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EXPERIENCE IN WATER RESOURCES MANAGEMENT UNDER THE CLIMATE CHANGE CONDITIONS ON THE EXAMPLE OF NORWAY

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Climate change in Norway is occurring gradually, yet its consequences are becoming increasingly evident. There is a steady rise in average temperatures, an increase in annual precipitation and runoff, as well as a growing intensity of extreme weather events. Various regions of the country are experiencing more frequent and intense rainfall, which directly affects the hydrological regime and the formation of surface runoff. These climatic shifts raise concerns due to their impact on freshwater sources, especially during periods of heavy precipitation, when higher levels of bacterial contamination, increased water turbidity, and intensified coloration are observed; this indicates elevation of concentrations of organic matter and suspended particles in the water.

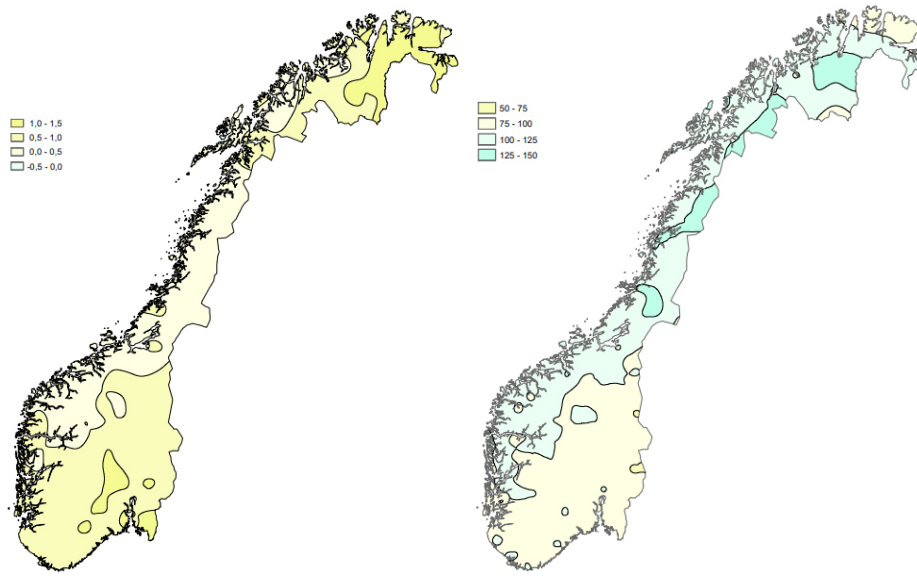
Amid growing climate risks, there is a pressing need for thorough regional analyses of how these changes affect water quality. Such analyses form the foundation for timely upgrades to water treatment facilities, as the increasing burden on filtration and disinfection systems could compromise their effectiveness, particularly in smaller settlements. By the end of the 21st century, the situation is expected to worsen, with forecasts indicating a further rise in waterborne pollutants due to soil erosion, runoff from agricultural lands, and urbanized areas.

According to climate research, the rise in air temperature, especially when combined with changes in precipitation patterns, will significantly influence hydrological processes [1]. Precipitation in Norway is expected to become predominantly convective in nature, occurring more frequently and with greater intensity [4]. This will pose new challenges for water supply systems, particularly in maintaining consistent drinking water quality. Norway has already experienced an increase in the average annual temperature of about one degree Celsius since the early 20th century [1]. This trend is accompanied by shifting snowmelt seasons, increased winter and spring runoff, and changes in the amount and distribution of precipitation. A particularly noticeable rise in precipitation occurred after the 1970s, amounting to approximately an 18% increase compared to initial values.

Keywords: climate change, drinking water quality, Norway, precipitation, runoff.

Statement of the problem. The purpose of this article is to examine Norway's experience in water resource management under the conditions of global change.

Analysis of Recent Studies and Publications. In recent years, short-duration rainstorms in Norway have become not only more frequent but also more intense, as documented by meteorological observations over the past decades. These climatic changes are already contributing to an increased frequency of floods, and this trend is expected to intensify further in the future. Air temperature and precipitation in Norway in 2022 and their deviation from the norm are presented in Figure 1.



a *b*

Fig. 1. **Air temperature, °C (*a*) and precipitation, mm (*b*) in Norway in 2022 as deviation from the norm (*a*) and as a percentage (*b*) [2]**

According to high greenhouse gas emission scenarios, the average annual temperature in Norway is projected to rise by 4.5 °C by the end of the century, while annual precipitation is expected to increase by at least 18 % [6].

The rise in precipitation will directly affect the frequency of rain-induced floods. In the context of higher temperatures and earlier snowmelt in spring, the seasonal flood dynamics may shift. Spring floods are likely to occur earlier in the year, while the risk of flooding in late autumn and winter will increase. All of these factors create additional pressure on both natural and artificial water purification systems. Small water intakes, in particular, may find themselves in

a vulnerable position due to their limited capacity to quickly adapt infrastructure to the new conditions [3].

Generalizing, the projected climate changes represent a serious threat to the stability of water supply in Norway. To prevent the deterioration of drinking water quality, it is necessary to take action now to increase the resilience of treatment facilities, improve monitoring systems, and develop regional-level adaptation strategies.

Presentation of the main research material. *Integrated water resources management in Norway: structure, approaches, and key instruments.* The rational use and effective management of water resources is one of the key prerequisites for ecological and economic sustainability. In Norway, where water resources hold not only great environmental importance but also serve as a foundation for energy, industry, agriculture, and drinking water supply, a clear system of integrated water ecosystem management has been developed. This system includes coordination across national, regional, and municipal levels, public participation, consideration of ecological needs, and the use of modern planning and monitoring tools.

The need for a comprehensive approach to water resource management arose with the intensive development of hydropower in the first half of the 20th century. As river systems were developed, the country faced challenges related to limited water volumes, source pollution, and conflicts among various users – from energy producers to environmental advocates. At the same time, it became increasingly important to preserve drinking water quality, maintain biodiversity, and consider land-use changes.

In response to these challenges, Norway established a network of administrative bodies that cover different levels of water governance. At the local level, municipalities are responsible for forming water supply strategies, controlling water quality, organizing wastewater treatment, and accounting for the impacts of land use on water resources. The regional level manages planning within river basins, develops long-term programs, and oversees lakes and reservoirs [5].

Norway's institutional model emphasizes the active involvement of citizens and stakeholders in planning and decision-making processes. Public hearings, open consultations, and the participation of local organizations and residents ensure transparency and balance in resolving water-related issues. This inclusive approach allows for the consideration of all user interests – both industrial and ecological.

The ecosystem approach and the role of nature in water management. Integrated management in Norway is based on the principle of recognizing natural ecosystems as full participants in the water cycle. Rivers, streams, lakes, wetlands, groundwater, and forested areas are viewed not only as sources or storage of water but also as regulators of its quality and quantity. The ecosystem approach aims to ensure the harmonious coexistence of human needs with natural water cycles while maintaining ecological balance.

Due to growing pressure on water resources from urbanization, agriculture, and climate change, Norwegian policy focuses on the preservation of ecosystem services provided by natural landscapes. This includes the protection of groundwater health, prevention of erosion, flood mitigation, and the reduction of pressure on infrastructure.

The General Water Resources Plan and Watercourse Protection Plan. To regulate the use of water resources and reduce inter-sectoral conflicts, Norway introduced the General Plan for Water Resources in 1985. This was a strategic response to the need for a systemic approach to hydropower development. The plan included a prioritized list of projects that could be considered for licensing based on environmental, social, and economic factors.

The plan's primary objective was to identify areas that could be used for energy production without causing significant environmental harm. During its development, 16 major user interest groups were identified, including nature conservation, drinking water supply, fisheries, pollution control, tourism, and agriculture. Project assessments were conducted at the river basin level, taking into account regional development and the ecological value of territories.

In parallel, the Watercourse Protection Plan was developed to designate priority water bodies for conservation in their natural state. As of 1993, 341 water bodies were protected, with a combined potential hydropower capacity of approximately 35 TWh – about one-fifth of Norway's hydropower potential. These areas include both large river basins and smaller systems with high conservation value.

Environmental Impact Assessment (EIA) in water use. Another important tool ensuring the sustainable development of the water sector in Norway is the Environmental Impact Assessment (EIA) procedure. It applies to projects that may have significant environmental impacts. According to legislation, developers must initiate the EIA process at the planning stage by submitting a notice and proposal for the assessment program. All interested stakeholders, including the local community, have the opportunity to participate in discussions and provide feedback.

EIA results are taken into account during licensing decisions. This process helps reduce ecological risks and foster dialogue among sectors such as energy, ecology, transport, agriculture, and tourism. The EIA procedure strengthens the role of environmental authorities, giving them powers to monitor environmental quality and implement sustainable water management solutions.

Regulatory framework and licensing procedures in Norway's water sector. Norway implements an effective policy for the protection and sustainable use of water resources based on a solid legal framework. This framework ensures transparency in decision-making and promotes the participation of all stakeholders in governance. The country's legal mechanisms form the foundation for coordinated functioning of various actors – government bodies, businesses, local communities, scientific institutions, and environmental organizations – allowing for the avoidance of conflicts of interest and contributing to long-term ecological safety.

Among the most important legislative acts in Norway are the Planning and Building Act and the Water Resources Act. These two laws provide the

legal foundation for the protection of natural river systems and the prevention of uncontrolled interventions in aquatic ecosystems. Particularly significant in this context is the regulation of hydropower activities, which requires the issuance of special licenses under the Watercourse Regulation Act and the aforementioned Water Resources Act. These licenses govern not only the construction of facilities (such as hydroelectric power stations, dams, etc.) but also the conditions for their operation, taking into account safety, environmental protection, and cultural heritage preservation requirements.

Developers are also obligated to implement measures that preserve the historical and cultural value of the area, minimize environmental impacts, prevent pollution, and adapt projects to local ecological conditions. For instance, infrastructure design may include fish passages, ecologically justified minimum water flows, the clearing of regulated zones from excess vegetation, and the construction of spillways [5].

A particularly relevant legislative instrument is the Pollution Control Act, which sets forth the overarching goal of preventing environmental degradation, reducing anthropogenic emissions, and ensuring the responsible management of industrial and domestic waste. All of these legislative provisions are integrated with the Environmental Impact Assessment (EIA) procedure, which guarantees systematic project screening from the early planning stages.

Furthermore, Norway has several special laws that provide additional protection for aquatic ecosystems and biodiversity. These include the Nature Conservation Act (which classifies protected areas into categories such as national parks, nature reserves, biotopes, and natural monuments), the Cultural Heritage Act (which ensures the safeguarding of historical sites near water bodies), and the Salmon and Freshwater Fish Act (which regulates the conservation of fish resources in water-related activities).

System of assessment, monitoring, and forecasting of water resources. In response to increasing pressure on aquatic ecosystems, Norway is continuously improving its observation and forecasting systems to enable timely identification and mitigation of potential risks. Key threats include the deterioration of water chemical composition, more frequent flooding due to urbanization and alteration of natural catchments, as well as unpredictable changes in hydrological regimes as a result of global warming.

To ensure effective water resource management, Norway is modernizing its hydrological data collection systems on a large scale. The Norwegian Water Resources and Energy Directorate (NVE) oversees the implementation of new technologies, such as the modernization of the national network of hydrological stations and the installation of automated sensors. These sensors provide continuous monitoring of water dynamics, enabling real-time data transmission and storage in a centralized electronic system.

Analytical efforts are also supported by advanced mathematical modeling. These models help simulate potential climate change scenarios and assess their impact on river basins. In addition, specialized water balance maps are

developed to evaluate water availability, identify regions at increased risk of droughts or floods, and analyze long-term resource distribution trends.

This comprehensive monitoring approach is a vital part of Norway's integrated water resource management system. It enables evidence-based decision-making, rapid response to emerging challenges, and effective prevention of crisis situations.

International cooperation and institutional capacity building in partner countries. Over the past few decades, Norway's foreign policy has evolved from a traditional aid-based model to a full-fledged institutional partnership approach. The main goal of this shift is not only to provide financial support but also to promote the development of local institutions through knowledge exchange, capacity-building, and the transfer of innovative technologies.

A key player in this process is the Norwegian Agency for Development Cooperation (NORAD), which serves as a coordinating center for international partnership programs. Through NORAD's efforts, a mechanism has been created to involve leading Norwegian institutions, including government agencies, research centers, environmental NGOs, educational institutions, cultural organizations, and private companies, in international projects.

Norway actively promotes a model in which highly qualified water management experts assist developing countries in formulating strategies tailored to local conditions. This cooperation extends to both planning and implementation phases, facilitating the adaptation of Scandinavian experience to diverse regional contexts.

Water management is considered a priority area due to its strategic importance for environmental security, agriculture, public health, and sustainable development. Norwegian organizations are prepared to share their expertise in ecosystem-based approaches, water basin planning, anthropogenic pressure mitigation, monitoring systems, and climate resilience strategies [5].

Analytical comparison of the functional roles of key institutions in Integrated Water Resources Management in Norway. Integrated water resources management (IWRM) in Norway is carried out through close inter-agency cooperation among several institutions, each responsible for specific tasks within the broader framework of water and environmental policy. Their functions complement each other, forming an effective system for control, monitoring, planning, and regulation of sustainable water use.

1. Ministry of the Environment (MOE) acts as the central coordinating authority, shaping national environmental policy, including the management of aquatic ecosystems. The MOE approves strategic documents, sets environmental priorities, coordinates the activities of subordinate institutions, and ensures the fulfillment of international environmental obligations, including the implementation of the EU Water Framework Directive. The MOE serves as a systemic integrator, harmonizing decisions across different sectors involved in water management.

2. Directorate for Nature Management (DN) focuses on the practical implementation of nature conservation policy, especially in terms of preserving

biodiversity and ecological stability. It identifies ecologically valuable zones, conducts scientific environmental impact assessments, provides recommendations on the protection of aquatic and coastal ecosystems, and coordinates projects for the restoration of degraded natural areas. Unlike the MOE, DN concentrates on specific ecological parameters and fieldwork implementation.

3. Norwegian Pollution Control Authority (SFT) performs regulatory functions aimed at reducing anthropogenic pressure on water bodies. Its core responsibilities include overseeing compliance with environmental legislation regarding pollution prevention, issuing discharge permits, developing water quality standards, and conducting ongoing chemical monitoring of water bodies. Thus, SFT ensures adherence to environmental standards in economic activities related to water use.

4. Ministry of Petroleum and Energy (OED) is responsible for the development of the energy sector, particularly hydropower, which in Norway heavily relies on river systems. OED implements policies for sustainable energy development, approves water use for electricity generation, ensures national energy security, and assesses the environmental impact of energy projects. Its activities often intersect with those of environmental agencies, requiring effective coordination of interests.

5. Water Resources and Energy Directorate (NVE), operating under the OED, is tasked with technical and administrative management of water resources in relation to hydropower. NVE issues licenses for hydropower plant construction, manages flood risks, regulates watercourses, and assesses the risks associated with hydraulic structures. Additionally, NVE contributes to the implementation of integrated river basin management plans, working alongside other institutions to maintain a balance between energy production and environmental protection.

6. The Geological Survey of Norway (NGU) carries out scientific research in the fields of geology and hydrogeology. Its role is to provide reliable data on groundwater reserves, geomorphological conditions, soil vulnerability to pollution, and environmental changes related to climate change. NGU supplies critical information for decision-making in water protection, especially in rural areas and regions with potential industrial impact.

In conclusion, water management authorities in Norway operate as components of a unified integrated system (Table 1). The MOE provides strategic leadership; DN and SFT implement policies in nature conservation and pollution control; OED and NVE oversee the technical and energy-related aspects of water use; NGU supports data management and scientific analysis. This functional division ensures the effective consideration of all aspects of water resources management – from ecological to economic [5].

Conclusions. Norway's experience in water resources management under climate change conditions demonstrates a high level of adaptability, inter-agency coordination, and science-based decision-making. The comprehensive model of integrated water management, built on close cooperation between environmental,

energy, scientific, and administrative bodies, enables the country to effectively respond to contemporary challenges. These include increasing flood intensity, reduced water availability in certain regions, and shifts in hydrological regimes.

Table 1. **Comparative table of functions of key institutions in Integrated Water Resources Management in Norway**

Institution	Main role	Key features	Features of the activity	Cooperation with other bodies
Ministry of the Environment (MOE)	Environmental policy formation	• Strategy development • Inter-agency coordination • Implementation of international obligations	Centralized planning of environmental policy, particularly in the water sector	Coordinates plans with DN, SFT, OED; coordinates implementation of the Water Framework Directive
Directorate for Nature Management (DN)	Implementation of nature preservation policy	• Ecological expertise • Identification of protected areas • Biodiversity conservation	Focus on field research and ecosystem protection	In collaboration with the MOE, defines security zones; transmits data to the SFT
Norwegian Pollution Control Authority (SFT)	Environmental quality control	• Issuance of discharge permits • Environmental monitoring • Implementation of water quality standards	Performs supervisory and regulatory functions in the water sector	Exchanges data with DN, negotiates permissions with NVE and MOE
Ministry of Petroleum and Energy (OED)	Hydropower Development Strategy	• Water use planning for energy • Energy project approval • Environmental impact monitoring	Represents the interests of the energy sector in water management	Coordinates projects with NVE; takes into account environmental requirements of MOE and SFT
Water Resources and Energy Directorate (NVE)	Technical management of water resources	• Hydropower Plant Licensing • Flood Protection • Basin Management Planning	Practical implementation of water management solutions	Works under the direction of OED; coordinates with MOE, SFT, DN
The Geological Survey of Norway (NGU)	Geoinformation support	• Groundwater Reserve Assessment • Geomonitoring • Hydrogeological Surveys	Provides scientific data for management decisions	Transmits the results of studies to MOE, SFT, NVE

Key factors contributing to this effectiveness include the clear division of responsibilities among institutions (MOE, DN, SFT, OED, NVE, NGU), transparent decision-making procedures, and a strong focus on scientific data and long-term planning. Noteworthy elements also include the practical implementation of the river basin management principle, active public participation in environmental monitoring, and open access to information.

Norway's experience can serve as a benchmark for countries aiming to reform their water governance systems in line with the principles of sustainable development and climate adaptation. This approach not only helps preserve ecological balance but also ensures reliable water supply, energy security, and protection of the population from the adverse impacts of climate change.

ДОСВІД УПРАВЛІННЯ ВОДНИМИ РЕСУРСАМИ В УМОВАХ ЗМІНИ КЛІМАТУ НА ПРИКЛАДІ НОРВЕГІЇ

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Кліматичні зміни в Норвегії відбуваються поступово, але їхні наслідки стають дедалі помітнішими. Спостерігається стабільне зростання середніх температур, збільшення обсягу річних опадів і обсягу стоку з територій, а також посилення екстремальних метеорологічних явищ. У регіонах країни фіксуються більш інтенсивні зливи, які проявляються частіше, ніж раніше, що безпосередньо впливає на гідрологічний режим і умови формування поверхневого стоку. Ці зміни клімату викликають занепокоєння через їхній вплив на джерела прісної води, оскільки саме під час періодів інтенсивних опадів спостерігається підвищення рівнів бактеріального забруднення, збільшення каламутності води та посилення кольоровості, що свідчить про підвищення концентрацій органічних речовин і частинок у воді.

В умовах зростання кліматичних ризиків постає необхідність ретельного регіонального аналізу впливу цих змін на якість води. Такий аналіз є основою для своєчасної модернізації водоочисних споруд, оскільки підвищення навантаження на системи фільтрації й знезараження води може поставити під загрозу їхню ефективність, особливо в менших населених пунктах. Очікується, що до кінця XXI століття ситуація ускладниться: прогнозується подальше збільшення кількості домішок у воді, які пов'язані з ерозією ґрунту, стоком із сільськогосподарських угідь та урбанізованих територій.

Згідно з результатами кліматичних досліджень, підвищення температури повітря, зокрема в поєднанні зі змінами структури опадів, матиме значний вплив на гідрологічні процеси [1]. Очікується, що опади в Норвегії набудуть переважно зливового характеру, стаючи частішими й потужнішими [3]. Це створюватиме нові виклики для систем водопостачання, зокрема щодо забезпечення стабільної якості питної води. Вже зараз у Норвегії спостерігається зростання середньорічної температури приблизно на один градус Цельсія з початку XX століття [1]. Така тенденція супроводжується зміщенням сезонних меж сніготанення, збільшенням зимового й весняного стоку та змінами у кількості та розподілі опадів. Особливо помітне зростання кількості опадів сталося після 1970-х років і становило приблизно 18 % порівняно з початковими значеннями.

Ключові слова: зміна клімату, якість питної води, Норвегія, опади, стік.

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