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THE GENERAL STATE OF WATER RESOURCES IN MONTENEGRO

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Water resources are essential for the functioning of societies and ecosystems, affecting public health, food production, industry and overall environmental stability. A country's ability to manage and maintain its water resources is closely related to economic prosperity, social well-being and ecological health. The paper shows Montenegro's current state of water resources, highlighting negative trends and challenges. It focuses on three significant issues: difficulties securing sufficient water quantities, escalating problems related to water protection from floods, and growing threats to humans and the environment due to water pollution and ecosystem destruction. Global climate change exacerbates these challenges, affecting rainfall patterns and leading to destructive water waves. Despite the apparent abundance, the irregular distribution of water resources poses a significant problem, particularly in the Dinaric karst area. The paper discusses limitations in water resource management, emphasising the challenges posed by spatial, ecological, urban, and sociological factors. It also addresses the untapped hydro energy potential in Montenegro, highlighting the country's dependence on electricity imports despite having the capability to generate a substantial portion through hydro energy. The general conclusion emphasises the need for a comprehensive and sustainable approach to solving the complex challenges facing water resources in Montenegro. Finally, the paper calls for increased international cooperation in developing and implementing effective policies for the sustainable use and preservation of water resources as one of the most critical resources of a country.

Keywords: hydro potential, flood protection, hydropower, resource paradox, water pollution, water resources

1 INTRODUCTION

Water, a fundamental and irreplaceable component of our natural environment, is pivotal in sustaining life, ecosystems, and socioeconomic activities. The intricate interplay between water resources and the environment is paramount. As the pressures on global water systems continue to intensify due to population growth, climate change, and anthropogenic activities, understanding the general state of water resources becomes critical.

Montenegro's water resources and water-related activities face several negative, even crisis-inducing trends. Particularly noticeable are the following:

- there is a sudden increase in difficulties in securing necessary water quantities for all types of usage;
- problems related to protection from harmful water effects, especially in flood protection, are intensifying;
- dangers to humans and the environment are increasing due to water pollution and the destruction of aquatic ecosystems.

In recent times, severe water-related issues have become even more complex due to the consequences of global climate change, which are increasingly evident in rainfall and runoff patterns. One of the most severe consequences of global climate change is the worsening of extreme non-stationary phenomena. In summary, due to observed changes in rainfall patterns, especially high intensity, more destructive waves of large water volumes are formed, with severe consequences for settlements, economic and infrastructural objects, and ecosystems. This is followed by long, arid periods, reducing the flow of small waters compared to what was previously considered normal. Extended low-flow periods are observed, jeopardising even watercourses' essential ecological functions. This phenomenon increasingly undermines and renders meaningless the indicators that were once used to assess the water potentials of a country based on average annual values [1].

The relativity and increasing uncertainty in concluding the water potentials of a country, when evaluated through average values, are particularly pronounced in the case of Montenegro. If a specific module of average surface runoff q [$l \cdot s^{-1} \cdot km^2$] is adopted as a measure of water present in a territory, which globally amounts to only 7 $l \cdot s^{-1} \cdot km^2$, Montenegro, with its 43 $l \cdot s^{-1} \cdot km^2$, ranks as one of the wealthiest areas in the world in terms of water formed within its territory because such or even higher specific runoff occurs in only 3 to 4% of the total land area worldwide [1].

In Montenegro, several significant watercourses are formed, flowing in two directions. Significant rivers Piva and Tara flow towards the Black Sea, merging at the exit from Montenegro to form the Drina, one of the most important rivers on the Balkan Peninsula. Draining towards the Adriatic Sea is through the Morača, the main tributary of Lake Skadar, which is vital for the water regimes of the lake, one of the most significant but also the most sensitive aquatic ecosystems in Europe.

2 SPECIAL HYDROLOGICAL SITUATION IN MONTENEGRO

However, hydrological analyses of flow distributions, revealing significant irregularities in space and time, strongly relativise the mentioned optimistic data and present a considerably unfavourable picture when concluding Montenegro's water wealth. Temporal irregularity is one of the most unfavourable in Europe. There are very long low-flow periods when even large rivers, such as Morača, dry up along more prolonged stretches of their beds, with severe consequences for the ecological and social environment [2].

Monthly water availability values of 95% (relevant for water quality protection measures) are more than twenty times less than average. In addition to the extreme example of Morača mentioned earlier, where periods of complete river drying occur at the Zlatica water gauge (although the average flow at that profile is 58.5 m^3/s), a very characteristic case is the Duklov Most water gauge on the Zeta River, where minimum flows drop below 100 l/s (recorded at only 80 l/s), and in longer intervals, even for a few months, have extremely low values, around 200 times (!) less than average [1]. A straightforward comparison is the following: specific runoff in long low-flow periods at some profiles is less than one $l \cdot s^{-1} \cdot km^2$ (Duklov Most q = 0.24 $l \cdot s^{-1} \cdot km^2$), which puts the supposedly abundant water of Montenegro, averaging 43 $l \cdot s^{-1} \cdot km^2$, in a completely different light. Ratios between relevant small monthly flows (95%) and large flows with a probability of 1% on some rivers exceed the ratio of 1:1000, even exceeding 1:2000 (Duklov Most on the Zeta, the ratio of these relevant small and large flows is 0.11 m^3/s: 300 m^3/s, or 1:2700) [1], which falls into the most unfavourable, most irregular water regimes in Europe. It is also relevant that prolonged low-flow periods coincide with the tourist season in the warm part of the year when the demands for all consumer consumption are highest. In low-flow periods, available amounts of groundwater are drastically reduced, causing increasing problems for a series of water supply systems that rely on such sources. All of this shows that thinking from the standpoint of average water quantities can be dangerous for multiple reasons: it leads to incorrect conclusions about the development strategy, not only in the water sector but also much broader; it creates unwarranted optimism about the water potential of the country and feeds the entirely wrong belief that water needs can be satisfied without the implementation of complex systems [3].

The uneven distribution of available water potentials in space is also very pronounced. A significant part of Montenegro's surface belongs to the Dinaric karst area, often with very deep karst bases, numerous sinkholes and karst formations. Such karstified areas are particularly pronounced in the western parts of Montenegro, which, as a result, lack developed surface hydrography and practically have no constant surface runoff [4]. Consequently, in large areas of Montenegro, there is an increasingly evident "resource paradox" that rarely exists in the world: rainfall is high, but there is no surface runoff because water from precipitation (rain, snowmelt) immediately drains through karst forms underground toward the Adriatic Sea or into another watercourse outside the territory of Montenegro, as is the case with underground drainage from part of the Old Montenegro karst toward the Trebišnjica River basin [5].

This "resource paradox" is most evident in areas with the highest rainfall. It is known that the Orjen zone has the highest rainfall in Europe, exceeding 4,500 mm, but due to the exceptional karstification of that area, all these waters immediately sink and cannot be tapped and used. Therefore, even cities on the edge of Orjen (Risan and Herceg Novi) have great difficulties in water supply and must be connected to regional systems with water supplies from distant sources [4]. The same situation applies to other coastal cities and tourist regions (Kotor, Budva, Bar), which have mountains (Lovćen, Rumija) with rainfall over 2,000 mm in the immediate hinterland but still face significant difficulties in water supply during the summer period, in the peak of the tourist season when flows at all karst springs used as water sources are drastically reduced [6].

A particular problem lies in the fact that due to increasingly pronounced spatial, geotechnical, ecological, urban, sociological, cultural, and other limitations, only a more minor part of waters present in the watersheds can be valorised as water resources, i.e., as water that can be regulated in reservoirs and used for rapidly growing needs, as well as for improving water regimes in critical low-flow periods. Therefore, it is characteristic of Montenegro more than any other country in the world that it is rich in water only in average values but lacks sufficient water precisely in periods of most excellent consumption, which coincides with critical hydrological periods when flows are several tens of times lower than average values.

3 CHALLENGES FACING THE WATER SECTOR IN MONTENEGRO

Due to all of this, despite data that, at a superficial glance, might suggest abundant water resources, Montenegro faces evident problems caused by the lack of sufficient water quantities due to unfavourable hydrological phenomena and significant spatial and temporal irregularities in flow. Almost no settlement escapes problems with drinking water supply in specific periods of the year. One of the most evident proofs of the "resource paradox" is the consideration of desalination of seawater as one of the variants for supplying water to settlements in the coastal tourist region, just a few kilometres in a straight line from mountain ridges with an average annual rainfall exceeding 2,000 mm. It's a unique case globally, disrupting the stereotypical paradigm of alleged water abundance [3].

A particularly significant problem is the increasing lag in harnessing hydroenergy potentials, which are not negligible (Table 1). Montenegro is one of the few European countries utilising only 25-27% of its exploitable hydro energy potential, depending on the possible utilisation variant. Developed European countries have fully exploited their hydroenergy potentials, expanding former systems to increase installed capacities and enhance their performance with additional facilities. Surrounding countries have utilised about 50% of their potential and plan more complete realisation.

Due to the lag in hydro-energy infrastructure development, Montenegro has become one of Southeast Europe's largest electricity importers (importing over 40% of consumption) despite its significant water potential, proven by valid technical documentation to be successfully utilised for hydro energy. Its natural capabilities could enable it to cover over 80-85% of its electrical consumption from hydro energy, a renewable and environmentally clean source, aligning with the Kyoto Protocol, securing economic subsidies, and significant political benefits [5,7].

Table 1. Energy potential along the main rivers [8]

River	Power (MNJ)	Energy (GNJh/year)
Piva	155	1361
Tara	257	2255
Ćehotina	53	463
Lim	164	1438
Ibar	14	118
Morača (before meets Zeta)	168	1469
Zeta	229	2007
Mala Rijeka	52	452
Cijevna	32	283
Total	1124	9846

The percentage of agricultural land irrigation is very low (only about 3% of agricultural areas), resulting in negligible economic effects on agricultural production. Freshwater and marine fisheries and mariculture development are poorly developed despite significant natural possibilities, as is the overall use of the sea. Only recently has some progress in bottling high-quality underground water, yielding commercial effects [2].

Considering the natural characteristics of Montenegro, the spatial and temporal distribution of water resources and their users, as well as the interplay of water use, water protection, and protection from water, water management across the entire territory of Montenegro must be conducted uniformly, comprehensively, and rationally. This implies treating all water-related activities as part of spatial planning, environmental and biodiversity protection and executing them as closely connected segments of large integrated development projects [4].

In recent times, even at the mere hint or announcement of projects for the realisation of critical water-related facilities and systems in Montenegro, significant opposition has arisen from various informal interest groups, NGOs, and even political parties. A well-organized action by informal groups successfully halted the implementation of an integral development project in the ”Sastavnica” Drina zone (known as the Buk Bijela Hydroelectric Power Plant) [6]. This will undoubtedly have severe consequences from an economic, energy, and hydro-agricultural standpoint and in the now economically underdeveloped Piva region's social, urban, traffic development, and ecological organisation. A similar practice continued with the suspension of a major integrated development project in the Morača River basin, which has a broad spectrum of goals, some of which are crucial, particularly from an ecological perspective (improving the water regimes of the Morača River) and the protection of cultural-historical and significant high-ranking structures, such as the Morača Monastery [1]. It is undeniable that permanent protection of this nationally and globally significant cultural monument must be addressed as soon as possible, regardless of whether the Morača system is built. All measures for the permanent protection of the entire monastery complex (geotechnical securing of the river terrace on which the monastery is located, road relocation, draining the plateau where high groundwater currently threatens frescoes, organising the entire area around the monastery in line with its sacred functions and the importance of this national and world monument of the highest rank) were envisaged by that integrated project. Therefore, groups advocating for the suspension of this integrated project should consider the consequences of maintaining the current situation without working to protect the monastery's security.

There are several reasons for this opposition, which is becoming a severe obstacle to realising necessary integrated development projects. The key ones are:

- there is still a prevailing, falsely optimistic belief in the public that increasingly serious water management problems can be solved as in the times of "water abundance" without significant river systems;
- the public has not been presented with clear evidence that due to very uneven water regimes, Montenegro cannot meet its needs for water and energy, secure areas along rivers with very flash flood regimes, and maintain good water quality without building reservoirs to redistribute water over time and space;
- it has not been adequately explained to the public that integrated development systems can harmoniously fit into the environment, achieving both goals of spatial planning and environmental protection and goals of water use, organisation, and protection [1].

The globally accepted environmental conservation strategy is not a conservative approach - do nothing, as some conservative circles consider it now - but a strategy based on active water management to improve water regimes in

quantity and quality compared to those existing in rivers without water systems with reservoirs. Purposeful management of headwater reservoirs in watersheds, according to the demands of downstream ecosystems, is expected to improve water regimes, increase small waters, and improve oxygen regimes, creating conditions for more favourable ecological conditions compared to the current state, to preserve water and coastal ecosystems and enrich biodiversity. That's why this strategy is called "enrichment of small waters." Purposeful management of reservoirs in the upper course of the Morača River would improve the regimes of small waters downstream and prevent the current extreme events of completely drying up certain canyon sections [5]. At the same time, most suitably - by the purposeful release of clean water from upstream reservoirs - it could help Lake Skadar in critical ecological conditions, especially in low-water periods in the warm part of the year, when there are increasingly severe deteriorations of ecological conditions due to anthropogenic influences that adversely contribute to the development of eutrophication processes. This is precisely how good ecological statuses of numerous lakes are maintained globally - by actively managing water release from reservoirs at river inflows. Therefore, it is surprising that some opponents of this project, without any evidence, cite that the system will adversely affect Lake Skadar. It is entirely the opposite and easily demonstrable.

4 CONCLUSIONS AND RECOMMENDATIONS FOR THE FUTURE

The analysis of water resources and the approach to integrated development in the water sector are also part of Montenegro's obligations in accordance with several international conventions and recommendations. Let's mention one decisive recommendation from the highest international forum - the United Nations Conference on Environment and Development (Rio de Janeiro, 1992), which recommended that all governments create national sustainable development strategies in the water sector and implement them by 2025 [3].

Considering all these indisputable facts, the rational behaviour of an organised state in the field of water could be summarised in the slogan: Think globally, plan comprehensively, and implement timely! If global thinking and comprehensive planning are adopted, the key long-term strategic commitments would be:

- Transitioning to significantly more rational water and other resource consumption technologies, with mandatory water recirculation and multiple water use. Implementing rationalisation measures to reduce specific water consumption in all consumption spheres.
- Protecting current and future sources of high-quality water. This should be achieved through spatial planning measures and economic policy, with appropriate valorisation of water as a natural resource with value like any other resource.
- Directing a portion of the resource (water) rent to areas where sources are located - incentivising local self-government to protect water, bringing them a constant income. This is particularly important for passive areas where locations for major systems are situated (Morača, Upper Piva, Upper Tara, Ćehotina basin, Lim).
- Since water management systems have stricter location requirements for development than other systems, spatial planning measures are needed to preserve necessary spaces for future development. The fight for water and energy increasingly becomes a battle for space necessary to realise significant water management systems, especially reservoir basins!
- By implementing spatial planning and organising space, the rise of potential flood damages in vulnerable areas should be halted. Prevent unnecessarily, irresponsibly, and uncontrollably constructing expensive structures in endangered areas and demand that society protect these vulnerable zones from infrequent large floods. A crucial warning: protective systems do not increase national wealth and income; they merely shield against flood destruction. Therefore, investing in very expensive protective systems, which would not be necessary if unreasonable construction in flood-prone areas had not imposed them, only hinders the country's development.
- Implement anti-erosion measures to systematically and timely prepare watersheds to construct water management facilities, especially reservoirs. To achieve adequate protection through biological measures, time is required, necessitating a strategy: synchronise anti-erosion protection and watershed management with the planning and implementation of comprehensive systems with reservoirs.
- Addressing institutional and organisational obstacles promptly for implementing comprehensive water management systems at large watersheds is crucial for harnessing water potential and protection from water.
- Patiently and persistently working on public education to understand the necessity of implementing comprehensive water development projects as a crucial precondition for development, spatial organisation, and environmental protection.
- Working on international cooperation and support to assist Montenegro in developing and implementing effective policies for sustainable water resource utilisation and conservation.

5 REFERENCES

[1] Đorđević, B., Sekulić, G., Radulović, M., Šaranović, M. (2010). *Vodni potencijali Crne Gore*. CANU, Montenegro. ISBN 978-86-7215-261-6

[2] Government of Montenegro, Ministry of Sustainable Development and Tourism. (2015). *Rezime drugog nacionalnog izvještaja Crne Gore o klimatskim promjenama prema okvirnoj konvenciji Ujedinjenih Nacija o promjeni klime*.

[3] Radulović, M. M., Stevanović, Z., Radulović, M. (2012). A new approach in assessing recharge of highly karstified terrains – Montenegro case studies. *Environmental Earth Sciences*, 65, 2221-2230. https://doi.org/10.1007/s12665-011-1378-0

[4] Government of Montenegro, Ministry of Agriculture and Rural Development. (2017). *Strategija upravljanja vodama Crne Gore*.

[5] Đorđević, B., Šaranović, M. (2007). *Hidroenergetski potencijali Crne Gore*. CANU, Montenegro. ISBN 978-86-7215-192-3

[6] Đorđević, B., & Sekulić, G. (2015). *Iskorišćenje vodnih potencijala Crne Gore, kao odgovor na politiku iskorišćenja obnovljivih izvora energije*. CANU, Montenegro. ISBN 978-86-7215-357-6

[7] Đorđević, B., Šaranović, M., & Vujadinović, S. (2008). *Uslovi, mogućnosti i kriterijumi za izgradnju malih hidroelektrana u Crnoj Gori*. CANU, Montenegro. ISBN 978-86-7215-206-7

[8] Government of Montenegro. (2001). *Vodoprivredna osnova Crne Gore*.

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