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ENVIRONMENTAL MONITORING OF EUTROPHICATION PROCESS IN WATER BODIES ACROSS UKRAINE

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The article is devoted to the study of the development of processes of eutrophication of environmental components and its consequences in the form of «blooming», which can lead to the degradation of natural biocenoses, populations and even ecosystems, and in the future poses a threat to human health. To assess the degree of ecological and social (medical) danger of the development of processes of eutrophication of surface water bodies, soils and polluted atmospheric air (bioaerosols) by cyanobacteria and their products of vital activity and to prevent the negative impact of a high level of eutrophication on various types of water use (drinking water supply, recreation, energy , agriculture, etc.), proposals for improving special ecological monitoring in regions with a high level of eutrophication of aquatic ecosystems are offered. It is proposed to organize special complex observations of water bodies during the growing season, which will include data from ground observations and data from remote sensing of the Earth. On the basis of the obtained data, it is proposed to calculate 2 indicators, namely, an integrated assessment of the impact of wastewater on aquatic ecosystems, which helps determine long-term implementation measures, and an indicator that determines the concentration of chlorophyll in the reservoir water above discharges downstream and is used in the process of making operational decisions. When determining the appropriate categories of the quality of water bodies according to the level of their eutrophication, authorities at different levels can rely on the developed operational-preventive recommendations for ecological, social and technical solutions and organize the implementation of these recommendations in the relevant settlements, which will ensure timely protection of the population and reduce the negative impact of eutrophication of water bodies. *Key words:* eutrophication, environmental components, special observations, water quality, remote sensing of the Earth.

Екологічний моніторинг процесу евтрофікації водойм України. Дмитрієва О.О., Цапко Н.С., Колдоба І.В., Лисов Б.В., Телюра Н.О.

Розгляну та систематизовано питання розвитку процесів евтрофікації компонентів навколишнього природного середовища та наслідків даного процесу у вигляді «цвітіння», яке може призвести до деградації природних біоценозів, популяцій і навіть екосистем, а в майбутньому становить загрозу здоров'ю людини, умовам його життєдіяльності. Оцінити ступінь екологічної та соціальної (медичної) небезпеки розвитку процесів евтрофікації поверхневих водойм, ґрунтів і забрудненого атмосферного повітря (біоаерозолі) ціанобактеріями та продуктами їх життєдіяльності та запобігти негативному впливу високого рівня евтрофікації на різні види водокористування (питне водопостачання, рекреація, енергетика, сільське господарство тощо). Авторами запропоновані пропозиції щодо вдосконалення спеціального екологічного моніторингу в регіонах з високим рівнем евтрофікації водних екосистем. Пропонується протягом вегетаційного періоду організувати спеціальні комплексні спостереження за водоймами, які включатимуть дані наземних спостережень та дані дистанційного зондування Землі. На основі отриманих даних обґрунтовано доцільність розрахунку двох показники, а саме інтегральної оцінки впливу стічних вод на водні екосистеми, яка допомагає визначити довгострокові заходи впровадження, та показник, що визначає концентрацію хлорофілу, дані показники особливо є актуальним і використовується в процесі прийняття управлінсько-експлуатаційних рішень. При визначенні відповідних категорій якості водних об'єктів за рівнем їх евтрофікації органи влади різних рівнів можуть спиратися на розроблені оперативно-профілактичні рекомендації щодо екологічних, соціальних і технічних рішень та організовувати виконання цих рекомендацій у відповідних населених пунктах, що забезпечить своєчасний захист населення та зменшить негативний вплив евтрофікації водойм як джерел питаного водопостачання та рекреаційного використання. *Ключові слова:* евтрофікація, компоненти навколишнього середовища, спеціальні спостереження, якість водойм, дистанційне зондування Землі.

Analysis of the existing problem. The deterioration of the environment as a result of intensive eutrophication is one of the most challenging environmental and social issues on a global scale. The elevated rate of eutrophication is a factor contributing significantly to the development of environmental diseases [1–4]. Understanding the synergetic effects of eutrophicated components of the environment on living conditions across Ukraine is one of the most topical issues in the context of Ukraine's sustainable development.

Relevance of research. Poor condition of water resources is one of the most pressing issues globally, including our country. Significant water deficit faced by Ukraine is a result of overconsumption and deterioration of limited water sources. These studies should involve the identification and assessment of environmental, social and health threats associated with the progressive eutrophication of surface water bodies, soil and ambient air (due to the release of bioaerosols) caused by cyanobacteria and their lifecycle products.which will ensure

timely protection of the population and reduce the negative impact of eutrophication of water bodies.

The connection of the author's work with important scientific and practical tasks. Signing the Association Agreement between Ukraine, on the one hand, and the European Union and its countries, on the other, member states open up new opportunities and create new standards in various spheres of public life, including the sphere of environmental protection [8-9]**.**

Analysis of recent research and publications. Anthropogenic eutrophication and effects thereof such as algal blooms could ultimately result in the degradation of natural biocoenoses, populations and even ecosystems and lead to homeostatic disorders and accumulation of toxic metabolites threatening human health. Ongoing military operations cause ecocide, massive destruction, and release of pollutants to the ambient air, water and soil promoting eutrophication processes. This calls for the need for environmental, social and health studies focusing on their impacts on human life [5–6].

These studies should involve the identification and assessment of environmental, social and health threats associated with the progressive eutrophication of surface water bodies, soil and ambient air (due to the release of bioaerosols) caused by cyanobacteria and their lifecycle products.

Water resources play a vital role in ensuring and maintaining sustainable development because water is an integral component of the environment, a natural resource and a social and economic good. Water resource use is a crucial factor shaping the development of the society, human health and living conditions. Having enough water of good quality is considered as a pillar of national security [7].

Before the war, Ukraine ranked 87th in the world's water quality ranking [10-12]. It is now important to ensure a regular water quality monitoring in the active combat zones including «vulnerable» areas.

The authors [13–15] defined groups of indicators and indicators for the implementation of the selection procedure. Using the proposed approach makes it possible to involve local self-government specialists of various profiles in the management of environmental security of agglomerations from the standpoint of their sustainable development. The advantage of the proposed [14–15] multi-criteria methodical approach is the possibility to combine into a single decision-making algorithm raw data that differ in content (ecological, social and economic-technological) and form of presentation (statistical, predictive, direct measurements) data, expert assessments).

Highlighting previously unsolved parts of the general problem, to which the specified article is devoted. The recommendations outlined below aim to enhance the environmental monitoring of aquatic ecosystems affected by eutrophication in order to prevent adverse effects thereof on various water uses (drinking water supply, recreation, energy, agriculture etc.):

1. Special observations over water bodies should be organised and conducted throughout the vegetation period (i.e., from April through October).
2. These special observations should combine both ground-based monitoring and space observations involving the use of remote-sensing technologies (RST). The latter would serve to collect primary information while the ground-based monitoring would be used to verify remote sensing data.
3. The results of special observations would be used to estimate the following two indicators describing the level of eutrophication: 1) E as an integral value characterising the impact of wastewater discharges on aquatic ecosystems and supporting the identification of long-term actions; and 2) chl1, which is the chlorophyll concentration measured upstream of a discharge and used to support operational decision-making.
4. The ground-based and space observation protocol outlining specific observation actions for water bodies with different eutrophication levels (see a draft shown in Table 1) should be developed and approved as required.

The value of the indicator E (an integral assessment of impact of wastewater discharges on aquatic ecosystems) could be used to support funding decisions on allocating resources from the national, regional and local environmental funds for financing priority environmental projects aiming to reduce wastewater impacts on aquatic ecosystems [5].

Originality. The value of the integral indicator E would be used to prioritise projects by urgency, i.e., the higher the estimated impact of wastewater discharges on an aquatic ecosystem, the more urgent the project. So, the site whose wastewater discharges have the highest estimated impact resulting in the most significant deterioration of water bodies would rank first in terms of urgency of intervention required (E1), followed by the site with the second-highest value (E2) etc.

$$\begin{matrix} (1) & (2) & (3) \\ E1 & > E2 & > E3 & > \ldots \end{matrix}$$

Methodological importance and Presentation of the main material. Funds allocated to reduce the impact of wastewater discharges on aquatic ecosystems should be used to finance the following environmental projects:

– Provide treatment to municipal wastewater discharges;

– Ensure the continuous operation of wastewater treatment facilities, and upgrade/construction of existing/new facilities;

– Prevent storm sewers from clogging and blockage by litter in populated areas;

– Provide routine maintenance, repair and upgrade of domestic, industrial and storm sewers etc.

All these actions extend over a long period of time and would achieve the expected reduction in impact of wastewater discharges on water bodies in the longer-term future.

Table 1

Ground-based and space observations over eutrophication processes in water bodies

Eutrophication Indicator TSI(chl)*	Water Quality Status	Ground-based Observations			RS Data Analysis Frequency
		Monitored Parameters	Monitoring Frequency	Monitoring Location	
TSI(chl) ≤ 53	Clean, slightly polluted (Categories I and II)	Chlorophyll-a, pigment index, turbidity, colour, oxidability	Once or twice per month	1 location for calibrating remote sensing imagery	Weekly
54 <TSI(chl) ≤ 71	Moderately polluted, heavily polluted (Categories III–IV)	Chlorophyll-a, pigment index, turbidity, colour, oxidability	Weekly	1 location for calibrating remote sensing imagery	Daily
		A complete list of parameters required to assess the level of danger to the environment and society based on the intensity of algal bloom	Monthly	Locations considered as most representative for assessing the effects of algal blooms	
TSI(chl) > 71	Very polluted (Category V)	A complete list of parameters required to assess the level of danger to the environment and society based on the intensity of algal bloom	Weekly	Locations considered as most representative for assessing the effects of algal blooms	
TSI(chl) > 71 (quick assessment)	Very polluted (Category V)	Chlorophyll-a, pigment index, algal indicators	Weekly	1 location for calibrating remote sensing imagery	

The other indicator, i.e., the chlorophyll concentration in a water body upstream of the discharge (chl_1), is proposed to be used to support operational decision making and actions designed to reduce direct effects of eutrophication on water users receiving water from eutrophic water bodies (Table 2).

A timely response to changes in the chlorophyll-a concentrations in water layer near drinking water intakes would help make adequate management decisions on reducing adverse effects of eutrophication.

When assigning a relevant water quality category to a water body based on the eutrophication level, decision

Table 2

Operational and preventive measures to reduce the direct impact on water use of eutrophic water bodies

Water Quality Status / Eutrophication Indicator TSI(chl)	Assessment of Eutrophication Impact on the Condition of the Anthropogenically Modified Natural System	Forecast Based on the Analysis of Satellite Imagery and Phytoplankton Indices	Recommendations (Actions) on Reducing Environmental and Social Threats Related to Algal Blooms		
			Recommended Environmental and Social Actions (Solutions)		Recommended Technical Actions (Solutions)
			Water Quality Monitoring	Social Actions (Solutions)	
1	2	3	4	5	6
Category I, Clean / TSI(chl) ≤ 40	No indication of any adverse impact	Deterioration of current status (Category I) is unlikely	As per recommended monitoring programme for Category I–II waters	All water uses are allowed based on the existing water use permits	Water treatment systems operate as normal
		Deterioration of current status (Category I) is highly likely			
Category II, Slightly Polluted / 40 < TSI(chl) ≤ 53	A film develops on water surface, sensitive organisms are inhibited. Water treatment process is impeded due to the presence of live algal cells	Deterioration of current status (Category II) is unlikely			1. Improved control over water treatment process. 2. Increased usage of coagulants and longer water settlement times.

Continuation of the table 2

1	2	3	4	5	6
		Deterioration of current status (Category II) is highly likely	As per recommended monitoring programme for Category III–IV waters	1. Inform the public that a deterioration of water quality is possible 2. Inform water management companies that environmental situation might get worse	
Category III, Moderately Polluted / 53 < TSI(chl) ≤ 63	An algal layer floating on the surface; production/destruction balance distorted; self-purification processes slowed down, changes in species and population diversity. Water treatment process complicated. Deterioration of microbiological indices, unpleasant odour and taste in water	Deterioration of current status (Category III) is unlikely		1. Inform the public that tap water should be boiled for longer time 2. Recommend the public to use advanced water treatment appliances at their homes (filters etc.) 3. Restrict recreational water uses	1. More thorough water disinfection. 2. Develop recommendations on water treatment system upgrades for the future
		Deterioration of current status (Category III) is highly likely		Inform water management companies that environmental situation may get unfavourable	

makers at the national, regional and local levels could use proposed recommendations on mitigation and prevention measures to make appropriate environmental, social and technical decisions and organise their implementation within their jurisdictions and thus ensure the timely protection of human health and reduction of adverse effects of eutrophication.

Main conclusions. Eutrophication is a process that has a seasonal pattern and starts in water as a result of increases in the availability of nutrients. Under conducive climate conditions, this process can affect soil and ambient air.

The anthropogenic eutrophication of the environment leading to algal blooms and overabundance of nutrients can eventually result in the degradation of natural biocoenoses, populations and ecosystems; and lead to accumulation of toxic metabolites threatening human health. Ongoing military operations significantly exacerbate eutrophication processes and this requires further study.

The discussions in this paper also suggest that green innovation in the public sector should be given more attention in future research. The implementation of environmental standards requires special requirements for monitoring technology that can regulate the level of pollution. Such methods of multi-criteria multi-level hierarchy of choice may be particularly relevant for understanding possible future ways of greening key industries.

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