

SUSTAINABILITY OF WATER SUPPLY SYSTEMS UNDER CONDITIONS OF NEGATIVE ACTION NATURAL AND MAN-MADE PHENOMENA

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Abstract. This analyzes the sustainability of water supply systems under the effects of natural and anthropogenic factors. In theoretical terms, probability-based quantitative models will here be developed to serve stability assessment needs for water supply systems at different levels. This paper proposes a general scheme for assessing the stability of centralized water supply systems in its physical, technological, technical, and institutional aspects. The results indicate that continuous availability of water should be achieved to meet increasing demand together with environmental degradation and climate change. The findings provide an imperative test on how far the present system can go toward sustainability in supplying water in regions characterized by scarcity and improving it. An integrated approach to resource management is designed here after destabilizing factors such as pollution and infrastructure inadequacy are assessed. Results shall guide the formulation of programs on how to better manage water and ensure sustainability in the long run of a water supply system. Findings from this study are imperative for policymakers, urban planners, and environmental managers who plan an appropriate intervention concerning issues pertaining to global challenges where scarcity of water resources exists.

Keywords: *sustainability, water supply system, anthropogenic impact, reservoir, inflow, scarcity*

Introduction

The possibilities of consumption of fresh water reserves by all mankind are currently limited by natural, climatic, anthropogenic, technical, economic and many other factors. An increase in the number of people, including urban ones, changes in social conditions and lifestyle, trends in the development of the global economy, accompanying climate change, and an increase in anthropogenic pressure on ecosystems and natural water bodies are the reasons for restrictions on water consumption in some regions of the world. The shortage of water resources, especially freshwater, is a global problem that is becoming one of the modern challenges to humanity (Postel, 2014; Danilov-Danilyan and Losev, 2006). Therefore, one of the most important tasks of water use in the 21st century is to ensure the sustainability of centralized water supply systems in cities. Providing society and the economy with water resources in the context of global climate transformations, as well as limited freshwater reserves, depends on a high-quality solution to this problem. Stability, as a characteristic of a complex technical system, is used to describe the stability of a system, process, or sequence of its states, as properties and abilities to withstand external natural and anthropogenic influences, as well as internal processes that disrupt the structure and normal functioning of both the entire system or process and their individual parts over a certain period of time. At the same time, the stability of the system is considered as its two interrelated properties: (1) the ability of the system to resist the effects of the external

environment and operate in normal mode with specified permissible deviations, (2) the ability of the system to return to its original state after the cessation of the impact that disrupted this state.

The stability of CB in many studies and in practice is accepted as its ability to withstand external natural and anthropogenic influences, as well as internal processes that ensure (guarantee) the absence of interruptions in the supply of water of the required quality to consumers, while ensuring the operational level of quantitative parameters in terms of pressure and flow (Płuciennik-Koropczuk and Kumanowska, 2018; Bivalkevich, 2004; Galperin, 2003; Khramenkov, 2003). Despite these qualitatively understandable concepts, the interpretation of the concept of "CB stability" remains not fully established, along with a full description of this characteristic. A large number of factors, including the parameters and time characteristics of water supply sources, have a significant impact on the quality of CB functioning and their stability. Thus, for water-deficient regions, one of the important conditions for ensuring uninterrupted water supply is the availability of the required volumes of water with acceptable quality parameters. The degradation of water resources, which occurs in the modern period, with a negative change in the hydrobiological composition of water used as a source of water supply, is also a problem, which is associated with the intensification of economic activity and other factors of influence, as a result of which the loss of the stable condition of vulnerable water systems, which are sources of pollution, is possible. Taking into account the above, the sustainability of CB must be presented from the perspective of a systematic analysis that considers the problem not in isolation, but in the entirety of the components, cause-and-effect relationships and processes of natural and anthropogenic factors of influence, which will allow taking into account the effects of the complex effects of negative factors, such as synergy, additivity, neutralization, and involves taking into account the principle of emergence. The main problem of analyzing the stability of centralized CB is the lack of a holistic conceptual understanding of the causes of its loss under the influence of external natural and anthropogenic influences, as a result of internal processes, which necessitates the development of methods for their quantitative assessment.

Results and Discussion

The problems related to water consumption and scarcity have become so acute in recent decades that they have become regarded in the world as one of the global evidences of the general crisis of modern civilization. The growth of the Earth's population, urbanization with the transformation of people's fields of activity and living conditions, climate change, as well as the deterioration of the ecological state of the environment, increases competition for natural resources, which is a global problem for all mankind. These factors greatly exacerbate water scarcity, affect the health and well-being of residents, the quality of the natural environment, as well as the socio-economic development of countries and regions (Ribeiro and Rosa, 2024; Zeng et al., 2022). Water scarcity is one of the existential threats to the national security of many countries and their regions, since water is a resource without which a person cannot live, ensure agricultural and industrial production, as well as the environmental safety of the regions of residence. Worldwide, water resources are under increasing strain due to the growing demand for freshwater, increasing scarcity, and the urgent need for sustainable development strategies. According to the UN, by the 3rd decade of the 19th century,

almost 1.8 and 4 billion people will face absolute and acute water shortages, respectively (WCED, 1987). Population growth, especially in the agricultural sector, which currently accounts for 70% of water intake, is leading to a significant increase in demand for water. One in three Africans suffers from water scarcity, which is exacerbated by demographic growth, urbanization, and climate change (Liu et al., 2017). It is projected that during this period, almost 230 million Africans will experience water scarcity, with up to 460 million living in water-scarce regions. As the population increases, climate change increases and water needs increase, solving this problem becomes more urgent, as the situation is predicted to worsen in many developing countries (WCED, 1987). According to forecasts, by 2050 it will be necessary to increase water intake by 15% in order to feed the expected 10 billion people by that time (Poff et al., 2016).

Negative anthropogenic impacts on surface waters may lead to the situation that in 2050 the number of river basins in the world experiencing water shortages caused by water quality will increase threefold when comparing shortages caused by quantity and quality with shortages caused by water quantity. In order to reduce the burden on freshwater reserves, it is important to support the transition to a reasonable and more integrated management of water resources (Wang et al., 2024). Water scarcity is also exacerbated by fragmentation of water resources both internationally, taking into account 276 transboundary river basins and 300 common aquifer systems, and within countries, which requires coordinated management efforts to manage 60% of the world's water resources (Baggio et al., 2021). It is highly likely that the water use situation will worsen due to climate change, which increases hydrological unpredictability and exacerbates extreme weather events such as floods and droughts. Water scarcity issues have prompted many countries, including Israel, the United States, Germany, Australia, Brazil, India, China, and others, to develop strategic plans and regulations, including national water supply policies, building codes, and financial incentives, including public engagement, leading to the creation of innovative water management systems (Wang and Fu, 2021; Makropoulos and Butler, 200). Sustainable water use around the world is currently becoming a key issue, as the growing anthropogenic impact, many natural processes, including global warming, have a strong impact on usable water resources (Olosutean and Cerci, 2022). The founding report of the United Nations Brundtland Commission "Our Common Future" WCED (1987) states that "sustainable development" and "sustainability" are the main ideas in the development of policy, state and regional governance and scientific research in various fields of human activity; and the new common goal becomes "development that meets the needs of the present, without compromising the ability of future generations to meet their own needs." In the fundamental work, the definition of "sustainability of water resources" is presented as the ability to use water resources in quantity and quality appropriate to both current and future needs of human populations and ecosystems, in a way that protects the Earth's population from the effects of natural or man-made hazards. An important problem related to the sustainability of the urban water cycle is the efficiency of CB (Simion et al., 2024). This, in turn, is determined by the functionality and stability of the components of this system. In this context, the sustainable use of water resources, which is associated with centralized water supply systems, has become one of the most discussed topics worldwide over the past decade.

Ensuring the sustainability of urban life support systems in general is an urgent task to combat various risks and dangers in today's rapidly changing world. Therefore, it is

necessary to assess the degree of ensuring the high-quality and sustainable functioning of SW, which are a complex complex of interconnected engineering devices and structures that provide consumers with water of a given quality in the required quantity. A system, including a CB, is understood as a structure that can be divided into interconnected and interacting elements, subsystems, in a certain way. In general, a complex system is a certain integrity and a set of subsystems that are in certain relationships and relationships with each other and with the external environment. With this in mind, centralized sanitation and sanitation systems are important subsystems in the life support systems of cities. The stability of CB is related to its ability to maintain its integrity and mode of operation for a certain period of time under the influence of external natural and anthropogenic influences. Thus, ensuring the sustainability of CB is one of the necessary conditions for the sustainable development of regions and cities, as long-term progress that meets people's desires and improves their quality of life while ensuring a balanced state of the environment, human health and well-being, and society as a whole in the context of their development. For simple technical systems, the properties and indicators of stability have unambiguous representations, and are formally standardized only for certain fields of research, and are in a continuous stage of development. While maintaining, maintaining, and restoring an operational state, the technical system is stable, but upon exiting this state, the system loses stability. In this case, a loss of stability can be detected both in time and in terms of functioning parameters. Therefore, indicators of the stability of technical systems should be probabilistic. The definition of the basic concepts of stability theory, which has received wide recognition for simple mechanical systems, was presented at the end of the 19th century. According to his view, a line of movement or development can be called stable only under the conditions that the system does not exceed the range of constancy, with certain limits of fluctuations indicated based on a small marginal deviation. To ensure stability, constraints are defined for perturbations under which the system will not leave the constant zone. The opposite of stability for technical systems is their instability. Accordingly, instability assessment is aimed at determining disturbing effects in which initially small differences can lead to serious discrepancies. There is an inversely proportional relationship between stability and instability: the more severe the impact of disturbing factors, the more difficult it is to maintain the stability properties.

Poisson stability of systems assumes that the corresponding phase trajectory of its parameters at the process time $t \rightarrow \infty$ does not leave a limited region of phase space. Being in this area for an infinitely long time, it will inevitably return to an arbitrarily small area of finding the starting point. The return time can correspond to a period or quasi-period with regular movement and is a random sequence if the solution corresponds to the dynamic chaos mode. In fact, a stationary state is called stable if small deviations do not take the system too far out of the region of this stationary state. A stationary state is called asymptotically stable if small deviations from it fade over time. A stationary state is called unstable if small deviations increase over time. Sometimes a less strict criterion is used, understanding stability as the limitation of the solution from above and below, that is, Lagrangian stability. For ecosystems represented by an unlimited number of constantly changing processes over time, this type of sustainability may be the most characteristic. A clear illustration of Lagrangian, Poisson, and Lyapunov stability is shown in Figure 1.

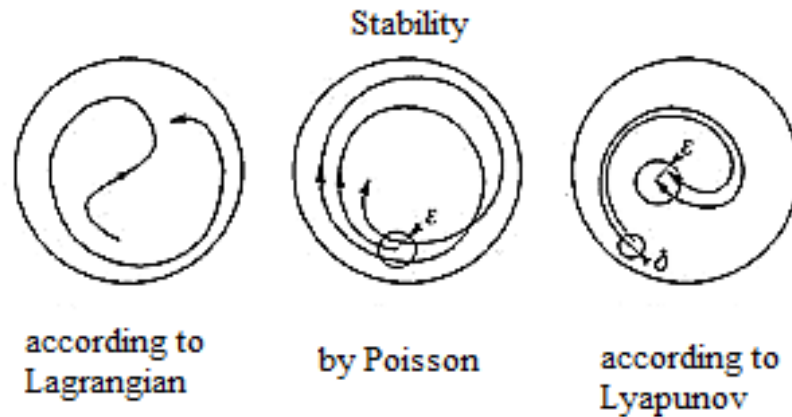


Figure 1. The Lagrangian, Poisson, and Lyapunov stability.

An analysis of studies on the problem under consideration has shown that CB sustainability is often defined as the absence of interruptions in the supply of high-quality water to consumers while maintaining the required level of indicators at water supply facilities or as its ability to maintain the stability of the structure and current operating mode, maintaining an optimal level of water quality at certain supply and pressure levels for a given number of users and for a certain period of time, during which water supply interruptions may occur, taking into account the negative environmental impacts on water supply sources. A systematic approach to the analysis of the stability of the functioning of water supply networks was also presented and a method was proposed for calculating the minimum reliability parameters with a decrease in water supply to the consumer and pressure relative to their design values (Galperin, 2003). The works consider the principles of stable and reliable operation of structures during the reconstruction of buildings and in conditions of reduced water consumption. In a broader interpretation, the stability of a system that undergoes negative impacts is understood as the ability of a system to maintain internal structural connections and functional features while being within the region of steady state (Bivalkevich et al., 2004). The results of assessments of the effects of anthropogenic impacts may vary depending on the interpretation of the concept of "sustainability". It should be noted that despite the exceptional relevance of the problem of sustainability and the related vulnerability of water systems, they also have not been clearly defined. If, under anthropogenic or natural influences, some parameters of the system responsible for stability acquire critical values, then such a system is characterized only by relative resistance to certain types of influences. Therefore, for a deeper understanding of the proposed concept of sustainability for CB, it is necessary to consider various aspects of this property of the system, and for its analysis it is especially important to evaluate the factors that ensure sustainability.

CB stability is the property of resisting external natural and anthropogenic influences, as well as internal processes that ensure the absence of interruptions in the supply of water of the required quality to consumers while ensuring the operational level of quantitative parameters. The stability of water supply systems is significantly influenced by the parameters of the stability of water bodies as sources of water supply, but also by the parameters of water treatment, distribution and supply schemes, the structure of which must meet regulatory requirements for water quality, including taking into account anthropogenic impact in conditions of excess or shortage of water resources. Figure 2 shows a scheme for assessing the stability of CB in the face of the

negative effects of natural and man-made phenomena. In many scientific studies and in practice, the stability of centralized wastewater treatment plants is considered as the ability to prevent interruptions in the supply of water of the required quality to consumers while ensuring the operational level of quantitative parameters at water supply and distribution facilities in terms of pressure and flow.

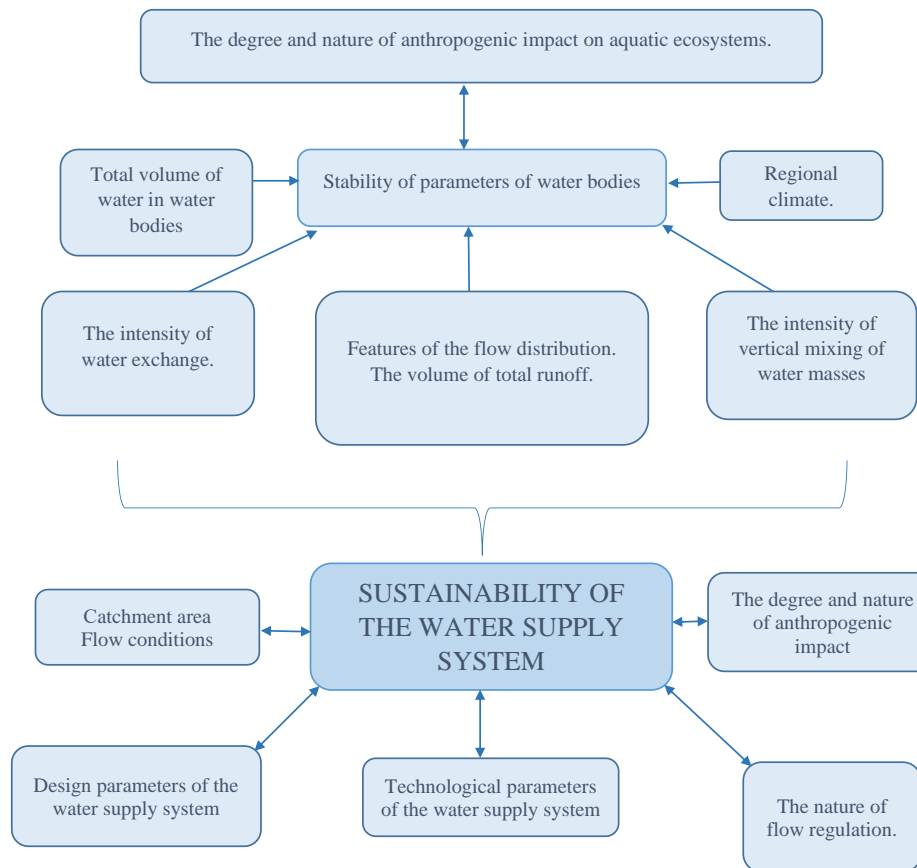


Figure 2. Scheme for assessing the stability of CB.

An analysis of the conditions of loss of stability of water supply systems, which are related to the state of water bodies, taking into account external influences and internal changes, has shown that a violation of the stability of water supply systems can be classified at four levels: (1) 1st level-physical: Lack of required volumes of water in the water supply source(s), (2) 2nd level-technological: Significant changes in water quality indicators in the water supply source due to an increase in the concentration of pollutants, including the identification of new types of pollutants that existing water treatment schemes are not adapted to eliminate, (3) 3rd level-technical: Malfunction of the elements of the water supply system that are functionally connected to water bodies, (4) 4th level-institutional: Violation of the possibility of access to a water source(s) due to or as a result of the actions of international, state, regional and local authorities and water resources management. The levels of stability of CB in the presented form are distributed according to the degrees of possibility of stabilizing or destabilizing effects

on the system. The presented classification of CB loss conditions into four levels allows for each of them to determine the conditions, the operating external and internal factors, the area of their permissible changes relative to which the system will be considered stable, which will justify the assessment methods on the basis of which to ensure the stable operation of the systems. CB studies on sustainability are generally presented as solutions to two main tasks at a certain time interval of its functioning: (1) assessment of the stability of the system when changing parameter values, that is, determining the values of parameters that lead to malfunction, (2) determination of ranges of system parameters that do not compromise its stability.

Solving the problems of ensuring the stable operation of complex systems requires the creation of theoretical foundations, which include probability theory and mathematical statistics, as well as a number of other disciplines in technogenic safety, computer science, modeling of technical systems and their elements. The theoretical foundations of quantifying the stability of CB should be presented on the basis of probability theory, since their stable operation over a certain period of time is influenced by various elements of environmental uncertainty, complexity, and multi-causality of stability losses, which are characteristic of random phenomena. Centralized CB systems operate under conditions of random impacts at various levels, without which it is impossible to assess the stability of the systems, as well as the goals and opportunities for sustainable development. Methods for quantifying random phenomena are well developed in probability theory, the subject of which is specific patterns in which the degrees of possibility of various random events are considered. The study of quantitative estimates of random events in probability theory makes it possible not only to predict them, but also to purposefully influence the course of these phenomena, control them, limit the scope of randomness, and reduce its impact on the operating conditions of technical systems. Comparing the degree of possibility of various random events, those events that occur more often are considered more likely, those that occur less frequently are less likely, and those that almost never occur are unlikely. Therefore, the unit of measurement for the probability of a random event and the range of its change are numbers from zero to one. As mentioned above, the stability of a technical system is the property of resisting external natural and anthropogenic influences, as well as internal processes that lead to the loss of its operability over a certain period of time. Taking into account the fact that the impacts on CB are mainly stochastic in nature under the influence of many random processes, the quantitative assessment of CB stability should be probabilistic, that is, it should be estimated as the probability of maintaining stability for a certain time. Taking into account the above, we take as a quantitative characteristic of stability for CB the probability of maintaining stability of operation $S(t)$, defined as the probability of the system being in a stable state for a given period of time $t_0 \leq t \leq t_k$, where t_0 and t_k are the start and end times of the considered period of time for which CB stability is determined. Since the state of the CB during a given period of time changes randomly, as a result of the influence of various internal and external factors, the probability of maintaining stability is in the range:

$$0 \leq S(t) \leq 1 \quad \text{Eq. (1)}$$

Where; $S(t)=1$ corresponds to the probability of guaranteed stability of the SVB over a period of time t , and $S(t)=0$ corresponds to a loss of stability over a period of time t . The characteristic opposite to the probability of guaranteed stability of the CB is the

probability of loss of stability of the CB $NS(t)$, as the probability that the system will lose stability during a given period of time $t_0 \leq t \leq t_k$ and is determined by the dependence:

$$NS(t) = 1 - S(t) \quad \text{Eq. (2)}$$

Therefore,

$$1 \geq NS(t) \geq 0 \quad \text{Eq. (3)}$$

Where $NS(t)=0$ corresponds to the probability of guaranteed stability of the CB over a period of time t , and $NS(t)=1$ corresponds to a loss of stability over a period of time t . We will assume that the stability of each of the 4 levels is independent of each other, and the stability of the entire CB depends on the stability of each of the levels and becomes zero if the stability of at least one of them is equal to zero. Therefore, the probability of maintaining the stability of CB over a period of time t is represented as:

$$S(t) = \prod_{i=1}^4 s_i(t) \quad \text{Eq. (4)}$$

Where; $s_i(t)$ is the probability of maintaining stability for the i -th level for a given period of time t . The probability of maintaining stability of CB for each of the i -th level is in the range:

$$0 \leq s_i(t) \leq 1 \quad \text{Eq. (5)}$$

For each of the i -th level, the characteristic opposite to their probability of guaranteed stability is the probability of loss of stability of this level $ns_i(t)$, as the probability that the i -th level of the system will lose stability over a given period of time, and is determined by the dependence:

$$ns_i(t) = 1 - s_i(t) \quad \text{Eq. (6)}$$

For the first level, the loss of stability of the CB with a single source of natural runoff from the reservoir during a given period of time $t_0 \leq t \leq t_k$, will occur if the actual filling of $w_f(t)$ reaches the value of the dead volume W_{mo} . The dead volume of a reservoir is a part of the total volume of the reservoir that is not used under normal operating conditions at the lowest possible water level in the reservoir. The most common way to assess the stability of a dynamic system is to build and study their theoretical models. It is necessary to use specific characteristics on the basis of which it is possible to describe the operating modes of the system, with the allocation of stable or unstable states. As a practical tool for applying theoretical methods for studying the stability of CB, Figure 3 presents a model for determining the stability of the first level.

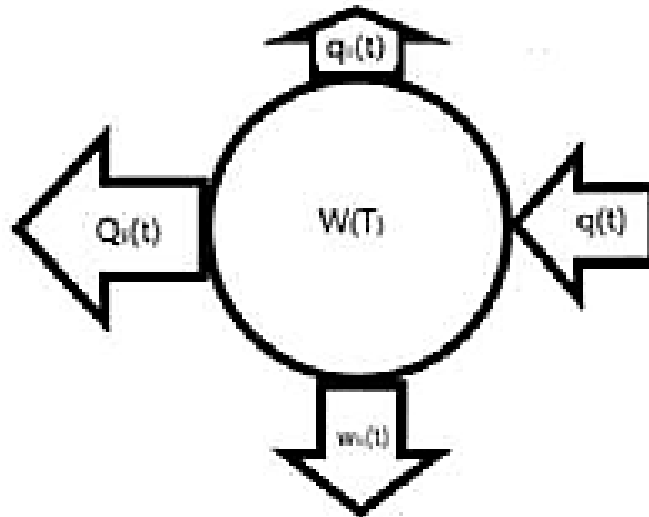


Figure 3. Diagram of the model of water use in a locality from a surface water supply source to determine the stability of CB.

This scheme is created on the basis of a database of daily data on all these five indicators from the summaries of operating organizations based on the summaries of the GC on water resources for a 5-to-8 years period. Taking into account the restrictions $0 \leq w_{Tc}(t) \leq w_{Tcmax}$ is the maximum throughput capacity of facilities for technological discharge; the value is controlled and regulated by $W_{mo} \leq W(T) \leq W_{max}$, W_{mo} , W_{MO} is the dead volume of the reservoir, at which it is impossible to supply water from it, therefore the water supply system loses stability. W_{max} is the total design volume of the reservoir, the value of which limits the possibility of further inflow due to overflow; $Q_B(t)_{min} \leq Q_B(t) \leq Q_B(t)_{max}$ is the range of daily water consumption, which depends on the population, water supply schemes, comfort level, technical condition of networks, promising development schemes, etc. When $Q_B(t) < Q_B(t)_{min}$ is applied, the stability of the city's water supply system is disrupted. The value of $Q_B(t)$ is regulated and controlled during the day, or daily, taking into account weekends and weekdays, as well as the seasons of the year. It is the main one for a water supply system, since it determines the amount of energy consumption, the cost of water, and also affects reliability indicators: $q_0(t) = f [W(T), t^0 C(T), v(T)]$ – evaporation from the surface of reservoirs depends on the surface area of the water in them, air temperature, and wind speed. The creation of a neuro-network model for this scheme allows us to solve the main task for assessing the stability of the first level, in the form of finding and justifying methods for optimal technology for regulating the volume of actual filling of reservoirs to ensure the stable operation of water supply systems, that is, to prevent a decrease in the volume of the reservoir less than dead. Related tasks can also be solved to determine the optimal conditions for CB technological processes, taking into account changes in water consumption regimes: population increase, changes in water use regimes, reduction of losses in the system, etc. To quantify, we determine the probability that the first CB level will lose stability over a given period of time relative to:

$$ns_1(t) = \frac{W_{mo}}{W_f(t)} \cong 1. \quad \text{Eq. (7)}$$

In this case, the probability of maintaining stability for the first level is:

$$s_1(t) = 1 - \frac{W_{mo}}{W_f(t)} \cong 0 \quad \text{Eq. (8)}$$

Actual filling of the reservoir:

$$W_f(t) = W_f^*(t_0) + W_1(t) - W_2(t) - W_3(t) - W_4(t) \quad \text{Eq. (9)}$$

where $W_f^*(t_0)$ is the actual filling of the reservoir with natural runoff at the initial moment of time, $W_1(t)$ is the inflow to the reservoir during a given period of time t , $W_2(t)$ is the flow rate for water supply, $W_3(t)$ is losses for filtration and evaporation, $W_4(t)$ -is technological reset. The actual filling of the reservoir with natural runoff at the initial moment of time can be represented as the sum of:

$$W_f^*(t_0) = W_{mo} + W_{fs}(t_0) \quad \text{Eq. (10)}$$

where $W_{fs}(t_0)$ is the useful volume of the reservoir at the initial time. Taking into account formula (7), we obtain the probability of maintaining stability for the first level of CB with a single source-a natural runoff reservoir:

$$s_1(t) = \frac{W_{fs}(t_0) + W_1(t) - W_2(t) - W_3(t) - W_4(t)}{W_f(t)} \quad \text{Eq. (11)}$$

To assess the stability of the second-level SW, it is necessary to compare, over a given period of time, the distribution of the main indicators of the quality of the source water and the analysis of the possibilities of technological schemes of water treatment plants. The methods presented in Rak and Pietrucha-Urbanik (2019), Rak and Żywiec (2019) as well as Han et al. (2017) can be used as approaches to assessing the stability of the second-level SVV. The assessment of the stability of the third level of CB is currently the most developed both theoretically and practically, based on numerous works in the field of reliability of both the entire system and its elements. The sustainability of the fourth-level CB is caused by a violation of the possibility of access to water sources, which can be caused or aggravated by the actions of international, state, regional and local authorities and water resources management. This can manifest itself in various forms, including policy decisions, legislative acts, administrative measures, and infrastructural changes. Such actions may include changing the boundaries of water bodies, redistributing water resources, as well as introducing quotas for water use. These measures can significantly affect access to water resources for various groups of the population and sectors of the economy. In some cases, violations may be related to conflicts between various stakeholders, such as Governments, private companies, and public organizations. In other cases, they may be the result of insufficient planning and management of water resources, which leads to inefficient use of water and ecosystem degradation. It is important to note that access to water is an inalienable human right and a necessary condition for maintaining life and health. Therefore, it is very important that authorities and water management authorities pay due attention to water accessibility issues and take measures to ensure sustainable and equitable water use. To assess the stability of the fourth-level CB requires further research, which is not part of the objectives of this publication. Thus, the analysis

convincingly shows that in the 21st century, due to the real problem of the global water crisis, new approaches and transitions to intensive methods of water use and new technologies for solving water scarcity problems are needed. For many districts and settlements located in water-deficient regions, in order to balance consumption levels with available water resources, it is necessary to carry out an assessment of the sustainability of CB in order to analyze it and develop measures for more efficient water use.

Conclusion

An analysis of recent studies on the problem under consideration has shown that CB stability is often defined as the absence of interruptions in the supply of high-quality water to consumers while maintaining the required level of performance at water supply facilities, or as its ability to maintain the stability of the structure and current operating mode, maintaining an optimal level of water quality at certain supply and pressure levels for a given number of users and during a certain period of time during which there may be interruptions in the water supply. The stability of CB is related to its ability to maintain its integrity and mode of operation for a certain period of time under the influence of external natural and anthropogenic influences. Ensuring the sustainability of CB is one of the necessary conditions for the sustainable development of regions and cities, as long-term progress that meets people's desires and improves their quality of life while ensuring a balanced state of the environment, human health and well-being, and society as a whole in the context of their development. To assess the stability of the CB, the external and internal factors acting on it are presented, the influence of which and the range of parameters are significant, and the areas of permissible changes relative to which the system will be considered unchanged, that is, stable, are established. A comprehensive analysis of CB stability is proposed, which takes into account the parameters of four levels to ensure an objective and comprehensive assessment of their condition. This approach makes it possible to develop effective measures to increase the sustainability of CB in the face of the negative effects of natural and man-made phenomena. Quantitative estimates of the stability of CB at four levels are presented on the basis of probability theory, since the stable operation of water supply systems over a certain period of time is influenced by various elements of environmental uncertainty, which cause various causes of stability losses characteristic of random phenomena. Calculated dependences are presented for estimating the first level of loss of stability of CB, physical due to the lack of required volumes of water in the water supply source(s), based on determining the probability of maintaining or losing stability. The analysis of approaches to the determination of quantitative indicators for assessing the stability of CB at other levels has been carried out. Taking into account the global problem of water scarcity, the results of the proposed assessment of water sustainability are the basis for creating programs for the sustainable development of regions and cities, as they allow developing and implementing programs to improve water resources management, introduce modern water use technologies, and raise public awareness of the importance of rational water use.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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