water resources for most of Ukraine has already reached levels exceeding their ability to self-recovery in most cases" (Serbov et al., 2021).

The team of authors developed scientific recommendations for assessing the anthropogenic impact of marine use on the ecological state of the environment, taking into account the socio-economic consequences of Ukraine's development trends in accordance with the Marine Strategy Framework Directive 2008/56/EU and Water Framework Directive 2008/105/EU (Research Report, 2021). Scientist (Matsievich, 2016) explored ways to optimize the financial support of environmental programs and measures formulated on the example of the use of water resources in the Black Sea region. Scientists (Molchak et al., 2021) carried out an ecological and economic analysis of the current state of water supply of the region, took into

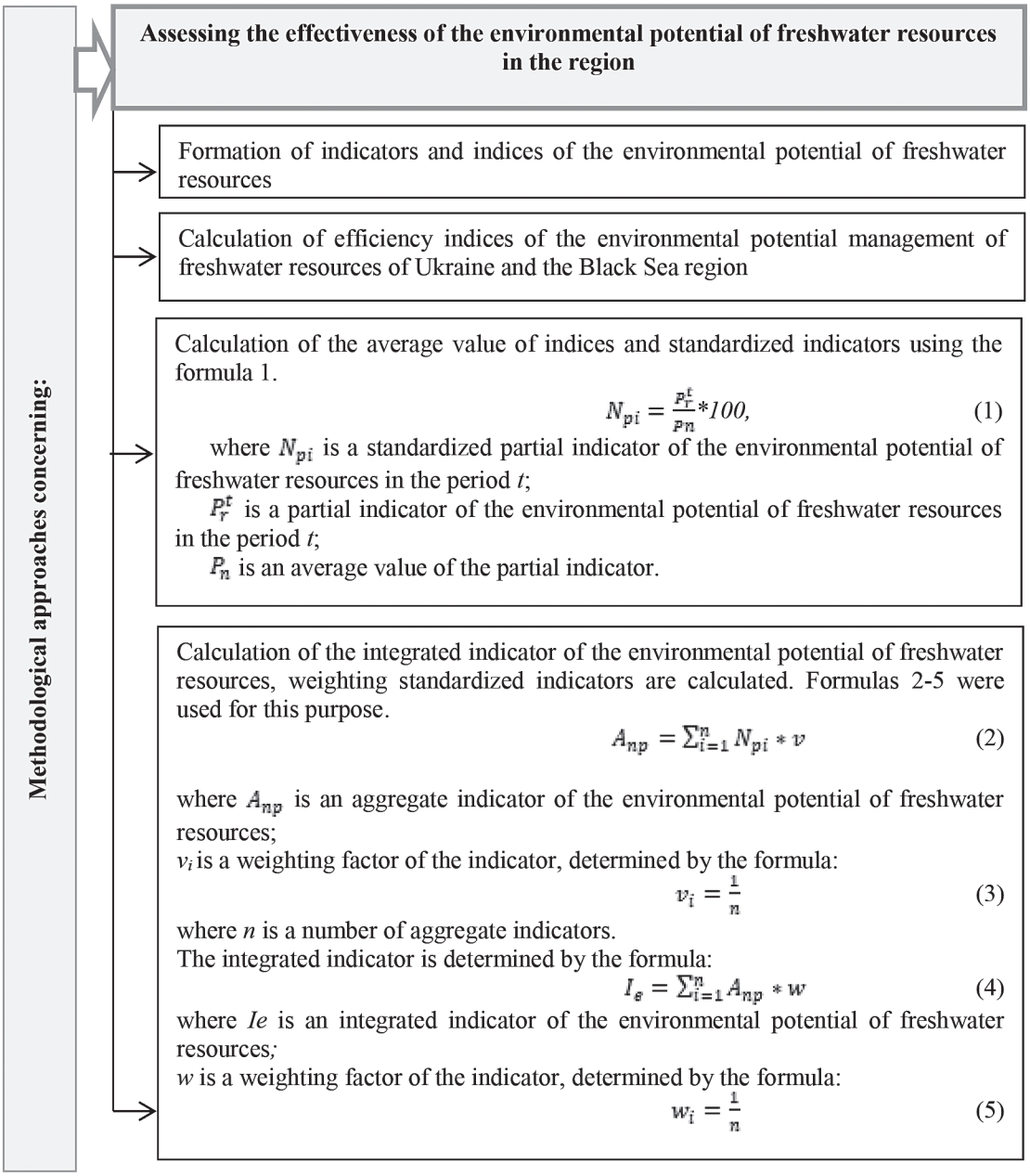

Figure 1. Methodological approaches to assessing the effectiveness of the environmental potential management of freshwater resources

account the water factor in forecasts of economic development of the region, suggested ways of ecological and economic problems of water supply. (Bomba, 2012) considered the environmental issues of the condition of water resources, as well as ways of their management in the context of addressing the freshwater safety problems in Ukraine.

Researchers (Andrusiv et al., 2021 and Boiko et al., 2022) substantiated the essence and features of global environmental priorities of society, environmental policy, adaptation of decisions in view of ratified commitments in partnership, identifying opportunities to use a systematic approach. **(**Levkovska, et al., 2019) developed the theoretical and methodological grounds for the formation of a sustainable water supply system against the background of environmental constraints.

Scientists (Malyuta et al., 2014; Danylyshyn et al, 2021; Yakymchuk et al., 2022 and Horoshkova et al., 2020) determined the ecological imperative of ensuring economic security in terms of sustainable development of society. (Dmytrenko et al., 2016; Zelinska et al., 2020 and Was et al., 2020) studied the current state of the problem of environmental degradation of Ukraine's small rivers and the establishment of the main sources of their anthropogenic pollution.

However, this issue being a key to sustainable development has not received enough attention from scientists and practitioners. Therefore, the purpose of the article is to explain the approaches to assessing the effectiveness of environmental management of freshwater resources in compliance with the Sustainable Development Goals.

MATERIALS AND METHODS

We propose to develop methodological approaches to assessing the effectiveness of environmental management of freshwater resources. Methodological approaches are formed from two stages (Figure 1):

- assessment of the effectiveness of the environmental potential of freshwater resources of the region and Ukraine as a whole,
- formation of indicators and indices of the environmental potential of freshwater resources,
- calculation of indices of efficiency of the environmental potential management of freshwater resources of Ukraine and the Black Sea region,
- calculation of the average value of indices and standardized indicators,
- calculation of the integrated indicator of the environmental potential of freshwater resources, weighting standardized indicators.

For that purpose, we distinguish the following components: bioproductivity, energy, water transformation, and innovation. In order to assess the environmental potential of freshwater resources, we use the set of indicators given in Table 1 and formula 6 to determine the integrated indicator of the environmental potential of freshwater resources:

$$П = f\,(x1, x2, \ldots, xn), \tag{6}$$

where $П$ is a general assessment of the environmental potential of freshwater resources implementation,
$x1$, $x2$, …, xn are integrated indicators of bioproductivity, energy resources, water transformation, and innovation components of the environmental of freshwater resources of the region.

Indicators and indices of the environmental potential of freshwater resources are given in Table 1. To test the proposed methodological approaches, the environmental potential of Ukraine's freshwater resources management was selected, in particular for assessment at the level of the Black Sea region.

RESULTS AND DISCUSSION

According to Odesa Region Council, Odesa region is located in the extreme southwest of the country and covers an area of 33,400 km^2. It is the coastal and border region of Ukraine. The region has 1134 small rivers and streams and 15 freshwater and seawater estuaries. It is located within the Danube (24% of the region area), Dnister (16%), and Southern Buh (8%) river basins and other of the Black Sea area (52%) (Odesa Regional Council, 2021).

Mykolayiv region is in the south of Ukraine within the Southern Buh (59.5%) and Dnipro (23.5%) river basins and other of the Black Sea area (17%). Overall, 7.3% of the region's area is covered by water bodies, including 19,800 ha by rivers and streams, 5600 ha by channels, collectors, and ditches, 90,100 ha by lakes, landlocked ponds, and estuaries, 17,800 ha by

Table 1. Indicators and indices of the environmental potential of freshwater resources

Index	Indicators	Indication of the indicator
Bioproductivity (B)	Use of fresh water per capita by region, m^3	b_1
	Water intake per capita, m^3	b_2
	Volume of gross (regional) domestic product at constant prices in 2016 per unit of water consumption, UAH / m^3	b_3
Energy efficiency (E)	Specific weight of discharged polluted waters in % before their collection	e_1
	Capacity of treatment facilities, million m^3 per 1 m^3 of collected surface water	e_2
	Savings in water intake due to circulating and re-sequential water supply by region per capita, million m^3	e_3
Water transformation (V)	Discharge of return waters into surface water bodies per capita of the region, million m^3	v_1
	Share of discharged polluted return waters into surface water by regions per capita, %	v_2
	Share of discharged normatively clean without treatment return water in surface water bodies by regions per capita of the region, million m^3	v_3
Innovation (I)	Capital investments in environmental protection by types of environmental protection measures per capita, UAH	i_1
	Current expenditures on environmental protection by environmental protection measures per capita, UAH	i_2
	Share of environmental protection expenditures in gross regional product per capita, UAH	i_3

reservoirs, ponds, and other man-made water bodies, 21,100 ha by swamps, and 5600 ha by hydraulic and other water facilities (Regional office of water resources in the Mykolayiv region, 2021).

Unlike Mykolayiv region, Kherson region is located in the dry steppe zone at the watershed of the lower Dnipro river and the Black Sea. It is washed by the Black and Azov Seas and Syvash (Rotten Sea). It is worth mentioning that water bodies in Herson region cover 430,500 ha but 15-20 times less water accounts per resident than in other Ukrainian regions. 26 rivers cross the territory of the region, there are 693 lakes of a total area of 170,220 ha and 1154 ponds of 12,300 ha. Man-made reservoirs cover 64,280 ha (Kherson Regional Department of Water Resources, 2021). Therefore, the rivers in the south steppe part are used for small-scale irrigation of agricultural lands and water supply. That is why the decreased water level, shallowing, and contamination of small rivers can be observed in summer.

The results of the assessment allowed us to trace several trends in Ukrainian regions and the country as a whole in the period 2015–2019 (Table 2):

- the annual increase in the use of freshwater per capita;
- the volume of national (regional) domestic product at constant prices in 2016 per unit of water consumption;
- increase in capital investment and current expenditures on environmental protection by types of environmental measures per capita;
- reduction of the share of discharged polluted return waters into surface water bodies in total;
- reduction of the share of environmental protection expenditures in the GDP per capita.

Indices of efficiency of the environmental potential management of freshwater resources of Ukraine and the Black Sea region for the period of 2015–2019 differ on different criteria. Thus, according to the criteria of bioproductivity and energy resources, the highest value is observed in the Kherson region, innovation in the Mykolayiv region (Zelinska et al., 2021 and Kupalova et al., 2021). It should be noted that according to the criterion of water transformation, the indicators for the Black Sea region are lower than for Ukraine. Exceeding the average values of the indices of the components of the environmental potential of freshwater resources of Ukraine and the Black Sea region for the period 2013–2019 is observed:

- for the criterion of bioproductivity – the Kherson region;
- for the criterion of energy resources – the Kherson region;
- for the criterion of water transformation – the Kherson region;
- for the criterion of innovation – the Mykolayiv region.

Table 2 Indicators of efficiency of the environmental potential implementation of freshwater resources of Ukraine and the Black Sea region for the period of 2015–2019

Criteria	Indicators	In Ukraine as a whole		Odesa region		Mykolayiv region		Kherson region	
		2015	2019	2015	2019	2015	2019	2015	2019
Bioproductivity (B)	Use of freshwater per capita by region, m^3	166.6	172.7	106.3	130.4	148.5	202.7	976.9	926.4
	Share of discharged polluted water in % before their collection	8.8	6.6	5.8	4.2	9.0	8.6	0.0	0.1
	Volume of gross (regional) domestic product at constant prices in 2016 per unit of water consumption, UAH / m^3	279.1	549.5	392.6	635.9	280.2	407.2	31.1	65.1
Energy efficiency (E)	Volume of water intake per person, m^3	231.5	260.2	330.4	379.6	211.8	211.8	1437.3	2406.0
	Capacity of treatment facilities, million m^3 per 1 m^3 of collected surface water	0.5	0.5	0.4	0.3	0.5	0.2	0.06	0.05
	Savings in water intake due to circulating and re-sequential water supply by region per capita, million m^3	961.9	797.9	5.21	31.3	2855.5	3042.2	19.8	17.6
Water transformation (V)	Discharge of return waters into surface water bodies per capita of the region, million m^3	125.1	128.2	76.5	64.9	64.3	65.6	65.1	84.3
	Share of discharged polluted return waters into surface water bodies by regions per capita, %	15.9	13.7	25.0	23.7	28.4	26.6	0.0	1.1
	Share of discharge of normatively treated return waters into surface water bodies in the total volume, %	12.9	22.1	10.8	49.4	28.4	2.7	0.0	24.1
Innovation (I)	Capital investments in environmental protection by types of environmental protection measures per capita, UAH	179.8	387.9	11.1	28.4	113.2	111.9	7.5	7.3
	Current expenditures on environmental protection by environmental protection measures per capita, UAH	396.1	655.9	116.9	166.7	1306.5	831.4	67.6	98.7
	Share of environmental protection expenditures in gross regional product per capita, UAH	1.24	1.10	0.31	0.24	3.42	1.15	0.25	0.18

Table 3. Weighting standardized indicators of the components of the environmental potential of freshwater resources of Ukraine and the Black Sea region for the period 2013–2019

Criteria	Indicators	In Ukraine as a whole		Odesa region		Mykolayiv region		Kherson region	
		2015	2019	2015	2019	2015	2019	2015	2019
Bioproductivity (B)	b_1	15.54	16.11	9.91	12.16	13.85	18.91	91.12	86.41
	b_2	53.90	40.43	35.53	1.39	55.13	52.68	0.00	0.61
	b_3	27.90	54.94	39.25	63.57	28.01	40.71	3.11	6.51
Energy efficiency (E)	e_1	11.18	12.56	15.95	18.33	10.22	10.22	69.39	116.15
	e_2	52.59	52.59	42.07	31.55	52.59	21.04	6.31	5.26
	e_3	32.85	27.25	0.18	1.07	97.51	103.88	0.68	0.60
Water transformation (V)	v_1	49.00	50.21	29.96	25.42	25.19	25.69	25.50	33.02
	v_2	31.23	26.91	49.11	46.55	55.79	52.25	0.00	2.16
	v_3	22.64	38.79	18.96	86.71	49.85	4.74	0.00	42.30
Innovation (I)	i_1	56.03	120.89	3.46	8.85	35.28	34.87	2.34	2.28
	i_2	28.73	47.57	8.48	12.09	94.76	60.30	4.90	7.16
	i_3	41.49	36.81	10.37	8.03	114.43	38.48	8.37	6.02

Table 4. Calculation of the integrated index of the environmental potential management of freshwater resources of Ukraine and the Black Sea region

Parameter	In Ukraine as a whole		Odesa region		Mykolayiv region		Kherson region	
	2015	2019	2015	2019	2015	2019	2015	2019
Bioproductivity (B)	32.12	36.79	27.95	25.45	32.01	37.06	31.09	30.86
Energy efficiency (E)	31.88	38.25	19.21	16.81	52.91	44.60	25.20	40.26
Water transformation (V)	33.95	38.25	32.35	52.37	43.17	27.29	8.41	25.57
Innovation (I)	41.66	67.74	7.36	9.56	80.68	44.11	5.15	5.10
Calculation	$I = \sum B * 0.25 + E * 0.25 + V * 0.25 + I * 0.25$							
Integrated index of use of the environmental potential of Ukraine's freshwater resources	20.67	15.02	14.83	17.21	21.34	25.69	20.67	15.02

Weighting standardized indicators were calculated to measure the integrated indicator of the environmental potential of freshwater resources. Formulas 3–6 were used for this purpose. Determination of weighting coefficients was carried out according to formulas 4–6. Given the equal number of indicators, the weighting coefficient of individual indicators is set at v_1=0,33, and weighting coefficients according to the main evaluation criteria at w = 0.25. The results of calculations at 2 levels of aggregation are in Table 3.

In addition to inefficient management (Vasyutynska et al, 2020; and Simkiv et al, 2021) note that "the most threatening situation of water scarcity has been identified for Kherson, Odesa, Mykolayiv, Kirovohrad regions, which can be explained by the synergistic impact of negative climate factors of steppe and forest-steppe zones, low water supply in the southern regions, high water consumption and agriculture".

Based on the data from Tables 1–3, the integrated indices of potential components and the general integrated index of the environmental potential management of freshwater resources are calculated (Table 4).

CONCLUSIONS

The evaluation of efficiency of the environmental potential management of freshwater resources in a cut of its components reveals that the integrated indicator of the environmental potential management of the Mykolayiv region is the highest. This trend is explained by the greatest importance of the innovation criterion. Increase in expenses for nature protection activity in the Mykolayiv region allowed for modernization of a water supply infrastructure, and also effective management of fresh-water resources through the implementation of a number of actions for restoration of fresh-water resources. All these directions allowed the Mykolayiv region to take first place among regions of the Black Sea region and Ukraine as a whole on an integral indicator of the environmental potential of freshwater resources management efficiency. The integrated indicator of the index of the environmental potential of freshwater resources of Ukraine shows a consistent growth of this indicator, which proves positive trends in the modernization of the network of freshwater infrastructure.

It is proved that at the regional level for the conservation and restoration of freshwater resources it is necessary to develop an effective policy for managing the existing environmental potential; to develop a concept for overcoming water scarcity; to reduce the ecological and economic risk of impact on the ecosystem of territories; to promote the development of regional environmental management; to ensure fruitful cooperation between public authorities, business, and society for creating a business model of freshwater resource management.

REFERENCES

1. Andrusiv, U., Zelinska, H., Galtsova, O., Kupalova, H., & Goncharenk, N. 2021. The modeling and forecasting of fuel and energy resources usage in the context of the energy independence of Ukraine. Polityka Energetyczna, 24(1), 29-47. doi:10.33223/epj/132892
2. Assessment of trends in the economic and social spheres of the coastal regions of Ukraine taking into account environmental criteria: Research Re-

port. 2021. Available http://www.sea.gov.ua/img/reports/2017/Theme_12.pdf

3. Boiko Y, Irtyshcheva I, Kramarenko I, Voit D and Popadynets N. 2022. Efficiency of decentralization as an important instrument of Ukraine's Socio-Economic Developmente. International Journal of Industrial Engineering & Production Research 33(1), 1-14.
4. Bomba M Ya. 2012. Ecological state of water resources and ways to solve freshwater safety. Scientific Bulletin 2 12-22
5. Danylyshyn B, Olshanska O, Zabaldina Y, Mazurets R, Khlopiak S and Pivnova L. 2021. Designing a marketing strategy for the development of industrial tourism in the region. Journal of Optimization in Industrial Engineering 14(Special Issue - Serial Number 29) 1-8, 10.22094/joie.2020.677809
6. Dmytrenko T V and Vergeles Yu I. 2016. Analysis of the current state of the problem of ecological degradation of small rivers of Ukraine. Municipal Utilities 132, 93-97.
7. Horoshkova L, Khlobystov I and Danylyshyn B. 2020. Multifactor mathematical modelling of ecological and economic systems (the example of coal mining development) Geoinformatics 2020 - XIXth International Conference "Geoinformatics: Theoretical and Applied Aspects" 17403.
8. Kherson Regional Department of Water Resources. 2021. Available http://vodgosp.kherson.ua/rivers.php
9. Kupalova, H., Goncharenko, N., Andrusiv, U. 2021. Environmental management of agricultural enterprises in the context of european environmentally-friendly food system. Journal of Environmental Management and Tourism, (Volume XII, Summer), 3(51), 718-728. DOI:10.14505/jemt.v12.3(51).11.
10. Levkovska L, Mandzyk V and Mytrofanova O. 2019. Theoretical principles of sustainable water supply system formation in the conditions of ecological constraints Time challenges. Available http://ecops.kiev.ua/files/2020(7)/7-Levkovska.pdf
11. Malyuta L, Melnyk L and Pohaidak O. 2014. Ecological imperative of ensuring economic security in the context of sustainable development of society Galician Economic Bulletin 44, 21-29.
12. Matsievich T O 2016 Methodological bases for determining tax and environmental fees from water users of the Black Sea region. Black Sea Economic Studies 5, 141-145.
13. Molchak Ya, Myskovets I and Horbach L. 2021. Prospects for the formation of an effective ecological and economic system of water use. Journal of socio-economic geography 30, 95-102.
14. Odesa Regional Council. 2021. Available http://oblrada.odessa.gov.ua/pro-oblasnu-radu/napryamky-diyalnosti/pryrodokorystuvannya/informatsiya-viddilu-z-pytan-pryrodokorystuvannya-aparatu-odeskoyi-oblasnoyi-rady/
15. Regional office of water resources in the Mykolayiv region. 2021. Available https://mk-vodres.davr.gov.ua/water_resources
16. Serbov M.H. and Osypenko D.S. 2020. Assessment of ecological risks of water pollution in the Ukrainian part of the Danube and Danube lakes (estuaries). Modern Scientific Researches 10, 114–130.
17. Simkiv, L., Shults, S., Lutskiv, O., & Andrusiv, U. 2021. Analysis of the dynamics of structural processes in the context of ensuring sustainable development. European Journal of Sustainable Development, 10(1), 153-167, doi:10.14207/ejsd.2021.v10n1p153
18. Vasyutynska K A, Barbashev S V and Kiminchidzhi M I. 2020. The danger of creating a deficit of water resources in the regions of Ukraine in terms of urbanization. Scientific and Practical Journal: Environmental Sciences 4(31), 42-48.
19. Was A, Sulewski P, Krupin V, Popadynets N, Malak-Rawlikowska A, Szymanska M, Skorokhod I and Wysoki´nski M. 2020. The potential of agricultural biogas production in Ukraine—Impact on GHG Emissions and Energy Production Energies 13, 5755, 1-20, doi:10.3390/en13215755
20. Yakymchuk A, Kardash O, Popadynets N, Yakubiv V, Maksymiv Yu, Hryhoruk I and Kotsko T. 2022. Modeling and governance of the country's energy security: The example of Ukraine. International Journal of Energy Economics and Policy 12(5), 280–286 https://doi.org/10.32479/ijeep.13397
21. Zelinska, H., Andrusiv, U., Daliak, N., Dovgal, O., & Lagodiienko, V. 2021. Sustainable development: Trends in Ukraine and the World. Journal of Environmental Management and Tourism, 12(5), 1179-1187. doi:10.14505//jemt.v12.5(53).03
22. Zelinska, H., Fedorovych, I., Andrusiv, U., Chernova, O., & Kupalova, H. 2020. Modeling and prediction of the gas pipelines reliability indicators in the context of energy security of Ukraine. Paper presented at the CEUR Workshop Proceedings, 2713, 415-433.