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DNIESTER HYDRO POWER COMPLEX SOCIAL AND ENVIRONMENTAL IMPACT STUDY

Non-technical summary

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Introduction

The “Dniester Hydro Power Complex Social and Environmental Impact Study” project was implemented between September 2018 and December 2021 by the United Nations Development Programme in Moldova (UNDP Moldova), at the request of the Ministry of Environment of the Republic of Moldova (MoE), with the financial support of the Embassy of Sweden in the Republic of Moldova. In addition to the UNDP Moldova experts, a large number of independent experts mainly from the Republic of Moldova, but also from other countries, were involved in this project.

As part of its efforts to protect the Dniester River, including under the Agreement between the Government of the Republic of Moldova and the Cabinet of Ministers of Ukraine on cooperation in the field of protection and sustainable development of the Dniester River basin, signed at Rome in 2012 (Rome Agreement), and taking also into account the various feedbacks received from the members of academia and civil society, the MoE considered that a comprehensive scientific assessment of the adverse effects of the operation of the Dniester Hydropower Complex (DHC) was required in order to better understand the source and extent of these effects on one hand, and to address the Ukrainian authorities for their elimination/minimization and to stop the degradation of ecosystems, restore them and conserve the biodiversity, in accordance with the provisions of the above-mentioned Agreement.

Cooperation with the Ukrainian authorities takes place both within the Commission on Sustainable Use and Protection of the Dniester River Basin (the Dniester Commission), established under the Rome Agreement, as well as within an ad hoc framework for regulating the operation of the DHC through an international agreement, in the context of Ukraine’s plans to further develop the Dniester’s hydropower potential through the construction of hydropower plants.

The objective of the project was the preparation of the Study on the existing environmental and socio-economic impact of the DHC on the territory of the Republic of Moldova. The study provides credible, unbiased, scientifically argued answers to many of the issues raised by the functioning of the DHC. The research results are summarized in this brochure.

The Study is divided into two parts. The first part, regarding the **impact**, focuses on the analysis of river hydrology and hydromorphology, water quality, hydrogeology, hydrobiology, water infrastructure, social and economic impacts.

The second part, concerning **damages**, estimates the possible direct and indirect costs and the disruption and loss of ecosystem services as a result of the existing and planned hydropower infrastructure of DHC in Ukraine on the border with the Republic of Moldova.

The Dniester Hydropower Complex – the impact on the hydrological status of the Dniester River

The Dniester Hydroenergetic Complex - DHC - consists of the Novodnestrovsk reservoir with HPP-1, the buffer reservoir with HPP-2, the artificial reservoir with a pumped storage hydroelectric power plant (HPSP). The reservoirs and the original shape of the Dniester river bed can be seen in figure no. 1.

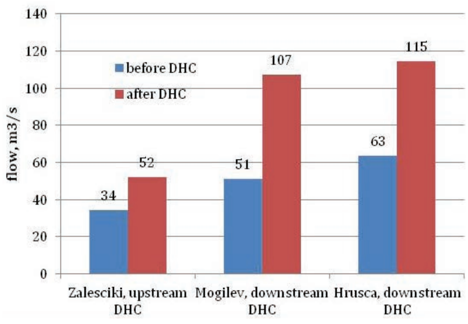
The main impact caused by the construction of dams along the Dniester River is considered to be **the interruption of the longitudinal connectivity** of the river, which in turn limits the upstream-downstream connection, and changes the upstream part into a reservoir while downstream the hydrological regime is controlled by the DHC operators by evacuating the water through the hydrotechnical structures of the dams.

The annual water flow and volume, upstream of the DHC, for the two periods (before and after DHC) are approximately equal. Downstream of DHC, hydrological characteristics decrease: water volumes are reduced from 8.7 km^3 to 7.9 km^3 or by 0.8 km^3, which represents 9.2%. The decrease of water resources continues towards the river mouth where volumes decrease by 1.5 km^3 of water, i.e. by 15%.

On a **monthly** level, in conditions of controlled flow regime, the **trends of water flows** decrease significantly in February-April: March - 40%, April - 27%, February - 18%, during the summer period the changes are minor, while for the autumn period increases by 10-14% are noted. Thus, there is a general trend of average monthly flow decrease for the spring and summer periods on the entire sector downstream of DHC towards the river mouth; an increase in flow is observed for the seasons characterized by lower flow values: autumn and winter;

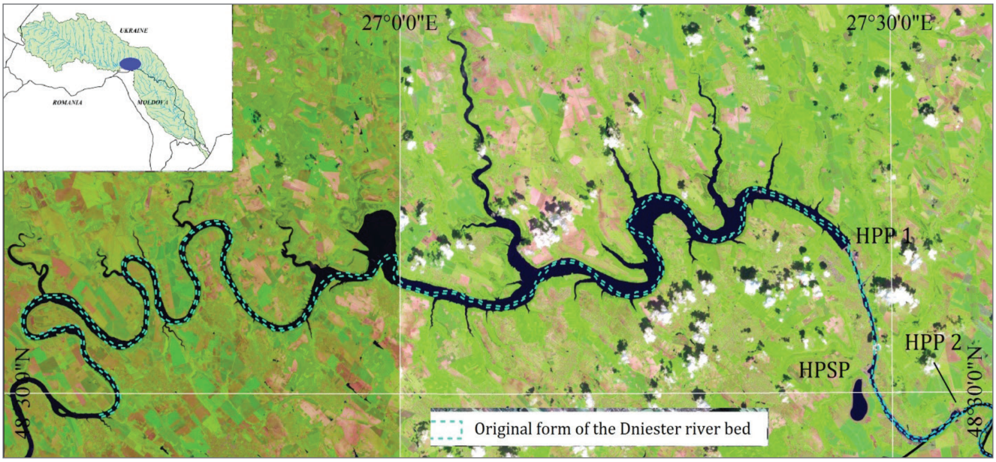
Regarding the **minimum flows**, it can be mentioned that in the upstream part of DHC, for the pre and post DHC periods they are equal to 34 m^3/s and 52 m^3/s, the increase being 52%. Downstream, the minimum daily flows have doubled reaching 107 m^3/s (compared to 51 m^3/s, pre DHC) (Figure no.2). Concerning the observance of the Regulation of DHC functioning and the 100 m^3/s water discharge, we mention that, in the downstream area, during the pre DHC period, the flows with values below 100 m^3/s were on average 62 days/year, which represents 17%, and post DHC, the share decreases by 2%, minimum daily flows below that value being occasionally observed.

Figure 2. Average minimum flow



Regarding the **impact of DHC operation** on the **maximum annual flows**, it can be mentioned that in the upstream part there is a slight increase of these characteristics, while towards the downstream part, there is a reduction of the maximum flows by about 30%. This has decreased the flood risk.

Figure 1. DHC reservoirs and the original form of the Dniester river bed



Source: satellite images Sentinel [https://earthexplorer.usgs.gov], (2019)

Spring floods phase is modified by reducing the maximum flow by about 38% downstream, its duration by about 26%, but also the movement of the manifestation period by about 20-25 days. Decreasing spring floods characteristics has a direct negative impact on the development of aquatic ecosystems.

It should be noted that since the 1990s, experts from Moldova and Ukraine have been making efforts to plan and carry out the so-called **spring ecological floods** – the purpose of which is to provide sufficient water volumes for the Dniester riverbed to ensure reproduction of fish and the stability of the Dniester ecosystems. Its main features should be: duration - 25-30 days, the manifestation period, on average – April 15 - May 15, a maximum flow of ≥800 m^3/s to be maintained for at least a week, total flood volume – 1 km^3. An important element in the planning of the spring ecological flood is the water temperature, which must exceed 12 °C to ensure optimal conditions for the development of ecosystems.

The effect of DHC on **pluvial floods** is manifested by changing the peak flow in the sense of decreasing it by about 25-30% downstream of DHC, transforming the flood wave hydrograph from triangle to trapezoid, thus causing a delay in the occurrence of the maximum flow by increasing the rising limb and slightly decreasing the recession limb of the flood wave. However, the increase in the frequency of natural floods must lead DHC to improve its preparedness for the management of these phenomena and the protection of areas from the downstream from major floods.

One of the direct effects of DHC operation is the **pulsating flow wave effect caused by the operation of HPP-2 turbines** or **the so-called hydropeaking effect**. It was found that the intraday level amplitude downstream of DHC amounts to 52 cm (5 km downstream, Naslavcea post). As the distance from HPP-2 increases, the pulsating effect is reduced, and only towards Soroca the fluctuation of water level reaches the values of 20 cm and towards Sanatauca of 14 cm. Thus the sector that is significantly influenced by the pulsating effect of the water discharge waves is over 100 km in length. On average, the rates of increase and decrease of water at level Naslavcea are 0.35 cm / min and 0.19 cm / min, while at Soroca and Sanatauca - the rates are ≤ 0.04 cm / min.

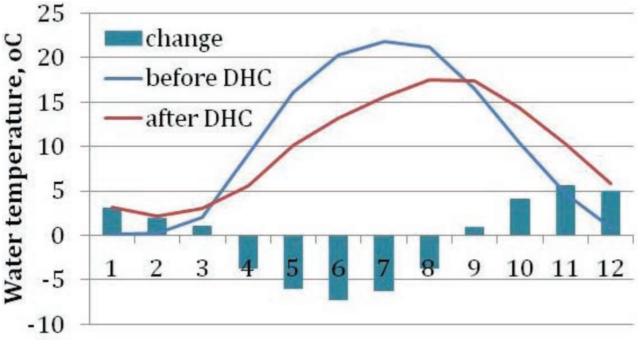
The hourly analysis of water levels shows that, in general, these increase in the afternoon and in the evening, when the demand for electricity is high. During these periods, water level values increase significantly in comparison to those between 00:00 and 10:00.

Another significant impact is attributed to the **change in the thermal regime of the water**. The outflow through the HPP-1 turbines takes place from the lower water layers of the reservoir. Here the water temperature is low and remains constant throughout the year, as it is not influenced by climatic factors (only the water on the reservoir surface changes its temperature under the action of the climatic factor). Thus, the average annual water temperature decreases downstream of DHC (p. Moghilev-Podolsk from 10.29 °C - pre DHC to 9.86 °C post DHC), it remains unchanged near the sector of p. Hrusca 10.4 °C), and

begins to rise from the Camenca area to the estuary. Thus, the sector that is subject to thermal changes is over 140 km in length. On a monthly basis, there is a decrease in the water temperature in the spring-summer period, and an increase in the autumn-winter periods downstream of DHC. In the summer season the temperature change is the biggest, if pre DHC temperatures were on average 20-21 °C then post DHC, they are already by 3.9 -7.2 °C lower and become in June - 13.1 °C, July - 15.6 °C, August - 17.5 °C. It is observed that post DHC maximum temperatures range from July-August to August-September, with values rising to 17.5 °C (3.6 °C lower than pre DHC) is reflected in Figure no. 3.

As a result of the construction of DHC, the **sediment transport process** was altered significantly. If pre DHC the suspended sediments were 160 kg/s at Moghilev-Podolsk and 230 kg/s at Hrusca then post DHC in these regions the values are reduced to 2.8 kg/s and at Hrusca - 19.6 kg/s. Therefore, because of DHC, suspended sediments decreased by 92-98%. The significant decrease in sediment volumes is specific to all months of the year. The reduction of sediment transport has increased the transparency of water, which as a result influences the development of the aquatic ecosystems.

Figure 3. Dynamics of the average monthly water temperature downstream DHC
(at p. Moghilev-Podolsk)



The Dniester Hydropower Complex has significantly reduced the bio-potential of the Dniester river

The functioning of the Dniester Hydropower Complex has led to a decrease in the number of phytoplankton species in the Dniester from 334 in 1971-1975 to 225 in 1990-2009. Also, there were structural changes of phytoplankton, which were revealed by a 1.5-fold reduction in species composition, a decrease in the number of oligosaprob species (living in clean waters, such as green algae), the predominance of mesosaprob species (which live in medium polluted water). After 2013, the following species disappeared from the structure of the Dniester phytoplankton: Polyedriopsis spinulosa, Desmatractum indutum, Characium falcatum, Diacanthos belenophorus and Closterium lanceolatum. At the same time, new invasive species have emerged, which are replacing local species. Because of the change in the thermal and hydrological regime of the Dniester waters, the number of species with a low resistance to temperature and hydrological regime fluctuations has been reduced. Unfavourable conditions are created on the Middle Dniester for the development of thermophilic chlorophyte species, more and more frequently, there are specific algae for cold waters. Worth mentioning that these processes are also influenced by the discharge of wastewater from the town of Soroca and other wastewaters, which are discharged in the Dniester River.

The Dniester is being silted, loses its self-purification capacity and turns into a lake

Until the construction of the DHC, invasive species were virtually uncommon or extremely rare. After the construction, the hydrological conditions have changed, contributing to reduction of the flow velocity, increase of water transparency, excessive growth of plants which, eventually, created new living conditions, making possible the intense development of invasive species, scarcely seen before.

The functioning of the DHC has led to the siltation the Dniester River. This siltation is confirmed by the appearance of the lily pond Butomus umbellatus, which in some places forms extensive thickets, particularly in the area of the Middle Dniester, as this plant prefers muddy soils. Mud deposits in some places cover almost all of the riverbank areas and partly the main riverbed.

> River siltation significantly reduces its capacity for self-purification, which the potential of the Dniester as aquatic environment.

The negative effects have also been felt at the level of zooplankton, which has an important role in the ecosystem, forming the foundation of the nutrient base of water bodies and actively participating in the self-purification processes of aquatic ecosystems. Because of the hydrotechnical

construction, there has been a considerable restructuring of the taxonomic composition of zooplankton (reduction of the number of rheophilic species or those who prefer running waters, and increase of the number of limnophiles species, who prefer stagnant waters), their numbers and biomass have decreased. By 2018, the quantitative development of zooplankton in the Middle Dniester has decreased considerably and amounted to 2200 ex./m^3 compared to 16 100 ex./ m^3 between 2000-2002 and 212 400 ex./m^3 – in the 1950s.

The deep river fauna was also affected by the construction and exploitation of DHC. Thus there has been a decrease in the productivity of the main groups of hydrobionts (aquatic organisms), which are the basic food for fish: zooplankton by 4.6–7.3 times or zoobenthos (organisms that live on the bottom of the lake) by 5–6 times.

Considerable quantities of fish have disappeared

The Dniester River has lost a significant part of the amount of fish that used to live in its riverbed, due to the functioning of the DHC. 19 species have disappeared in the middle sector of the Dniester, and in the lower sector – 15 species of fish. The number of fish species, including valuable fish species, has decreased and the share of small, small-cycle, low value fish species has increased. A general fall in fish stocks in the Middle and Lower Dniester has been recorded, due to the reduction in the number of fish breeding places, as a consequence of a decrease in water flow during spawning, which primarily reduced (eliminated) the breeding places of phytophilic fish species, which constitutes more than 50% of the river's diversity.

Another cause of declining fish stocks in the Middle Dniester is conditioned by the nature of the operation of the DHC, particularly, by the discharge of cold water, from

the lower layers of the reservoir with HPP-1. The water discharged through the turbines of the hydrotechnical node all year round has a temperature of 4 °C, which causes the disturbance of the natural thermal regime on the middle sector of the Dniester downstream and in the Dubasari accumulation lake.

Uneven discharge of water from the reservoirs during fish spawning causes a significant change in the water level in the river, and as a result roe often end up on a dry surface, dry out and perish.

The construction and operation of the Dniester Hydropower Complex changed the hydrological regime of the Dniester, which affected its biological diversity and the productivity of its flora and fauna.

The impact of the Dniester Hydropower Complex on the water quality of the Dniester River

The Dniester Hydropower Complex has also influenced the water quality along the river downstream of the reservoirs with HPP-1 and HPP-2. Thus, the content of suspended sediments decreases sharply in the Dniester downstream of the hydropower complex, where water becomes transparent. The reservoir with HPP-1 acts as a sort of "trap" holding back the movement of suspensions.

The DHC has affected the content of heavy metals in the Dniester waters. After discharge from the hydropower complex, the content of copper, zinc, etc., and other toxic organic compounds, which absorb onto particles and colloids, is reduced. These pollutants are 'trapped' in the main reservoir and are deposited at the bottom of this water body and do not move downstream. After the discharge from HPP-2,

mainly dissolved forms of metals are present in the water. Their total content is slightly reduced and maximum values of some metals in the water decrease.

The content of biogens, in particular ammonium and nitrate ions, decreases compared to the observation point located upstream from the reservoir. Water coming downstream is less rich in nutrients. Maximum values of ammonium ions (the most toxic form of nitrate in the water) are much lower after the discharge of water from HPP-2 compared to the river upstream of the DHC main reservoir.

Average dissolved oxygen values in water are practically the same both upstream and downstream of the reservoir, but oxygen concentration fluctuations downstream of the dam are noticeably higher, which is clearly caused by the operation of the hydropower complex. There have been recorded peaks of high oxygen content - when discharge takes place, alternating with a visible drop in oxygen content in the water - when discharge is minimal or absent.

The effects of the hydropower plants in Ukraine on tourism and recreation on the territory of the Republic of Moldova

The Dniester Hydropower Complex has several negative effects on areas and industries relevant to travel and tourism consumption, such as shipping, tourism and recreation. These negative effects subsequently also lead to a decrease in economic parameters, which ultimately have major social consequences, such as missed profits or fewer jobs.

The Dniester has practically ceased to be a tourist destination on an important Moldovan segment downstream of Naslavcea, due to factors caused solely by the DHC (low water temperature, hydropeaking, retention of natural sediments, reduction of flow speed, etc.) Under these conditions, local entrepreneurs are deprived of the opportunity to use the Dniester for tourism in many localities along the river and are forced to transfer their tourist activities to other economically friendlier areas.

Low water **temperatures** are shrinking the area appropriate for bathing in the river and shortening the suitable bathing season. The section of the Dniester between Naslavcea and Rezina is the area most affected by low water temperatures. Due to the change in the thermal regime and the drastic shortening of the bathing season, river beaches are abandoned and taken off the tourist circuit.

In addition, **unnatural fluctuations** in river water (known as hydropeaking) lead to flooding of beaches or islands, the areas of the banks with the highest concentration of natural tourist attractions, reducing their attractiveness and accessibility. At the same time, the phenomenon affects the landscape and natural areas. The perimeter most affected by daily water fluctuations is home to more than half of the state-protected natural areas in the localities along the river. The unnatural pulsating effect of the water, coupled with the reduction in water velocity, also leads to the

silting up of the navigable portion of the river and makes cruises on the Dniester or other forms of recreational and tourist boat operation impossible.

The substantial decrease of sediments (sand and gravel) leads to an abundance of aquatic vegetation, which worsens accessibility to beaches and islands, makes it difficult to practice recreational boating activities, alters the Dniester landscape, and all together negatively influences the attractiveness of vast sections of the Dniester and its coast for recreational use.

Landscapes affected by the direct effects of DHC activity, including unnatural flooding, abundant aquatic vegetation, muddy beaches devoid of sand, periodically flooded islands, change the traditional local culture, including occupations related to the exploitation of river resources. These are in danger of disappearing and no longer being used for tourism purposes. Also because of these changes caused by human factors, quality eco-labels cannot be applied to HoReCa establishments.

Altogether, the value tourist consumption potential present but unused at the Dniester for both countries is higher than the value of energy produced by hydropower plants and used only by Ukraine.

To mitigate these effects, the experts in the field come up with several recommendations:

- inventory and continuously monitoring of tourist locations exposed to the pressures of DHC modifying factors;
- organize the DHC activity so that the pulsating flow of water does not affect areas of beaches, islands and large areas of tourist attractions;
- additional and periodic covering of beaches with river sand to comply with the conditions of their use;
- clean and maintain the fairway for pleasure craft on the common stretch of the river border;
- promote measures to compensate entrepreneurs for losses in river tourism;
- promote measures to compensate and restore the natural attractions affected as a consequence of the functioning of the DHC (river forests, protected natural areas, endangered species, etc.);
- financing a programme to promote tourism on the Dniester downstream of the DHC, from Naslavcea to the Black Sea;
- promotion of bilateral joint tourist routes on both banks of the Dniester.

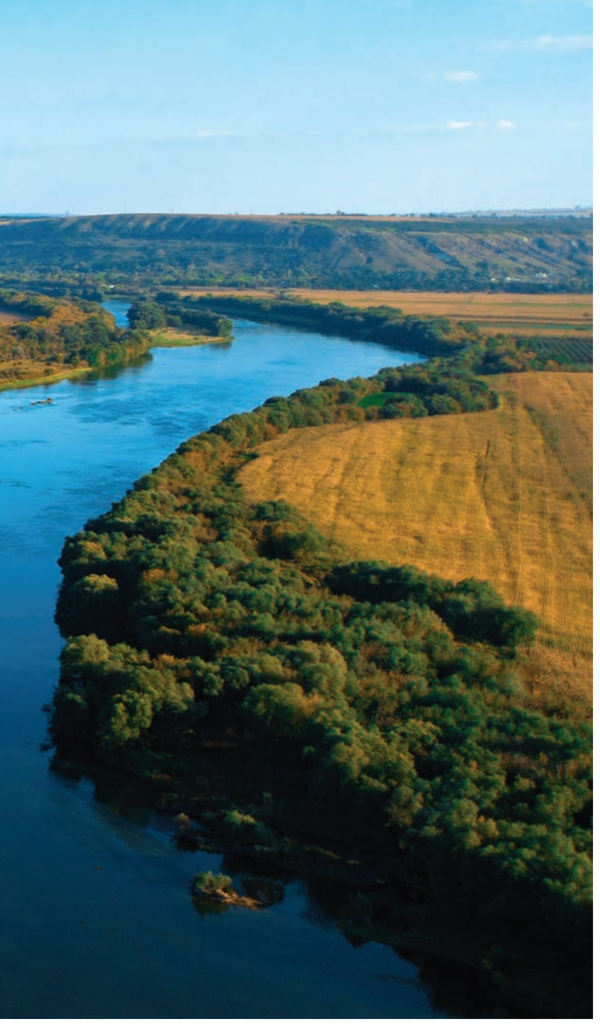
The Dniester Hydropower Complex has an impact both on the aquatic environment, as well as on the riparian ecosystems

The activity of the Dniester Hydropower Complex has a negative impact on the environment, including on plant and animal life in the region, with direct, indirect and cumulative effects on both the Dniester River aquatic environment and the riparian ecosystems.

The forest vegetation along the river is represented by zonal forests (sessile oak - ash, oak-common hornbeam, oak-blackthorn, etc.) and azonal forests (floodplain forests). Riparian forests (located in transition zones between aquatic and terrestrial ecosystems) are very sensitive to changes in the hydrological regime of the river (seasonal flow variations, hydropeaking, temperature changes) and environmental changes (pollution, climate change, etc.). The negative impact of these factors on floodplain forest ecosystems can be seen in the alteration of their functionality (decrease in the physiological and reproductive capacities of trees, with an obvious

decline in poplar and willow ecosystems). The impact of moisture deficit is higher on young trees and old trees (through inhibition of seed formation/development, seed germination and water stress). Thus, the decrease in flood-prone areas in the Dniester valley, particularly in the Lower Dniester (decrease in the number of stagnant areas, water basins, wetlands, lowering of the water table in these regions, etc.), combined with drying climate (presence of long droughts), can affect floodplain forests (willow stands, wicker thickets, aspen stands mixed with other species specific for wetlands, etc.). The cumulative impact, conditioned by anthropogenic actions (deforestation, inclusion of riparian lands in the agricultural circuit, poor management, etc.) and current trends of environmental changes, including climate change, present for forest ecosystems factors that induce a decrease in chorology/distribution, changes in quantitative and qualitative parameters.

It was found that the DHC had an impact on bird populations in the Republic of Moldova, particularly for species associated



with aquatic areas. The scientific data also indicate a decrease in the number of predatory bird species (between 2009 and 2015) caused by the loss of favorable areas and simultaneously by increased anthropogenic activity.

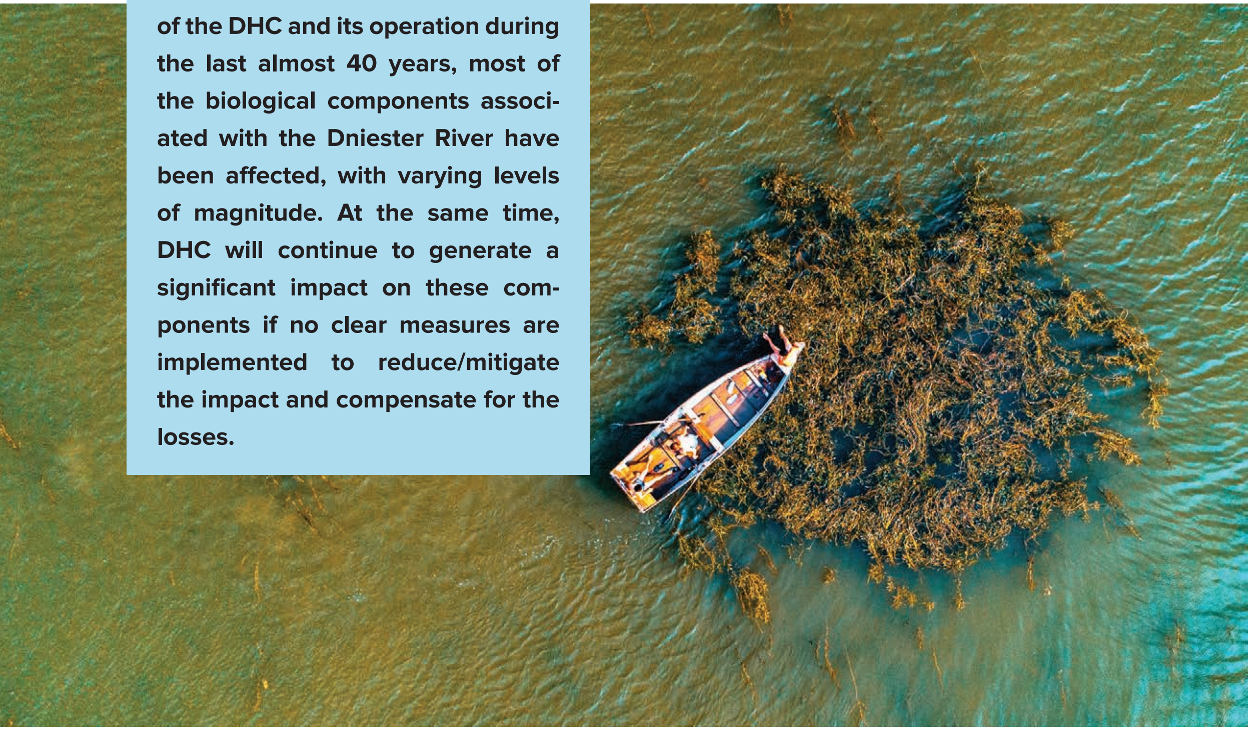
The above negative impacts can be explained by a general reduction in water flows (especially reduced spring flows) and reduced lateral connectivity of the river with the floodplain. As a result, foraging or breeding habitat has been partially lost for bird species associated with the aquatic areas. The reduction in the amount of food available for waterfowl species as a consequence of the significant decrease in fish resources is also a significant impact; fish populations are estimated to have decreased 15.6 times between 1950 and 2000. It is also noted that intra-day variations in water level (hydropeaking) lead to a size decrease of the areas where nesting of waterbirds (mainly those nesting in reeds or in the riparian area) is possible, both by directly affecting already established nests and by preventing the establishment of new nests.

By reducing flows, including spring flows, decreasing the lateral connectivity of the river, the DHC contributed to a loss of habitat for water-dependent species over an area of about 535 ha (corresponding to wetlands that had been periodically flooded before the construction of the DHC in the Middle Dniester Sector, and which ceased to be flooded after the construction of the complex). Thus, it is estimated that the DHC has caused a loss of about 3.6% of the optimal habitat of several species of fish, amphibians, birds, etc.

The impact of DHC on state protected natural areas, nationally and internationally protected species of flora and fauna, analysed from the perspective of EU nature and biodiversity policies (Directive on Birds and Directive on Habitats, 1992) indicates that the so-called “adequate” preservation stage for natural habitats and species of community interest is not achieved. These European policies broadly impose the following requirements:

- the area of natural extension and the territories falling within the protected area are stable or increasing;
- the specific structure and functions necessary for the long-term maintenance of the area exist and are likely to continue to exist in the foreseeable future; and
- the preservation stage of the species present is adequate (positive population dynamics, no threat to the range of the species, habitat favorable to development, no disturbance, no damage, etc.).

In conclusion, it can be considered that as a result of the construction of the DHC and its operation during the last almost 40 years, most of the biological components associated with the Dniester River have been affected, with varying levels of magnitude. At the same time, DHC will continue to generate a significant impact on these components if no clear measures are implemented to reduce/mitigate the impact and compensate for the losses.



How does the Dniester Hydropower Complex influence water supply in various socio-economic sectors

The Dniester Hydropower Complex has a significant impact on various sectors that depend on the quality and volume of water from the Dniester. The Dniester River is the most important water artery and source of drinking and technological water in the Republic of Moldova.

Under the current difficult social and economic conditions, as well because of accelerated climate change, supplying water to the population, public institutions and economic agents represents a key public policy requirement. Moreover, ensuring an even and sufficient water flow in the Dniester River and its tributaries is vital for the integrity and maintenance of the floodplain and aquatic ecosystems, their reproduction and the conservation of biodiversity.

The volume of water abstracted and used is limited by the demand for water, the available water resources, as well as the capacities for water abstraction, transport, treatment and use for various socio-economic activities.

The factors influencing the water resources

The **demand and consumption of water** is determined by the number and size of urban and rural centres, the volumes of industrial and agricultural production, of the irrigated areas, the existing aqueducts of rural settlements, and the amount and regime of atmospheric precipitation, especially for agricultural needs.

The **largest number** of users of water supplied from the Dniester is recorded in the lower reaches of the river - from the town of Dubasari to the mouths of the river.

In the northern area close to the DHC, the number of primary users has fallen considerably lately. In the sector from Naslavcea to the town of Soroca situated in the impact area, only 47 primary water users (2.8%) have been registered, see Figure no 4. The drop in the number of primary users and the volume of water abstracted and used from the Dniester is caused not only by the decline in population and agro-industrial activity, but also by the adverse effects of the operation of the DHC: hydropeaking and lower temperature water discharge (up to 7-10°C) during the months of May and June, when there is an increased demand for irrigation of agricultural crops. The temperature of the river water changed considerably once the DHC was built.

Risks

The construction of the DHC aimed to achieve major social-economic objectives for that time, in particular, the regulation of flows and the prevention of massive floods, the storage of the necessary water for domestic, agricultural and industrial uses, the development of modern fish farming, and the extensive irrigation of land.

In reality, the operation of the DHC has had a negative impact on the adjacent territories, associated with negative consequences on the environment, including on the economy and population of the riparian regions of the Dniester. At the same time, the risk of the situation worsening

will persist in the event of failure to comply with the DHC's operating regulations in terms of ensuring the regulated flow rates and downstream discharge requirements.

The agricultural enterprises as well as the industrial enterprises in the municipalities of Balti, Chisinau, and Ribnita, which do not have alternative sources of sufficient water supply, will be significantly affected. In addition, the impact on industrial and agricultural enterprises will also increase as a consequence of the priorities set for the supply of drinking water to the population.

The insufficient discharge of water from the DHC reservoir will make it difficult to meet irrigation water needs, and will significantly limit the capacity of irrigation water distribution through the main aqueducts.

The water discharge of lower-than-normal temperature in May-June will continue to significantly limit the capacities of water use for irrigation , which requires searching for costlier alternative solutions.

Reduction of flow speed and the increase of water transparency, which contributes to the massive development of the upper aquatic vegetation and causes the subsequent siltation of the river, will constantly worsen the conditions for water abstraction as well as its irrigation characteristics.

The destruction and disappearance of the beaches in the area directly impacted by

the DHC, coupled with the decrease of the water temperature in the river, will significantly reduce the attractiveness of the area for tourism and recreation and will reduce tourist and recreational activities.

The deterioration of ecosystems and the loss of biodiversity will further reduce the development potential of ecotourism and, consequently, the opportunities for economic development of the riparian area and the additional income for the local population.

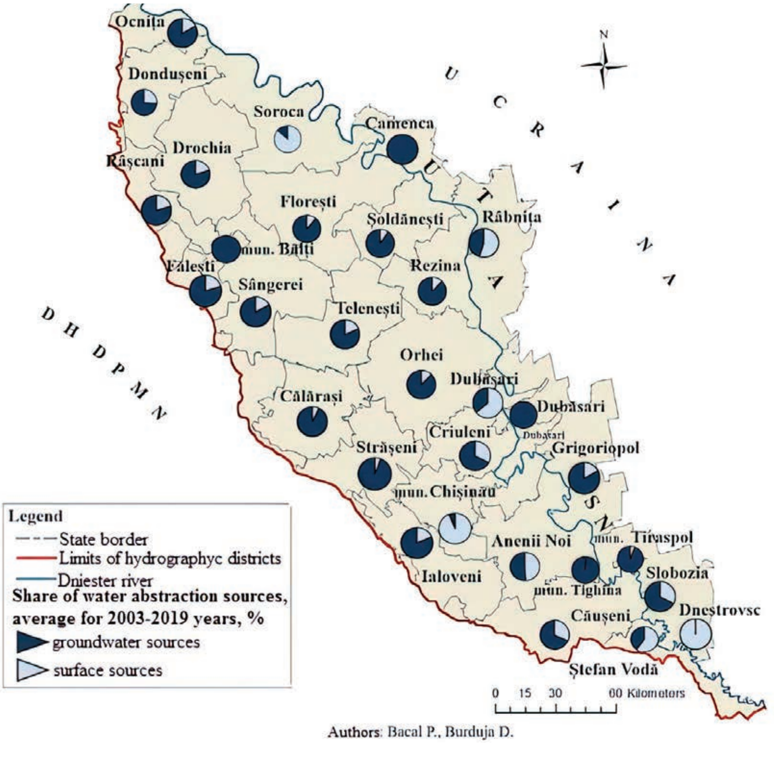
Compensation of environmental and socio-economic losses and rehabilitation of riparian area will entail very high social and economic costs.

Solutions

In order to successfully develop and implement policies for the sustainable use and management of water resources, a comprehensive analysis of the sources and capacities of water abstraction and water use for various socio-economic activities and ecological-economic functions is required.

Forecasting the needs and potential for the supply of suitable water resources should be carried out by taking into account the risks of worsening the state of ecosystems and losing the ecosystem services as a result of the impact of the DHC.

Figure 4. Share of water supply sources in districts and municipalities of the Dniester basin district, on average for 2003-2019



The cost of ecosystem services, lost due to the Dniester hydropower complex construction, reaches tens of millions of US dollars

The Dniester Hydropower Complex (DHC), located on the territory of Ukraine, was commissioned more than 30 years ago. However, in the last decade, it has attracted particular attention in connection with the Ukrainian authorities' plans to expand it by installing new hydro turbines. This can cause enormous damage to the Dniester River ecosystems and riparian population, more or less associated with the river.

The DHC expansion may negatively affect the most people of the Republic of Moldova and Odessa region, for which the Dniester is the main source of drinking and domestic water supply, as well as an important source of land irrigation, on which the sustainability of agriculture in the river basin largely depends. Although there are different scenarios, from moderate to catastrophic, of the DHC units expansion, it is not possible to calculate accurately the potential damage that could be caused by the proposed actions. Nevertheless, using various methods, it is possible to evaluate the damage that DHC brings on the river and its ecosystem services.

What are the ecosystem services?

The concept of *ecosystems services (ESs),* introduced by the GEF (Global Environment Facility) in 2018, defines them as "the many and varied benefits to humans provided by the natural environment and from healthy ecosystems."

Ecosystems can provide a variety of ecosystem services, which are generally classified into the following categories or types: *provisioning, regulating, habitat conservation, and cultural services.* Such services can be provided both as values that can be used and values without use. The latter are associated with the awareness that the natural environment exists and is preserved, for example, for future generations; this category is difficult to assess from a monetary point of view. When the point is about values that are used or can be used, their economic valuation quantitatively expresses, in monetary terms, the benefits brought by ecosystems, as well as the influence of their change on the population well-being.

The relationship between DHC and adverse changes in the Dniester ecosystems, as well as the resulting losses of ecosystem services, is well established. The construction of dams and their subsequent

operation lead to a significant change in the river hydrological regime, which in turn causes changes in river ecosystems and, ultimately, a wide range of negative consequences, from the loss of biological diversity of flora and fauna to the water supply and irrigation system damages.

In particular, an evaluation of the losses in water supply services based on a comparison of the Dniester flow volume in periods before and after DHC construction (1991-2015 vs. 1951-1980), caused by its operation, amount to about $ 27 million annually (at the market price of drinking water in Moldova 25 USD per m^3 on average).

In addition, some peculiarities of the DHC design and operation caused a decrease in the maximum flow rates and an increase in water transparency in the middle Dniester, which provokes the massive development of higher aquatic vegetation. The increased growth of algae and macrophytes provokes intensive siltation of the vast sections of the river channel which, in turn, affects the conditions for water intake for irrigation needs (frequent clogging of filters at water intake points) and also impairs water irrigating characteristics.

In this regard, with the current areas of irrigated lands, only the additional costs of water user associations for irrigation can amount to $ 2.9 thousand per year. Although this figure looks small, it should be considered in the context of an expected increase in irrigated areas and a decrease in the effectiveness of state support. As a result, the problem of an increase in operating costs, driven by a deterioration of water irrigating characteristics, is likely to increase in the future.

Decrease in quantity and quality of fish stocks

The loss of ecosystem services supporting fisheries has several components. Firstly, there are direct losses associated with reduced fish catches. If in the Dniester before the DHC construction about 93.2 tons of fish were caught annually, now the catch is only about 20 tons. Along with the general decline in fish stocks, a particularly significant decline in the resources of commercially valuable species takes place.

Further, the costs of maintaining the fish resources are also considered as a loss in the economic value of this ecosystem service. For example, juveniles of various fish species are released annually to maintain fish stocks.

Finally, an objective change in the scale of recreational fishing, caused by a decrease in fish stocks, leads to losses associated with a drop in income from this ecosystem service due to a decrease in the volume of annual fishing tickets sales.

Ecosystems' costs on tens of millions of US dollars

In addition to the loss of ecosystems' provisioning services, which are easier to evaluate economically, there are also losses of regulating services associated with changes in the functionality of forests on the Dniester banks, in the decrease of productivity of grass ecosystems and wetlands. As a result, the potential of ecosystem services for climate and air quality regulation (carbon sequestration, assimilation potential), water purification and habitat conservation decreases as well.

Changes in the Dniester flow and morphology (siltation, etc.) and in the temperature and humidity conditions of its basin, which were caused by the DHC operation and have led to negative consequences in aquatic and riparian ecosystems, affected also the attractiveness of recreational areas and economic value of their services. These losses limit the income of the local population and budget revenues, which significantly reduces the potential for socio-economic development of the Dniester riparian territories.

In general, the carried out economic valuation has showed the current value of ecosystem services losses, resulted from the DHC impacts, amounts in Moldova to tens of millions of US dollars from which 75% are provided by aquatic ecosystems, 22% – by wetlands and 3% – by forest and grass ecosystems.

The compensatory measures for the impact of the Dniester Hydropower Complex on the environment and biodiversity in the Republic of Moldova

The Dniester River Basin includes various interconnected systems covering about 70% of the territory of the Republic of Moldova. Although ecosystems can re-establish some of their lost elements, nevertheless the impact of DHC is so great that ensuring the potential for ecosystem recovery requires a bilateral approach involving both the Republic of Moldova and Ukraine. This is because any change in certain food chain links is felt by other chains and even the whole food web.

Any cost that would presume restoration and conservation of ecosystems and their elements, including the provision of a wardenship and protection regime for potential breeding areas, will not fully recover losses in ecosystems. However, the proposed compensatory actions could contribute to the existence and functioning of ecosystem elements.

The affected fish stocks in the Dniester River require restoration for ensuring the trophic security of the ecosystem

Hydroelectric dams have fragmented the river and modified the hydrological parameters of the Dniester. As a result, the number of fish of high and medium economic and ecological value has decreased at least 40 times, while low-value fish, such as flounder, smelt, burbot, perch, white bream, red mullet and European catfish, have multiplied in their place.

Valuable species include the sterlet, listed in the Red Books of Moldova and Ukraine as being endangered, and the only sturgeon species still to be found in the middle section of the Dniester between the Naslavcea and Dubasari dams. According to recorded data, before the construction of the DHC up to 200 sturgeon could be found/captured, nowadays this number is at most 5 per year. Other valuable species are carp, horse mackerel, pike and moray eel.

Catches of medium-value fish have declined from over 83 tons before 1983, when DHC became operational, to 2.1 tons today. In contrast, catches of low-value fish have increased from 34 to 58 tons of fish per year, replacing valuable species.

The floodplain forests affected by hydrological disturbances need restoration to maintain their ecological integrity

According to data from the Moldsilva Agency's forest management plans (updated every 10 years), compared with field research, a trend of substitution of common oak by sessile oak and hornbeam was observed, particularly in the Naslavcea - Dubasari sector, but also further downstream towards Talmaza. Although related, these species also have important habitat differences. Thus, common oak grows poorly on habitats with insufficient water, while sessile oak is less demanding of soil and moisture levels.

Therefore, the change in the hydrological regime has affected the territorial repositioning of these two species – and this change in time/space was quantified using area indicators – how much the area covered by oaks has shrunk – and productivity expressed in m3 per hectare.

According to data from the table below (Figure no. 5), between 1993 and 2016, the area of forests covered with common oak has shrunk by 423.4 hectares or at a rate of about 20 hectares per year. The dynamic of the yearly average growth was negative from 0.2 to 0.9 m^3/ha. The average production class, according to tree class categories from 1 (very good quality) to 5 (degraded), registered different values tending towards the deterioration of the stand by about 0.1 to 0.4 units.

The Lower Dniester Plain hosts sectors of secular forest with the presence of white poplar, which also provides habitat for many globally protected species. As a result of the influence of DHC, the floodplain forests with the presence of white poplar, which used to cover about 1324 hectares in the Talmaza Forestry Park, have lost about 28 hectares of their area, which are replaced by hybrids of Euro-American poplar.

Possibilities of compensating for the damage caused by DHC

Five types of compensatory measures are proposed to compensate for damage and to restore/conserve ecosystems, and only feasible modalities are considered:

1. Measures for revitalizing the water bodies of Moldova;
2. Measures for sediments (sand/gravel) resupply of the areas downstream of the DHC, which would re-establish the balance of mineral substances and contribute to the recovery of the attractiveness and the cultural and aesthetic values for the development of regional tourism;
3. Measures for the re-establishment and the conservation of the aquatic organisms and for the re-establishment of the forests/groves of trees through the promotion of native species;
4. Measures for the full conservation of biodiversity by strengthening and extending the network of protected areas in the Dniester River valley on the territory of the Republic of Moldova, but also the implementation of the concept of creating the National Ecological Network with the Emerald Network;
5. Technical measures for the administration, analysis and monitoring of the DHC operation with the participation of representatives of the Republic of Moldova and of Ukraine as well as the revision of the legal status of the dam with HPP-2 and the approval of compensation for lost ecosystem services.

Figure 5. Evolution of areas, annual average growth and average production class of oak groves/forests on the Otaci-Soldanesti section between 1993 and 2016

Forest district	Indicators	Baseline period (years)			Difference (loss)
		1993	2004-2006	2015-2016	
Otaci	Area (ha)		[44%]	[43%]	**-15**
	Annual average growth (m^3/ha)		4,8	3,9	**-0,9**
	Average production class (1-5)		3,4	3,5	**-0,1**
Soroca	Area (ha)		1156,9	1011,0	**-145,9**
	Annual average growth (m^3/ha)		3,7	3,3	**-0,4**
	Average production class (1-5)		3,4	3,5	**-0,1**
Șolcani	Area (ha)		944,7	938,5	**-6,2**
	Annual average growth (m^3/ha)		4,2	4,4	+0,2
	Average production class (1-5)		3,7	3,7	0
Cuhurești	Area (ha)	1305,9	1150	1067,5	**-238,4**
	Annual average growth (m^3/ha)	4,3	3,4	4,1	**-0,2**
	Average production class (1-5)				
Șoldănești	Area (ha)		1409,7	1349,1	**-18,2**
	Annual average growth (m^3/ha)		3,6	3,2	**-0,4**
	Average production class (1-5)				

Authors: Lozan A. & Talpă N., 2021 *(in red – areas that are shrinking)*

Conclusion

As a result of the study, it was found that the most important aspects of the impact of DHC operation can be divided into three categories:

- ***with negative effect*** - the impact on the hydrological state (hydropeaking effect), the morphological state (sediment transport), river temperature regime, on aquatic organisms (increased macrophyte-coated surfaces, decreased level of zooplankton and zoobenthos), significant impact on ichthyofauna, on ecosystem services (water use services, assurance with fish, with wood mass, hay, carbon absorption, water purification function, habitats maintenance, cultural services), on the socio-economic situation (impact on agriculture, industry, tourism, contribution to demographic decline and others);
- ***with regulatory effect*** - the minimum flows have doubled, and a minimum flow of 100 m3/s is ensured (mitigation of drought effects), the maximum flows were reduced in order to attenuate flood risks, seasonal flow regulation takes place;
- ***effects that need to be further studied*** - lack of certainty as regard to the permanent discharge of 100 m3/s, water losses through infiltration, volume of infiltrations, impact on groundwater, increased risk of moisture excess in neighbouring areas, non-compliance with DHC operation rules (including those as a consequence of human and technical errors).

The study scientifically confirms that the DHC has a significant adverse impact on the environment, and this impact, according to national and international environmental regulations, must be eliminated or reduced, and the losses incurred need to be compensated. The Ministry of Environment of the Republic of Moldova is thus provided with the scientific support that justifies taking certain measures, mainly in cooperation with the Ukrainian partners and secondarily through policies, programs and plans for protection of water resources, other natural resources and ecosystems of the Dniester river basin.

Contents

DNIESTER HYDRO POWER COMPLEX SOCIAL AND ENVIRONMENTAL IMPACT STUDY