TƏBİƏT ELMLƏRİ

NATURAL SCIENCES

DOI: https://doi.org/10.36719/2663-4619/122/102-108

Narmin Salmanli
Nakhchivan State University
Phd student
https://orcid.org/0000-0003-0490-2565
narminsalmanli@ndu.edu.az

Socio-Economic Problems of Water Resources Management and Efficient Use: On the Example of Nakhchivan City

Abstract

The article examines the issue of water security and efficient use in Nakhchivan city from the perspective of urban reality: hydrographic constraints (Araz basin, groundwater), structural distribution of demand, and network-infrastructure sustainability are assessed together. The approach is descriptive-analytical: existing indicators are synthesized, and a framework of measurable targets is presented. The findings show that per capita water availability demonstrates a decreasing trend over the years; in the urban context, domestic use predominates, the share of agriculture is formed at the expense of peripheral areas, and industry remains limited by technical needs. Network losses, pressure and quality fluctuations, as well as measurement-data gaps, have a multi-channel impact on social welfare, business processes and municipal finances. An integrated package is proposed as a solution approach: loss detection and priority renewal across DMAs, smart meter expansion and GIS/SCADA-based real-time management, stable operation of treatment plants, etc.

Keywords: *Nakhchivan, water security, efficient use, network losses, DMA, smart meter, GIS/SCADA*

Nərmin Salmanlı
Naxçıvan Dövlət Universiiteti
doktorant
https://orcid.org/0000-0003-0490-2565
narminsalmanli@ndu.edu.az

Naxçıvan şəhəri nümunəsində su ehtiyatlarının idarə olunması və səmərəli istifadəsinin sosial-iqtisadi problemləri

Xülasə

Məqalədə Naxçıvan şəhərində su təhlükəsizliyi və səmərəli istifadə məsələsi urbanistik reallıq prizmasından araşdırılır: hidroqrafik məhdudiyyətlər (Araz hövzəsi, yeraltı sular), tələbatın struktur bölgüsü və şəbəkə-infrastruktur dayanıqlığı birgə şəkildə qiymətləndirilir. Yanaşma təsviri-analitik xarakter daşıyır: mövcud göstəricilər sintez olunur, ölçülə bilən hədəflər çərçivəsi təqdim edilir. Nəticələr göstərir ki, adambaşına düşən su təminatı illər üzrə azalma meyli nümayiş etdirir; urbanistik kontekstdə məişət istifadəsi üstünlük təşkil edir, kənd təsərrüfatının payı periferik ərazilər hesabına formalaşır, sənaye isə texniki tələbatla məhdud qalır. Şəbəkə itkisi, təzyiq və keyfiyyət dalğalanmaları, həmçinin ölçmə-məlumat boşluqları sosial rifaha, biznes proseslərinə və bələdiyyə maliyyəsinə çoxkanallı təsir göstərir. Həll yanaşması kimi inteqrə olunmuş paket təklif edilir: DMA-lar

üzrə itki aşkarlanması və prioritet yenilənmə, ağıllı sayğacların tətbiqinin genişləndirilməsi və GIS/SCADA əsasında operativ idarəetmə, təmizləyici qurğuların stabil fəaliyyəti və s.

Açar sözlər: *Naxçıvan, su təhlükəsizliyi, səmərəli istifadə, şəbəkə itkisi, DMA, ağıllı sayğac, GIS/SCADA*

Introduction

Water resources are an integral part of human life. Water not only meets the daily needs of people, but also the activities of industry, agriculture, energy, and many other sectors are related to it. Currently, the shortage of water resources and their uneven distribution across regions are among the most important problems for both economically developed and developing countries. It is no coincidence that the water crisis has become a global problem. As in other economic and geographical regions of the Republic of Azerbaijan, the Nakhchivan Autonomous Republic also faces the problem of limited water resources. Water resource management in Nakhchivan requires special attention due to its geographical location, climate, and the scarcity of water resources in transboundary areas.

Research

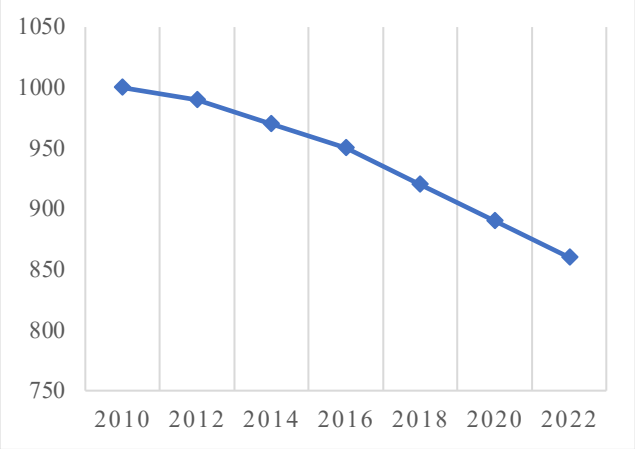
The purpose of the study is to analyze the current state of water resources in Nakhchivan city, identify priority problems, assess their socio-economic consequences, and highlight effective management methods.

Hydrographic features and water sources of Nakhchivan city. The geographical location and natural conditions of Nakhchivan city have a significant impact on its hydrographic features. The city is located in the valley of the Araz River, at an absolute altitude of 900–1000 m. Due to the fact that the study area is surrounded by mountains and highlands on all four sides, water resources are limited. Nakhchivan has a dry subtropical climate due to its climatic characteristics. The annual precipitation here is 200–350 mm, which is significantly less than in other regions of Azerbaijan (Institute of Geography of ANAS, 2020). Factors that weaken the city's hydrological balance and limit the renewal of water resources are related to the climate. These factors include high temperatures in the summer months, low precipitation, intense evaporation, etc. (IPCC, 2022). The Araz River, being the main water source of the city, plays an important role in providing drinking water to the population, supplying technical water to industry, and irrigating agricultural areas. The water supply of Nakhchivan city occurs at the expense of the lower part of the Araz River. However, due to its transboundary nature, there are certain risks in the quantity and quality indicators of its water. The mixing of industrial waste from the countries through which the river flows, as well as fertilizers and pesticides used in agriculture, reduces its quality. This aspect of the Araz River is assessed as a source of threat to the sustainable water supply of Nakhchivan city (UN, 2023).

In addition to the Araz River, small rivers flowing from the surrounding mountains are also important in the city’s water supply. These rivers are usually fed by rain and snow, so they are more abundant in the spring and summer months, and their flow decreases sharply in the autumn and winter months. The rivers around the city are mostly used to meet the irrigation needs of rural settlements and small farms. The main water resource of Nakhchivan city is considered to be groundwater. It is suitable for meeting the water needs of the population through artesian basins and springs. The degree of mineralization of these waters is considered suitable for human health. Even in some settlements of Nakhchivan city, artesian wells are used as the main source of drinking water. However, intensive use of such wells leads to a decrease in water quality and, at the same time, a disruption of the ecological balance. Therefore, the use of groundwater requires special control and balancing by the state (UNESCO WWAP, 2022).

Nakhchivan city is in a more sensitive state in terms of the overall hydrological balance compared to other urban settlements of the Nakhchivan Autonomous Republic. The demand for water is constantly increasing due to urbanization and population growth. According to calculations, while in 2010 the water supply per capita was approximately 1000 m³, currently this figure is 750–800 m³, which means a decrease of 20–25% (State Statistical Committee of the Nakhchivan Autonomous Republic, 2024) (Figure 1). According to international classification, this figure corresponds to the “water scarcity” indicator.

Figure 1. Per capita water resources in Nakhchivan city (2010-2024).

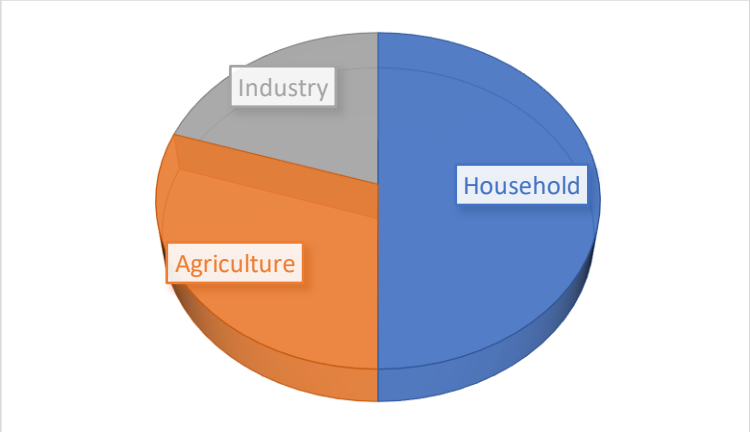


Use and structural distribution of water resources in Nakhchivan city.

The structural distribution of existing water resources in Nakhchivan city is related to the level of development of the city, and its use covers various socio-economic areas. Therefore, the correct structural distribution of water resources use and its management is one of the main issues in the socio-economic development of the city. The water resources of the city with a closed geographical position are limited and are increasingly burdened due to economic activity and population growth. Therefore, the efficient use of water resources in Nakhchivan city is of great importance not only in terms of environmental, but also socio-economic stability.

When looking at the structural distribution of water use in Nakhchivan city, it can be determined that three sectors are more prominent: household, agriculture and industry. If this distribution is expressed in percentage, it is 45–50% for household purposes, 30–35% for agricultural use, and 15–20% for industrial use (Figure 2).

Figure 2. Structural distribution of water resource use in Nakhchivan city.



The population is the largest consumer of water in Nakhchivan city. It is the daily life activities of people that play a key role here. Water supply is one of the main conditions for the provision of public services, social welfare and health of the population. Water is used more in the domestic sector as drinking water, for the use of household appliances and to meet the needs of urban agriculture. On average, the daily water consumption of each person in the population is 120–150 liters (Ministry of Ecology and Natural Resources, 2022). In addition, 20–25 percent of water is lost in Nakhchivan city due to the deterioration of existing water networks, which is a serious indicator for urbanization areas (Salmanov, 2022). In fact, although the water consumption per capita of a given population is in line

with international standards, the amount of water that should reach the population is reduced due to technical losses (WHO/UNICEF JMP, 2023).

One of the factors causing the shortage of water that is useful for the population is the weak culture of water saving in the domestic sphere. The experience of developed countries is more effective in this area. If the measures aimed at water saving in those countries are systematically implemented, the total consumption can be reduced by 15–20 percent, which is important in improving the overall water balance of the city.

As in all urban settlements, although agriculture is not very widely developed in Nakhchivan, there are livestock, horticultural and vegetable farms in the surrounding areas of the city. Based on the structural distribution of water use in the city, agriculture accounts for 30–35 percent of total water use here. This indicator may seem like a large figure for an urban environment, but it should be taken into account that agricultural areas on the outskirts of the city are also connected to the city's general water supply system. The widespread use of traditional irrigation methods in agriculture is one of the main problems of water use in agriculture. In open canal irrigation, approximately 25–30 percent of water is lost due to soil leaching and evaporation (Asian Development Bank (ADB), 2013). To put this in simple terms, for every 10 m^3 of water used in agriculture, up to 3 m^3 is lost without contributing to productivity (Azersu OJSC, 2023).

In the sectoral distribution of water use in Nakhchivan city, the industrial sector has a smaller share compared to the other two sectors, but it is strategically important. The share of industrial enterprises in total water use is 15–20 percent, which is spent on the technical needs of enterprises. In industry, water is mainly used for technological processes in food, light, construction materials and small production enterprises, for cooling equipment and cleaning. Although water use in this sector is currently low, in the future an additional burden may arise due to the development of the industrial sector.

Main problems and causes. Priority problems in water management in Nakhchivan city are concentrated in three areas: institutional-management constraints, technical-infrastructure deficiencies and climate and environmental risks. The combined effects of these three main problem blocks put pressure on economic stability, social well-being and environmental sustainability. Here, the inadequacy of measurement and information systems on the basis of management-institutional constraints, the weakening of the sealing capacity of outdated networks on the basis of technical infrastructure, pressure instability in the distribution system and seasonal fluctuations in demand on the basis of climate and environmental factors, etc. (Nakhchivan Autonomous Republic Ministry of Ecology and Natural Resources, 2023). As a result of the aforementioned problems, both "peak hour" tensions arise in the quality of service and losses increase.

Technical and infrastructure problems. Part of the water supply network in Nakhchivan city has exceeded its service life and is outdated, which has led to increased corrosion leaks, gaps in joints and a decrease in material quality. Hydraulic pressure drops along long network branches and mains result in intermittent supply in some areas. At the same time, breaks in outdated parts of the networks cause water losses and deformation of road surfaces, which increases the risk of local flooding and pollution.

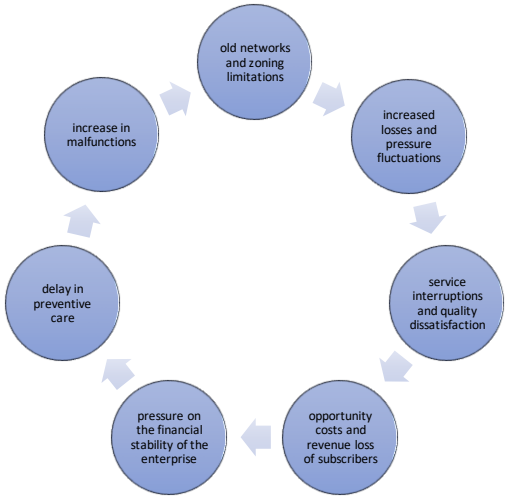
The lack of full implementation of DMA (District Metered Area) makes it difficult to quickly identify leaks. For the sustainable operation of water treatment plants, delays sometimes occur in the chain of spare parts, reagents and laboratory control, reduce efficiency and pressure fluctuations in some parts of the network can increase the risk of secondary pollution (World Bank, 2020). Energy consumption is also an important factor here. Deterioration in the network increases the energy footprint of water and increases operating costs.

Metering and information system problems. This includes the lack of smart meters, calibration delays in mechanical meters and incomplete address-area data, making consumption measurement difficult. The limitations of the SCADA/telemetry network prevent the conversion of real-time flow and level, time-pressure data into city-wide analytical management and control. This reduces the effectiveness of demand management.

Hydrological sensitivity and seasonal fluctuations. Dry subtropical climate, low rainfall and high evaporation lead to sensitivity of the water balance. As peak domestic demand increases in spring and summer months and garden irrigation causes a drop in system pressure, although the system operation is relaxed with a decrease in demand in autumn and winter, it creates difficulties in optimizing network and enterprise operation in the annual mode. Groundwater is considered a strategic resource. Their excessive exploitation can lead to changes in chemical composition, a decrease in its level and a long recovery period. Uncertainty in water levels and quality is more characteristic of the Araz basin. Hydrometeorological and anthropogenic changes characteristic of the upper reaches can translate into fluctuations in quantity and quality downstream.

Transboundary and ecological context. Due to the transboundary nature of the Araz River, problems with agricultural pesticides, hydromodification steps and industrial discharges in the upstream increase the downstream cleanup load (Mammadov, 2021). The unstable precipitation regime, rising temperatures and increased evaporation complicate long-term planning for the basin and make adaptation tools for water security relevant.

Figure 3. The final cause-and-effect chain.



Socio-economic problems of efficient use. The issue of efficient use of water resources in Nakhchivan city, on the one hand, acts as an engineering issue such as reducing technical failures, including the correction of measurement and distribution mechanisms. On the other hand, it acts as a complex socio-economic problem that coincides with social welfare, healthcare burden, income distribution, business sustainability and municipal finance sustainability. The dominance of domestic use in the structure of water use in urban environments, the formation of the relative share of agriculture at the expense of the suburbs and the potential for increased technical water demand in the industrial sector cause inefficient use of water to have different social consequences in each segment. Inefficient use or losses of water not only increase the costs for the population but also deepen problems with quality and continuity. At the same time, it weakens the financial sustainability of municipalities and service enterprises and increases risks for local businesses. As a result, resources for technical innovation are reduced, the problem returns to the social level and the "cost-quality-return" loop is closed (OECD, 2021).

The main social consequence of inefficient domestic water use is the affordability and accessibility dilemma. Here, fluctuations in network pressure, service interruptions, variations in sanitary-quality indicators, etc. create problems for the population. Thus, families turn to household filtration systems, purchasing water from alternative sources, additional pumping equipment and storage tanks. This creates additional costs for the family budget and at the same time deepens social inequality, especially in middle- and low-income groups. Additionally, there is a "time cost" when searching for alternative sources, collecting water during breaks, etc., which can reduce the hours that

should be allocated to employment, education and the work environment. The time loss caused by doing these things has a major impact on the quality of daily life, especially for the elderly and families with children.

One of the most sensitive dimensions of efficient use is the health aspect. Corrosion in worn-out parts of networks increases the risk of secondary contamination, which can cause episodic fluctuations in microbiological safety. As a result of secondary contamination, the risk of gastrointestinal infections in particularly vulnerable groups of the population and preventive and medical costs increase. Changes in water quality strengthen people's "purification" tendencies, and the application of filtration, boiling, chemical treatment, etc. increases the material and energy costs of households.

Inefficient irrigation methods increase water waste in the agricultural sector and disrupt the hydrophysical regime of the soil. As a result, productivity fluctuates in agricultural areas, the risk of structural degradation and soil salinization increases. Inefficient use weakens the income stability of garden and vegetable farms located on the outskirts of the city. The instability of irrigation in this area leads to quality fluctuations in agricultural products, which has a psychological impact on both the consumer basket and the food security of the city.

Finally, the accumulation of efficiency problems also weakens the city's overall economic dynamism and investment attractiveness. Uncertainties about water security increase the risk premium for new production and service projects, increase the cost of insuring businesses in long-term contracts and create a "hidden cost" in the quality of life for maintaining human capital. Since reputational factors are important in areas such as tourism, education and healthcare, uninterrupted and quality water supply also directly affects the city's "brand" indicators. Thus, the socio-economic consequences of inefficiency are manifested not only at the individual and family level but also in the entire social fabric of the city and in the long-term development trajectory.

Conclusion

Nakhchivan's water security is shaped by the combined effects of limited resources, climate vulnerability and an aging network; as a result, leaks, pressure-quality fluctuations and metering gaps harm both household welfare and the local economy. The solution is not a single "pipe change" but an integrated package: loss capture and renewal of priority pipe segments in DMAs, expansion of smart meters and real-time management with GIS/SCADA, stable operation of treatment plants and green-gray infrastructure for stormwater management and increased reuse for industry/greening (Alegre, Baptista, Cabrera, et al., 2016). This should be complemented by socially equitable tariff design, demand-side management and ongoing education.

Thus, when the tandem of technical modernization + digital governance + social justice is established, Nakhchivan's water services will be more stable, more accessible and sustainable in the long term.

References

1. Alegre, H., Baptista, J. M., Cabrera, E., Cubillo, F., Duarte, P., Hirner, W., Merkel, W., & Parena, R. (2016). *Performance indicators for water supply services* (3rd ed.). IWA Publishing.
2. Aliyev, A. (Ed.). (2020). *Water resources of Azerbaijan and their management*. Science and Education.
3. Asian Development Bank. (2013). *Bi-annual environmental monitoring report: Azerbaijan Water Supply and Sanitation Investment Program—Nakhchivan City WSS (Jan–Jun 2013)*. Asian Development Bank.
4. Azersu OJSC. (2023). *Annual report 2023: Water supply and sanitation indicators*. Azersu OJSC.
5. IPCC. (2022). *Climate change 2022: Impacts, adaptation, and vulnerability (WGII)*. Cambridge University Press.

6. Mammadov, T. (2021). Ecological status and use of water resources in the Nakhchivan Autonomous Republic. *Journal of Ecology and Natural Resources*, (2).
7. Ministry of Ecology and Natural Resources of the Nakhchivan Autonomous Republic. (2023). *Report on monitoring water resources in the Nakhchivan Autonomous Republic*. Ministry of Ecology and Natural Resources of the Nakhchivan Autonomous Republic.
8. Ministry of Ecology and Natural Resources. (2022). *Water resources of Azerbaijan: Annual bulletin*. Ministry of Ecology and Natural Resources.
9. Nakhchivan AR State Statistical Committee. (2024). *Water supply and sewage indicators for Nakhchivan city (2015–2024)*. Nakhchivan AR State Statistical Committee.
10. OECD. (2021). *Water governance in cities & OECD principles on water governance*. OECD Publishing.
11. Salmanov, R. (2022). *Efficient use of water resources and environmental problems*. ADPU Publishing House.
12. UNESCO WWAP. (2022). *The United Nations world water development report 2022: Groundwater—Making the invisible visible*. UNESCO.
13. United Nations. (2023). *SDG 6: Clean water and sanitation – Progress report*. United Nations.
14. WHO/UNICEF Joint Monitoring Programme. (2023). *Progress on household drinking water, sanitation and hygiene*. WHO/UNICEF JMP.
15. World Bank. (2020). *Water resources management in the South Caucasus: Diagnostic and opportunities*. World Bank.

Received: 30.05.2025
Accepted: 13.09.2025