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ANALYSIS OF UKRAINE WATER SECTOR USING A SYSTEM APPROACH

This research takles the problem of water supply in Ukraine, using a system approach. First, the notion of system and interactions within it are explained in the context of water use. This phase is followed by a presentation of the main elements of the external environment of the water use system which is finally analyzed by spliting it into five target subsystems namely «water source», «water management», «water use efficiency», «water quality» and «data and models».

***Keywords*: water supply; water managementm; system approach; water efficiency; water quality.**

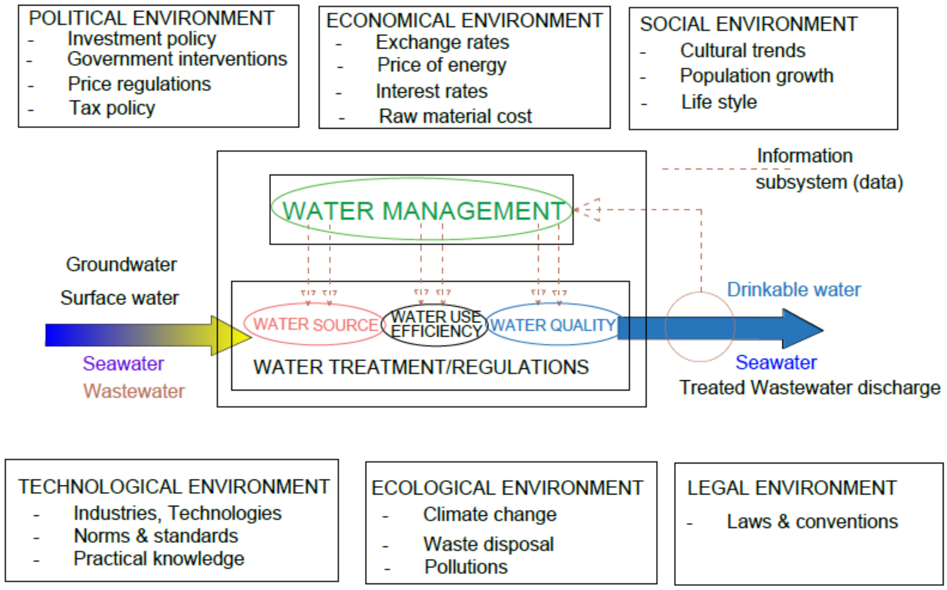
The problem of interaction between society and nature is one of the most important issues of humanity. However, it should be noted that despite the desire to improve the environmental situation, society still suffers from anthropogenic pressure. Moreover, climate changes and growing freshwater shortages due to higher water consumption, insufficient natural water resources and unsatisfactory water quality are increasingly comprehended as a major risk to the global economy. In Ukraine, outdated water infrastructure and management technologies, uncompleted and insufficient water policy and legislation, lack of finances from the state and private sector for modernisation and rehabilitation of infrastructures, irrigation and drainage systems are identified as potential gaps to be filled by the government. Finally, this situation is amplified by the low level of awareness of the population in the areas of water use and water resources protection.

For addressing these issues, scientists point out the need for transition to the complex system of sustainable water use, which requires :

- Appropriate government regulation,
- business sector initiatives,

- consumer responsibility
- System approach based management

The system approach is to think of the *“water use”* sector as a whole whose elements are interdependent and interrelated. More specifically, this system includes interdependent and interrelated elements, objectives to be achieved, inputs on which the elements act to transform them into outputs. It includes feedback which is used to indicate whether the objectives are being met or not (refer to figure 1). If these have not been achieved, then corrective action is taken. In addition, this system is in contact with other systems outside it (external environment).



Basic components of a complex System of water use (M. Diallo)

Figure 1. Basic components of a complex system of water use

In management theory, any system comprises an operational system, a steering system, and an information system.

The function of the operational system is the transformation of inputs into outputs. For example, transforming surface water, groundwater or seawater into drinkable water or treated wastewater before discharge and controlling water resources pollution are typically devoted to the operational system. In the area of Marine Environmental Protection, operational activities are about regulations to avert the introduction of invasive species into the maritime environment, prevent oil and chemical spills, and stop unauthorized ocean dumping. This operational system includes elements like workers, equipment, tools, electrical energy necessary for the various machines. It includes as well a set of processing operations required to treat water or control its pollution for meeting the required standards and/or norms.

In order for the operational system to function effectively, it must be piloted. The steering system for the water use in Ukraine is represented by the ministry of Environmental Protection and Natural Resources and its services. It includes a set of planning tasks (identification of objectives, means to achieve them and corrective measures if they are not achieved), coordination, monitoring, control etc. The planning activities consist in forecasting and establishing quantitative and qualitative objectives for drinking water, wastewater or seawater to be satisfied, the quantity of drinking water and treated wastewater produced every day, the production costs, maintenance plans for operating facilities, acquisition plans of new facilities etc.

Concerning the information system, it connects all parts of the system. Decisions coming from the steering system take the form of a plan, a directive or a procedure (information). It is transmitted to the operating system for execution. These send feedback regarding the progress of their work to the steering system. The latter then takes, if necessary, decisions such as corrective actions (piloting) or make other plans and so on.

When analyzing a complex system of water use in a country which can lead to important decisions and in order to apply this approach, one must have a global vision of the system (concept of globalism) and of the interrelations between this system and other systems with which it interacts. These former systems are referred to as components of the external environment. It includes Political environment, Economical environment, Social environment, Technological, Ecological and Legal environments (PESTEL environment).

The ***Political*** environment is about how government policy and actions intervene in the water sector. These include Tax Policy, energy price, Investment policies etc. More specifically, in the water sector, this system defines the investments, prices and regulation mecanisms.

The ***Economical*** environment includes interest rates, employment or unemployment rates, raw material costs, equipment cost and foreign exchange rates, availability of credit etc.

The ***Social*** environment includes changing family demographics, populations growth rates, education levels, cultural trends, attitude changes and changes in lifestyles. These factors usually have a considerable impact on water demand.

The ***Technological*** environment refers to technology incentives, the level of innovation, automation, research and development (R&D) activity, technological change. Innovating technologies include the remote sensing of water which can help with water accounting, non-revenue water remediation and much more; the internet of things, which enables smart irrigation, water quality control, and which, when coupled with new computing capacity, allows to develop complex models for water management.

The ***Ecological*** environment includes climate change, recycling procedures, carbon footprint, waste disposal and sustainability. This system has a noticeable effect on water quality, technologies and price.

The ***Legal*** environment includes specific laws in the field of water use, pollution, natural resources protection, employment laws, consumer protection laws, copyright and patent laws, and health and safety laws.

These components of the external environment have to be analyzed in detail for highlighting the opportunities and threats they represent with respect to the system of water use. Concerning the internal environment of our system, it is convenient to identify five target subsystems:

- ***WATER SOURCE***

Source water is water from rivers, streams, reservoirs, and aquifers that is treated and used for drinking water purposes. Surface water and groundwater are both important sources for community water supply needs. The water source subsystem is responsible for the development and ensuring the effectiveness of the water source. Surface water is the main water supply source in Ukraine and accounts for approximately 80% of total water supply. As result, in order to improve water management, the principle of river basin management needs to be further Implemented. Furthermore, the number of water quality standards needs to be lowered and they need to be implemented at true levels to enable their practical application. Concerning fresh water supply, it is known that in general, the quality of surface water is inappropriate for drinking, which is a consequence of pollution from municipal and industrial effluents, diffuse pollution from agriculture the atmosphere and that groundwater is less vulnerable. Last, in the field of marine environmental monitoring, the Ministry of Environmental Protection of Ukraine should build up its role as a coordinating governmental unit.

- ***RELIABILITY OF WATER MANAGEMENT***

This subsystem is about modernization and ensuring the reliability of water management and production, definition of strategies, strategic plans and realistic goals.

National action programs have already been developed for Dnieper bassin but, in order to improve substantially water management in Ukraine, the principle of river basin management needs to be further implemented (Nataliia Kovshun et al., 2021).“Integrated river basin management (IRBM) is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems” (Tim Jones et al., 2006).

Figure 2. Map of the Dniepre Basin

The Dnieper Basin is a unique Eastern European ecosystem sustaining a rich biological diversity and is as well a diverse economic region of environmental and socio-economic importance. It is the third largest river in Europe after the Volga and the Danube and the second largest river to feed into the Black Sea. The Dnieper River basin has a total area of 511,000 km^2 and length of 2,200 km. It is a trans-boundary system River basin: 20% of its area is situated within the Russian Federation, 23% within the Republic of Belarus, and 57% within Ukraine (UNENGO "MAMA-86" Kyiv 2015).

Large-scale land drainage covering about 4.5-5 million ha of the Basin territory, have contributed dramatically to major alterations of the hydrographic network, changes in the morphometric characteristics of water bodies and their catchments, modification of flow regime, and a fall in the water table of 1.0–1.5 m (UNDP Project Document, PIMS no. 3246).

Based on the Upper Dnieper River Basin Analysis 2013 (WFD Article 5) the significant anthropogenic pressures were identified and assessed as following: contamination of water by organic compounds, nutrients and hazardous pollutants caused by emissions of low treated and untreated wastewater from agglomerations, industry and agriculture point and non-point sources; As result, every year, about 1,500,000 tonnes of mineral substances and up to 700,000 of aggressive soluble organic compounds enter the Dnipro River with surface runoff from drained land, and this pollution load is further carried with river flow into the Black Sea.

There are other anthropogenic pressures/impacts identified in Upper Dnieper RB like contamination by Chernobyl accident, sediments accumulation and contamination, climate change and others. There is as well hydromorphological alterations including water flow regulation, river and habitat continuity interruption, disconnection of adjacent wetlands/floodplains and within the pilot river basin.

In an organizational point of view, the responsibility of water management bodies and the development of standards need to be streamlined. A clear responsibility for coordination should be defined and a mechanism for such coordination established. The establishment of a national body to unify standards and methods, i.e. the standardization body, needs to be considered.

Water consumption in Ukraine is quite high. This fact makes necessary the installation of water meters to detect the volume of its actual consumption and then save significant amounts of water. At the same time, water prices for utilities and industry are relatively low and this fee does not fully reimburse all costs, including investment. Significant efforts are needed to recoup the investment, maintenance and operation of water supply systems. Furthermore, increasing tariffs for water use and discharges are important steps to ensure adequate funding for water infrastructure, such as the reconstruction of water treatment plants.

For the construction and operation of sewerage networks and water treatment facilities, new financial support mechanisms adequate to real processes should be formed, with clearly defined responsibility of polluters. To improve the efficiency of wastewater treatment, further training of personnel on the operation of facilities and equipment and process control is needed. Responsibility for urban wastewater management and sewage disposal should be clearly defined. Furthermore, EU directive on urban wastewater and the use of sludge in agriculture should be followed. In addition, trained personnel should manage treatment plants. Low professional level of staff is identified as a common problem and this is why special training on the operation of facilities and equipment and process control could significantly improve the efficiency of treatment facilities.

For the marine environment, shipping and related activities are a major source of marine pollution, especially gasoline hydrocarbons. A wide network of administrative and scientific institutions has been formed to facilitate the management of the marine environment. However, it is necessary to define clear environmental policy objectives and include them in the national program for the protection and restoration of the Black and Azov Seas.

Another significant threat to the marine ecosystem is the penetration of exotic species, most often by removing ballast water. That is why it is necessary to develop special recommendations and implement appropriate measures. Ecological optimization and sustainable development of the water management complex are and should be the main direction of improving the environmental parameters and safety of water bodies.

- ***EFFICIENCY OF WATER USE***

The efficiency of water use subsystem is about the Rationalization and efficiency of water use in resource constraints. First, one needs to take appropriate legal and organizational measures and to establish and apply standards.

Municipal water supply systems include facilities for storage, transmission, treatment, and distribution. The design of these facilities depends on the quality of the water, on the particular needs of the user or consumer, and on the quantities of water that must be processed. In Ukraine, it is crutial to increase the capacity and technical condition of existing treatment facilities, to reduce water consumption and to increase the price of water supply and wastewater discharge.

Most cities and towns in Ukraine use treatment facilities for municipal and industrial wastewater. The quality and efficiency of wastewater treatment could be improved by increasing the capacity and technical condition of existing facilities. In particular, reducing water consumption would improve the operating conditions of treatment plants, as reducing the amount of wastewater would make it possible to process them more efficiently. This provision applies to both water treatment plants and treatment plants. In addition, the practice of sewage treatment is unsatisfactory and needs to be streamlined. These mules can never be returned to the rivers. The best option is to use them as fertilizers, provided that the metal content does not exceed the established limits.

The price of water should be transparent and realistic. It is necessary to introduce water meters for all water users, and the payment should be made in proportion to the amount of water used. The cost of water should correspond to the level of full reimbursement of all costs for investment, maintenance and operation of water infrastructure.

- ***DATA & MODELS***

First, one must improve the information system, the methodological support of water management and groundwater/surface water monitoring activities coordination.

Groundwater monitoring needs to be improved. Individual monitoring networks, using different software products, generate significant amounts of data that accumulate in different information banks. The Ministry of Environment of Ukraine is responsible for the coordination of these monitoring activities in order to ensure better integration and control of water quality. The implementation of these provisions will not only save significant funds and harmonize the monitoring data obtained from different programs, but will also allow the full use of monitoring results for decision-making and mainly at state level,which is not presently the case *(Nataliia* Kovshun et al., 2021). The system and scale of monitoring networks in the field of water use need to be improved.

Furthermore, data have to be made consistent and available for decision-making at state level. Consistency for data systems means that data from different sources do not conflict with each other from the aspects of format, semantics, and value.

Conserving ecosystems and their species is very important. There are more than 35 nature reserves and protected areas in the Dnieprer Basin that enjoy the national status and occupy only about 1.6% (8,100 km^2) of the catchments area. Clearly, the existing nature reserve capacity is not adequate to ensure full protection and conservation of plant and animal species, both native and migratory ones (UNDP Project Document, PIMS no. 3246). In order to do so, quantitative models and techniques need to be developed. They may sometimes be also referred to as Ecological optimization. A very frequent application of ecological models is to study the consequences of anthropogenic impact on the ecosystem with respect to the environmental fate of substances, habitat suitability of species, persistence of populations etc. In this way different management strategies can be compared.

Setting up ecological models requires a detailed system analysis of the processes of interest. A systematic way to achieve a concise and valid simulation model is to start with a conceptual model. This step is followed by the one consisting in translating conceptual models into computer models.

The two most important nutrients in sewage treatment processes are nitrogen and phosphorus. Excess of these nutrients stimulate algae growth, reduce dissolved oxygen, and negatively impact aquatic habitat and water supplies for downstream urban and agricultural users. A simple optimization model that identifies the cost-effective combination of management practices for reducing excess of these nutrients in water bodies can help solve this problem. In the light of optimization applied to species protection, ReVelle et al. reviewed five classes of the reserve selection problem: (1) species set covering problem (SSCP); (2) maximal covering species problem (MCSP); (3) backup and redundant covering problem (Maximal Multiple-Representation Species Problem; MMRSP); (4) chance constrained covering problem; and (5) expected covering problem. Out of the above-mentioned five classes, the MCSP was especially tackled by various algorithms (refer to Csuti et al., Rosing et al. and Mizumori et al.).

Other class of models are represented by nonlinear optimization problems that recommend water allocation for improving wetland species habitat. In an approach used in (A. Cabezas, 2015) to address this issue, the hydro-ecological performance for wetlands is measured using the weighted usable area that represents the available wetland surface area that provides suitable hydrological and ecological conditions for priority species. A variant of this problem can be a water allocations and invasive plant management problems in wetlands subjected to constraints like water availability, spatial connectivity of wetland units, hydraulic infrastructure capacities, financial and time resources availability invasive vegetation and water management (A. Cabezas, 2015).

- ***WATER QUALITY***

Certification of industries and technologies, as well as the effectiveness of water management have to be ensured. Moreover, providing the population with adequate drinking water that meets hygienic standards should be considered a priority along with public access to information on drinking water quality. In this framework, the use of water from relevant groundwater sources must increase significantly, and the protection of drinking water resources must be properly ensured.

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АНАЛІЗ ВОДНОГО СЕКТОРУ УКРАЇНИ ЗА СИСТЕМНИМ ПІДХОДОМ

У дослідженні розглядається проблема водопостачання в Україні з використанням системного підходу. По-перше, поняття системи та взаємодій всередині неї пояснюється в контексті водокористування. Після цього етапу представлено основні елементи зовнішнього середовища системи водокористування, яке остаточно аналізується шляхом поділу її на п'ять цільових підсистем, а саме «джерело води», «водоуправління», «ефективність водокористування», «вода – якість» та «дані та моделі».

***Ключові слова*: водопостачання; водне господарство; системний підхід; ефективність води; якість води.**

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АНАЛИЗ ВОДНОГО ХОЗЯЙСТВА УКРАИНЫ С ИСПОЛЬЗОВАНИЕМ СИСТЕМНОГО ПОДХОДА

В данном исследовании рассматривается проблема водоснабжения Украины с использованием системного подхода. Во-первых, в контексте водопользования разъясняется понятие системы и взаимодействий внутри нее. За этой фазой следует презен-

тация основных элементов внешней среды системы водопользования, которая в конечном итоге анализируется путем разделения ее на пять целевых подсистем, а именно «источник воды», «управление водой», «эффективность использования воды», «водопользование», «качество воды» и «данные и модели».

***Ключевые слова*: водоснабжение; управление водными ресурсами; системный подход; эффективность использования воды; качество воды.**