The peculiarities of the use of water resources in the Dniester hydrographical district (sector of the Republic of Moldova)

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Abstract: The Dniester River is the most important source of quality water in the Republic of Moldova. In the current difficult social-economic conditions, as well as the accelerated climate changes, the provision of quality water represents a primary imperative of public policies and an important direction of interdisciplinary studies. In this study were applied statistical, analytical, cartographic and comparative methods. In the analyzed period (2003-2020), the total volume of water used in the Dniester Hydrographical District was, on average, 759 million m³, including 670 million m³ (88%) in the Transdnestrian Region. For technological purposes was used, on average, 580 million m³ or over ¾ (76%) of the total volume of water used, for household purposes – 111 million m³ (15%) and for agricultural purposes – only 66.1 million m³ (8.7%), including for irrigation – 41.1 million m³ (5.4%). In the 2003-2020 years, the total volume of water used registers an oscillating dynamic. The maximum of water consumption in the 2007 and 2020 years are due to the manifestation of stronger droughts in these years. In the 2008-2016 years, there is a negative trend, which is due to the bankruptcy and reorganization of large agricultural companies and of Zonal Stations for Irrigation.

1. Introduction

The priority directions of water governance in the Republic Moldova are the sustainable exploitation and management of water resources and aquatic ecosystems, forecasting the requirements and the available supply of quality water. In this context, it is necessary a complex analysis of sources, volumes and catchment capacities is necessary and distribution of water, as well as the use of water for various socio-economic activities and for ecological-economic functions.

The present research is based on recent analytical studies on the implementation of the Management Plan of River Basin (EPIRB, 2016), which is stipulated in EU Water Framework Directive 2000/60/EC on integrated water management. For the study, the author has focused on management plans, which are being implemented, such as the Danube River Basin Management Plan (2015, 2021), Management Plan of Hydrographic Space Prut-Bârlad (2017), The Management Plan of Dniester Hydrographic District and of Danube Prut and Black Sea Hydrographical District (Bejan et al., 2017), The Management Plans of Prut (Bejan et al., 2016) and Botna river basins (Bejan et al., 2020). Those plans must include detailed diagnosis of the status of basins and of water bodies, recent trends of water consumption by source of catchment and by usage categories, economic analysis of water use, especially in the urban area. Very valuable, in particular for analysis of water use are research methodology and study of transboundary rivers in the Black Sea Region and Belarus (EPIRB Program, 2016). Also, for the elucidation of spatial, economic and social aspects of water use in Moldova, have
been consulted various publications in the field (Planul Bârlad, 2017), as well as analytical studies of authors of this article (Bacal et al., 2017), Bacal and Burduja, 2018, Bacal et al., 2022a, Bacal et al., 2022b).

The main objectives of this study are: a) identification and analysis of the research problem; b) estimation, at the level of hydrographic district and at river basins, the dynamics of the volumes of abstracted water in total and by catchment sources; c) evaluation of water consumption trends in total and according to the main usage categories; d) the peculiarities of abstracted and used water by management sectors of the Dniester Hydrographic District; e) identification of the problems of catchment, distribution and used water systems in the study area;

The separate analysis of the volumes of water captured and used on the right and left side of the Dniester is very important in the assessment and forecast of the total and sectoral water demand, under the conditions of the various operating scenarios of the Dniester Hydropower Complex (HPC) located at the entrance of the Dniester river in the Republic of Moldova and the need to prepare the basic and alternative plan (requests) in the negotiations with the Ukrainian side (Bacal et al., 2022a). It is also imperative that the public authorities responsible for the management of water resources in Chisinau and Tiraspol create common platforms for the completion of the Water Information System, the coordination and implementation of measures in the field of the exploitation and sustainable management of water resources.

2. Materials and Methods

The main informational and statistical support of this study included: 1) Generalized Annual Reports „Water use in the Republic of Moldova” elaborated by Moldavian Water Agency (2003-2020a,b,c); 2) Annual Reports of State Inspectorate for Environmental Protection (2033-2020); Annual Reports on water supply and sanitation companies of Association „Moldova Apa-Canal” (2003-2019); The Report of National Bureau of Statistics on the public water supply and sewerages systems (2022). The study comprised, especially, the 2003-2020 years.

The main methods, which are used in this study, are: statistical, analytical, comparative and cartographical as well as consultation of authorities in the field of assessment and managing of water resources. Statistical method was used in processing of data on the water use in the Dniester HD on the water management sector and on the administrative districts and municipalities from this hydrographic district. The analytical method was used for: a) to identify quantitative and qualitative aspects of water use; b) diagnosis problematic situations in this field; c) definition of priority directions for optimization of water resources management in the river basins. The comparative method was applied for evaluating the trends in the branch and spatial aspects of the water use. The cartographic methods, based on GIS techniques, are used for spatial representation of the main categories of water use on the administrative-territorial units from Dniester Hydrographic District.

3. Study area

The Dniester Hydrographic District (HD) occupies 19.2 thousand km² or ≈58% of the total surface of the Republic of Moldova, including total area of Chișinău and Bălți municipalities, 15 administrative districts (GD of RM from 17.10.2017) from the total of 32 districts on the right side of the Dniester river (Figure 1). Also, in the right side of Dniester HD is situated over 75% of Căușeni district, 60% of Ocnița district, over 40% of Râșcani and Ștefan Vodă districts, over 20% of Fălești district, and an insignificant part from Ungheni, Nisporeni, Glodeni and Edineț districts. In addition, in study area is located Bender municipality from the right bank of the Dniester, but controlled by the separatist authorities from right bank of Dniester River, Tiraspol municipality and 5 administrative districts (Camenca, Râbnița, Dubăsari, Grigoriopol and Slobozia).
Figure 1. The hydrographical districts and basins of Republic of Moldova

On the left side of the Dniester river is located the largest water user in the Republic of Moldova – the Dnestrovsk Thermal Power Plant (TPP), with a share of over 3/4 of the total volume of water used in the Republic of Moldova. In addition, the cities of Tiraspol and Bender, with a similar population to the city of Bălți, and the town, they have water consumption more than 4 times higher than the municipality of Bălți (Agenția Apele Moldovei, 2003-2020a). The town of Răbnița, where is located the Moldavian Metallurgical Factory, has a population by 2.3 times lower compared to Balti city, but has a water consumption by 2-3 times higher. This fact is due to the much more advanced industrialization of left side of the Dniester, for geopolitical reasons (Bacal and Burduja, 2018).

In the Dniester HD there are over 70% (2.6 million) of total population of the Republic of Moldova, including the municipality of Chișinău (780 thousand) and Bălți (130 thousand), 466 thousand from Transdnestrian Region (on the left bank and from Bender municipality from right bank of Dniester). Also, in the Dniester HD is concentrated over 80% of GDP of Republic of Moldova (without Transdnestrian Region), 97% of the total volume of abstracted and used waters.

Dniester Hydrographical District (the sector of the Republic of Moldova), includes 14 river sub-basins (Dniester Plan, 2017), including the basins of the largest right tributaries Răut, Bâc and Botna (Figure 1). The Răut river is the longest (286 km) right tributary of Dniester River. The surface of the water catchment is 7 760 km² or 23% of the territory of the Republic of Moldova, including 63% (4989 km²) in the Northern Development
Region (DR). The Răut River and its tributaries cross the municipality of Bălți and the cities of Dondușeni, Drochia, Râșcani, Florești and Sângerei from the Northern DR, Telenesti and Orhei from the Central DR. Also, in these districts are located most compact arable land and perennial plantations, on which water used massively for irrigation.

The length of Bâc river is 155 km and the surface of Bâc river basin is 2150 km², including most of territory of Chișinău city and of Calarasi, Straseni and Anenii Noi districts, a small part of Ungheni, Nisporeni and Ialoveni districts. The Bâc river crosses the Chișinău city and the towns of Călărași, Strășeni and Anenii Noi, and the volume of discharged wastewater from these cities is over 60 million m³ or ¾ of total volume of discharged wastewater from right side of the Dniester river. The length of Botna river is 146 km and crosses only Căinari and Căușeni towns, and the majority localities from Ialoveni and Căușeni districts. The surface of Botna river basin is 1540 km², and water is used for agriculture and fishing.

4. Results and discussion

According to the data of the National Agency "Apele Moldovei", during the analyzed period (2003-2020), the total volume of water used in the Dniester Hydrographic District (DH) was, on average, 759 million m³ or 97% of the total volume of water used in the Republic of Moldova. In the Transdniestrian Development Region (DR) was used, on average, 670 million m³ of water or 88% of the Dniester DH (Table 1), and in the right side (RS) of the Dniester River – only 89.1 million m³, of which 50.1 million m³ (57%) – in the Chișinău municipality and 22.8 million m³ (26%) – in the riparian districts of the Dniester river (Agenția Apele Moldovei, 2003-2020a). Over 70% of total volume of water used in the Dniester DH is abstracted from the Cuciurgani reservoir, being used, through the recirculation method, to cool the technological aggregates of the Thermoelectric Power Plant (TPP) from Dnestrovsk. From the Dniester riverbed were used, on average, 163 million m³ or only 22% of the total volume of water used in the Dniester DH (Table 1). Also, in the Răut river basin were used, on average, 14.7 million m³, which represents ≈17% of the total volume of water used in RS of the Dniester DH, including from the Răut riverbed – 5.0 million m³ (5.6%). In the Bâc river basin (without the municipality of Chișinău) were used, on average, 6.5 mil. m³ (7.2%), and in the Botna river basin – 2.2 million m³ or 2.4%.

Table 1. The volume of water used by catchment sources in the Dniester HD and in the basins of its main right tributaries (average of 2003-2020 years)

<table>
<thead>
<tr>
<th>Hydromorphological Basins</th>
<th>Total use</th>
<th>Surface</th>
<th>Underground</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume, million m³</td>
<td>Share from total volume</td>
<td>Volume, million m³</td>
</tr>
<tr>
<td>Dniester HD</td>
<td>759</td>
<td>97%</td>
<td>664</td>
</tr>
<tr>
<td>Dniester riverbed</td>
<td>163</td>
<td>22%</td>
<td>101</td>
</tr>
<tr>
<td>Răut</td>
<td>14.7</td>
<td>1.9%</td>
<td>17</td>
</tr>
<tr>
<td>Răut riverbed</td>
<td>5.0</td>
<td>0.7%</td>
<td>5.6</td>
</tr>
<tr>
<td>Bâc</td>
<td>6.5</td>
<td>0.9%</td>
<td>7.2</td>
</tr>
<tr>
<td>Botna</td>
<td>2.2</td>
<td>0.3%</td>
<td>24</td>
</tr>
</tbody>
</table>

Data source: Moldavian Water Agency (2003-2020a)

The maximum volume of water was used in the municipalities of Chișinău, Balti, Tiraspol. Bender, as well as in the river districts of Anenii Noi (3.7 million m³) and Orhei (3.3 million m³), Ștefan Vodă (2.5 million m³) and Căușeni (2.4 million m³), Soroca (2.3 million m³), Florești (2.0 million m³), Criuleni and Dubăsari (each 2.0 million m³). Most of these districts have direct access to the Dniester riverbed, larger sizes and/or a higher level of development of irrigated agriculture (Agenția Apele Moldovei, b), with more complete record keeping of captured and used water. The minimum volume of captured and used water is attested in the districts with smaller sizes and urban centers
(Dondușeni, Rezina, Șoldănești), as well as in the districts that are partially located within the Dniester Hydrographic district (Ocnița, Fălești, Râșcani).

Overall, 88% (664 million m$^3$) of the total volume of water used in the Dniester DH are abstracted from surface sources, of which 553 million m$^3$ (83%) is abstracted from the Cuciurgani reservoir, being used at Dnestrovsk TPP and only 101 million m$^3$ (15%) – from the Dniester riverbed. Surface sources predominate in the towns of Dnestrovsk (99.7%) and Râbnița (54%), in the municipalities of Bălți (99%) and Chisinau (94%), and in the districts of Soroca (87%), Dubăsari (65%), Ștefan Vodă (59%), Anenii Noi (51%) and, with large systems of water distribution from the Dniester river [8]. The absolute majority of the localities on both banks of the Dniester are supplied from underground sources. Also, underground sources predominate in the Bâc (97%), Râut (84%) and Botna (83%) river basins.

Due to the absolute predominance ($\approx$97%) in the total volume of water used in the Republic of Moldova, the share of water use categories in the Dniester HD is almost identical to that at the level of the Republic. Thus, in the Dniester HD, for technological purposes were used, on average, 580 million m$^3$ or over $\frac{3}{4}$ (76%) of the total volume of water used, for domestic purposes – 111 million m$^3$ (15%), and for purposes agricultural – only 66.1 million m$^3$ (8.7%), including for irrigation – 41.1 million m$^3$ (5.4%). Also, over 60% of the water abstracted from the Dniester riverbed is used for domestic purposes, especially in the Chisinau and Bălți municipalities. In agriculture was used, on average, 40.8 million m$^3$ or about $\frac{1}{4}$ of the total volume of water used, including 35.1 million m$^3$ (21%) – for irrigation, and 21.7 million m$^3$ (13%) – for industry (Agenția Apei Moldovei, 2003–2020a).

Due to the absolute predominance ($\approx$97%) in the total volume of water used in the Transdnestrian Region for technological purposes were used 85% (568 million m$^3$), for domestic needs – 9% (60 million m$^3$) and for agricultural purposes – $\approx$6% (39.6 million m$^3$). The volume of water used at the Dnestrovsk TPP determines the detached predominance of technological uses in the Dniester HD and in the Republic of Moldova, despite its pronounced agrarian character. In addition, according to the data of the Statistics Service of the separatist authorities from Tiraspol, for technological purposes are used by $\approx$300 million m$^3$ more than the volume indicated in the Reports of the Moldavian Water Agency. A massive consumption of water for technological purposes can be seen in the cities of Tiraspol (3.5 million m$^3$), Râbnița (3.0 million m$^3$) and Bender (1.7 million m$^3$), which have a higher level of industrialization and a net higher water consumption compared to the cities on the right side of the Dniester. This fact is due to the geostrategic planning of the Soviet period and the concentration of the most
important factories of heavy industry – in the left side of the Dniester river (Bacal P., 2018). The maximum share of water used for industrial purposes is observed in the Dnestrovsk (99.7%), Râbniţa (22%) and Tiraspol (16%) (Figure 3).

The maximum water use for domestic purposes in this region is recorded in the cities of Bender (19.9 million m$^3$), Tiraspol (18.6 million m$^3$), Râbniţa (10.8 million m$^3$) and Dubăsari (2.5 million m$^3$). At the same time, according to the Statistical Yearbook (2020) published by the Tiraspol authorities, the volume of water used for domestic purposes is about 3 times lower compared to the data of the Moldavian Water Agency, which would correspond more to reality, given the fact of the significant reduction of the population, especially in the Bender city.

In the right side of the Dniester Hydrographic District for domestic purposes, were used, on average, 50.7 million m$^3$ or 57% of the total volume of water used (Figure 2.b). This fact is conditioned, to a large extent, by the municipality of Chişinău, where, for household purposes, were used 41.8 million m$^3$ of water, or over 80% of the total volume of water used for these purposes in the right side of the Dniester Hydrographical District. In agriculture were used, on average, 26.5 million m$^3$ of water or 30% of the total volume, including for irrigation 8.4 million m$^3$ (10%), and for industrial purposes – 11.7 million m$^3$ (13%). In Chişinău and Bălţi municipalities, over 80% of the total volume of water were used for household purposes, 18% – for technological purposes. In the riparian districts of the right side of Dniester HD, over ¾ of the total water volume were used for agricultural purposes, including for irrigation – 27%, and for industry – 6%.

Despite the lowest share compared to industrial and household uses, agriculture predominates in the consumption of water resources in the absolute majority of districts and rural localities on both banks of the Dniester (Figure 3). The maximum consumption of water in agriculture is found in the districts with direct access to the Dniester riverbed and located in the proximity of the municipalities of Chişinău and Balti (the main sales
markets): Anenii Noi (2.9 million m$^3$), Dubăsari (2.2 million m$^3$), Orhei (2.0 million m$^3$), Căușeni (2.0 million m$^3$), Criuleni (1.8 million m$^3$), Ialoveni (1.7 million m$^3$), Soroca (1.6 million m$^3$), Drochia and Florești (1.5 million m$^3$). The large share is also caused by the allocation of water delivered through rural aqueducts to agricultural use (Bejan I. et al., 2017). A minimum volume of water used for agricultural purposes is attested in the Chișinău and Bălți municipalities, as well as in the smaller districts and urban centers, with limited access to the Dniester riverbed and with lower capacities for catchment, distributing and using of water for these purposes.

The maximum share (≥80%) of agriculture is found in the districts of Râșcani, Dondușeni, Ocnița, Criuleni, Dubăsari, Telenești, Șoldănești, Anenii Noi, Căușeni and Ștefan Vodă, where operate large agricultural companies, and household consumption is lower, as a result of smaller urban centers (Bacal et al., 2022a). The average share (60-80%) of agriculture is attested in the districts with medium-sized urban centers and with a greater share of domestic and industrial uses, including in the districts of Soroca, Florești, Drochia, Orhei, Strășeni and Ialoveni (Figure 3).

The predominance of water used in agriculture is attested, also, in the basins of the main right tributaries, including Botna (79%) and Răut (68%) (Table 2).

**Table 2.** The volume (million m$^3$) of water used and share (%) of key usage categories of water in the Dniester HD and in the main right tributaries (average of 2003-2020 years)

<table>
<thead>
<tr>
<th>Hydrographical Basins</th>
<th>households</th>
<th>technological</th>
<th>agriculture</th>
<th>other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V*</td>
<td>%</td>
<td>V</td>
<td>%</td>
</tr>
<tr>
<td>Dniester HD</td>
<td>111</td>
<td>15</td>
<td>580</td>
<td>76</td>
</tr>
<tr>
<td>Dniester riverbed</td>
<td>101</td>
<td>62</td>
<td>21,7</td>
<td>13</td>
</tr>
<tr>
<td>Răut</td>
<td>3,0</td>
<td>20</td>
<td>1,8</td>
<td>12</td>
</tr>
<tr>
<td>Răut riverbed</td>
<td>1,9</td>
<td>38</td>
<td>1,2</td>
<td>24</td>
</tr>
<tr>
<td>Băc</td>
<td>2,5</td>
<td>39</td>
<td>1,3</td>
<td>27</td>
</tr>
<tr>
<td>Botna</td>
<td>0,3</td>
<td>14</td>
<td>0,1</td>
<td>4,8</td>
</tr>
</tbody>
</table>

*V*=volume; Data source: Moldavian Water Agency (2003-2020a)

Also, the greater share of domestic (44%) and industrial (27%) usages in Băc river basin is due to water captured from underground sources for the water supply of rural localities and some cities in the Chișinău municipality, in the Anenii Noi and Strășeni districts. The share of industrial uses in the Răut river basin is, on average, 12%, including 24% in the perimeter of the Răut riverbed (due located of Bălți, Orhei and Florești towns), and in the Botna river basin– only ≈5%.

According to the data of the Environmental State Inspectorate (2003-2018), the maximum water use for agriculture is registered at: *Technological Stations for Irrigation* (TSI) and at *Associations of Water User for Irrigation* (AWUI) from Ștefan Vodă (1,1 million m$^3$), Anenii Noi (830 thousand m$^3$), Dubăsari (580 thousand m$^3$), Criuleni (570 thousand m$^3$) districts; *large agricultural companies with a complex profile*, especially for growing fodder and vegetable crops, especially from the districts of Dondușeni (972 thousand m$^3$), Soroca (560 thousand m$^3$), Criuleni (540 thousand m$^3$), Anenii Noi (530 thousand m$^3$), Râșcani (250 thousand m$^3$), Drochia (220 thousand m$^3$), Dubăsari, Ialoveni, Telenești, Strășeni and Ștefan Vodă. An average water consumption is recorded at *pig breeding complexes* in the districts of Anenii Noi (260 thousand m$^3$), Criuleni (52.4 thousand m$^3$), Florești (36 thousand m$^3$), Ialoveni, Orhei, Râșcani and Soroca; the poultry factories in the districts of Anenii Noi (110 thousand m$^3$), Criuleni (33.6 thousand m$^3$), Râșcani (28 thousand m$^3$), Telenești (24 ths m$^3$), Dondușeni (15.1 ths m$^3$) and Orhei. Also, we should not neglect the water use for raising animals in households, which are not, as a rule, equipped with sewerage systems and produce a major impact on the environment and the human body (Bacal et al., 2017).
For irrigation were used, on average, \( \approx 41.1 \) million m\(^3\) or 5.4\% of the total volume of water used, including on the left side of the Dniester HD – 32.8 million m\(^3\) (5\%) and on the right side of Dniester HD – 8.4 million m\(^3\) (9\%). In the riparian districts for irrigation were used, on average, 6.8 million m\(^3\) of water (30\%), and in the rest of the districts from right side of Dniester HD – 1.4 million m\(^3\) (13\%). The relatively small volume of water used in irrigation is conditioned both by natural conditions (insufficient rainfall, low flow of small and medium river, unsatisfactory status of water reservoirs), and by the technical and economic possibilities of using water for these purposes. Thus, the maximum volume of water used for irrigation is attested in the districts located near the Dniester rivers, which have large capacities for capturing and distribution of water in these purposes, including in the districts of Dubăsari (1,3 million m\(^3\) in the Transdnestrian DR and 1,2 million m\(^3\) in the Central DR, Grigoriopol (1,6 million m\(^3\)), Anenii Noi (1.5 million m\(^3\)), Ștefan Vodă (1.1 million m\(^3\)), Slobozia (920 thousand m\(^3\)), Căușeni (640 thousand m\(^3\)) and Soroca (570 thousand m\(^3\)). In the 2020 year, as a result of strongest drought, the water use for irrigation in these districts it was a several times higher.

The maximum share of the water used in irrigation from the total volume of water used is recorded, also in the riparian districts on both banks of the Dniester in the sectors between the Dubăsari Reservoir Lake and the mouth of the Dniester River (Figure 4), including in the districts of Dubăsari (63\% on the right side and 48\% on the left side of the Dniester), Grigoriopol and Ștefan-Vodă (60\%), Anenii Noi (40\%) and Criuleni (32\%). In most of the northern districts, including in the proximity of the Dnestrian Hydro Power Complex, is attested a medium share (15-30\%) of the water used in irrigation, which is due to the more pronounced commercial character of agriculture in the northern districts (Bacal et al., 2018). In addition, in recent years, there has been a frequent request from the performing agricultural companies in order to ensure the rising demands of the foreign market, especially from Middle East and European Union.

![Figure 4](image-url). Share of the volume of water used for irrigation (average of 2003-2020 years)
In the 1990-2002 years, as a result of the deep socio-economic crisis, the total volume of water use was reduced by about 4 times (from ≈3.3 billion m³ until ≈760 million m³), which is due to the similar reduction (by 4 times) of the volume of water used for technological purposes (from 2.5 billion m³ up to ≈600 million m³). The volume of water used in agriculture was reduced about 8 times (from 550 million m³ to only 70 million m³), including for irrigation – by about 10 times (from about 450 million m³ to 45 million m³). The lowest rates of reduction (by 1.9 times) are found in the volume of water used for domestic purposes (from ≈210 million m³ to ≈110 million m³), a fact conditioned by the slower rates of population compared to the rates of reduction of agricultural and industrial production in the respective period, as well as the data from the left side of the Dniester river and the municipality of Bender, which changed insignificantly.

In the 2003-2020 years, the total volume of water used (Figure 5) registers an oscillating evolution, caused both by the annual dynamics of atmospheric precipitation and the by demographic and economic evolution, as well as by the data from the left side of the Dniester river, which are almost constant during that period. Overall, is observed a weakly pronounced negative dynamic, and the values from 2020 year are almost equal to those from 2003-2006 years. The maximum values from 2007 and 2020 years are due to the maximum water consumption in the conditions of stronger droughts in these years.

Data source: Moldavian Water Agency (2003-2020a)

Figure 5. Dynamics of the volume of water used in the right side of Dniester HD (per total and by usage categories), in million m³ (average of 2003-2020 years).

At the same time, in the right side of Dniester HD, the oscillating evolution is very pronounced. Thus, in the years 2004-2007 there is a positive dynamic (by 1.2 times), marked both by the economic and demographic positive trends in that period, and by the high demand for water in the drier year 2007. The reduction of the total volume of water used can be seen in the Răut and Bâc river basins (by 1.3 times), but in the Botna river basin there is a significant increase (by 1.5 times). Later, in the years 2008-2014/16, is manifested a pronounced negative trend (Figure 5), and the total volume of water used in the right side of the Dniester HD decreased by more than 1.4 times or by 23.1 million m³, a fact that is due to the socio-economic instability, to the bankruptcy and reorganization of large agricultural and industrial enterprises and of Technological Station for Irrigation [3], to the decline of the population number, also to the spread of technologies with lower water losses and to the shortcomings of statistical records in this field. The negative trend is manifested in all categories of use, especially at household in the Chisinau municipality, industrial use – in the Northern Region and in Chisinau municipality, and for irrigation – in the Southern Region (Bacal et al., 2018). In the Bâc and Botna river basins (Bejan et al., 2020) is found an insignificant reduction
(by 1.2 times) of the total volume of water used in this period, and in the Răut river basin is observed a slow increase (by 6%), which is due to the Balti city. In the 2017-2020 years, there is an increase of the total volume of water used in the right side of the Dniester HD, including in the Răut, Bâc and Botna river basins, but most intensively in the riparian districts of the Dniester river. In 2020 year, the total volume of water used in Dniester HD was 760 million m$^3$ or 97% of the Republic of Moldova. In the right side of Dniester HD were used 93.1 million m$^3$ or only 12% of the total volume of water used in the Republic and in the Dniester DH. In the Chisinau municipality were used 46.7 million m$^3$ or 50% of the right side of Dniester HD and in the municipality of Balti − 4.7 million m$^3$ or 5.1%.

In the riparian districts were used $\approx$30 million m$^3$ (32%), and in the rest of the districts from right side of the Dniester DH − 11.7 million m$^3$ ($\approx$13%).

A big volume of water was also used in the riparian districts of Dniester, including Anenii Noi (5.7 million m$^3$), Criuleni (4.1 million m$^3$), Orhei (3.7 million m$^3$), Dubăsari (3.6 million m$^3$) and Soroca (3.0 million m$^3$), with higher consumption for agricultural and household purposes, especially for irrigation. The minimum volume is attested in the smaller districts − Dondușeni, Șoldănești, Rezina and in those located partly in the Dniester Hydrographic District.

About 80% of the total volume represents technological water (Figure 6), which was used at Dnestrovsk Thermoelectric Power Plant, industrial enterprises in the cities of Chisinau, Râbnița, Bălți, Tiraspol and Tighina. The maximum volume of water used at the Dnestrovsk TPP (552 million m$^3$) determines the detached predominance of technological water both in the Dniester HD and, overall, in the Republic of Moldova. The high share (>40%) of technological water in the sector between the Dubăsari reservoir and Bender city is caused by the massive consumption ($\approx$10 mil. m$^3$) of water at the industrial enterprises from Chisinau.

In the Răut, Bâc and Botna river basins predominates drinking water for the supply of the population and food industry enterprises.

Data source: Moldavian Water Agency (2003-2020a)

Figure 6. The share of water categories on the water management sectors of the Dniester DH (2020)

About 80% of the total volume of fresh water abstracted in the Dniester DH represents used water, 17% is fresh water sent outside to the catchment area. The maximum share of fresh water transmitted is recorded in the sectors between Naslavcea and Soroca and between the Dubăsari Reservoir and Bender city, which is exclusively due to the delivery of abstracted water by the pumping stations at Cosăuți (Soroca district) and at Vadul lui Vodă, to the Bălți and Chișinău municipalities and of some localities from its proximity.
Figure 7. Share of the amount of abstracted, used and transmitted water on the water management sectors of the Dniester DH (2020)

The maximum volume of water used at Dnistrovsk TPP determines the detached predominance of more than 90% in the total volume of water used in the sector between Bender city and the mouth of the Dniester river (Figure 8). The high share (over 40%) of technological water in the sector between the Dubăsari reservoir and the Bender city is caused by the massive consumption (10 million m$^3$) of water by industrial enterprises in the municipality of Chișinău. About 60% of the water used for domestic purposes comes from the Dniester river bed, destined for the municipalities of Chișinău and Bălți.

The predominance of water used in agriculture, including irrigation, can be seen in the Botna (82%) and Râut (71%) river basins, as well as in the Dniester river sector from Naslavcea to Soroca (52%).

Figure 8. The share of main categories of water use on the water management sectors of the Dniester DH (2020)

5. Conclusions

In the analyzed period (2003-2020), the total volume of water used in the Dniester HD was, on average, 759 million m$^3$, including 670 million m$^3$ (88%) in the Transdniestrian Region and 89.1 million m$^3$ (12%) on the right side of the Dniester river, of which 50.1 million m$^3$ (57%) in the municipality of Chișinău.

From surface sources was used, on average, 664 million m$^3$ or 88% of the total volume of water used in the Dniester DH. At the same time, surface sources predominate
only in the towns of Dnestrovsk (99.7%) and Râbnița (54%), in the municipalities of Bălți (99%) and Chișinău (94%), and in the districts of Soroca (87%), Dubăsari (65%), Ștefan Vodă (59%), Anenii Noi (51%) in the Dnestrovsk (99.7%) and Chisinau municipality (94%), as well as in the districts of Soroca (87%), Dubăsari (65%), Anenii Noi (51%) and Ștefan Vodă (59%). The absolute majority of the localities on both banks of the Dniester are supplied from underground sources. Also, underground sources predominate in the Bâc (97%), Răut (85%) in the Botna (83%) river basins.

For technological purposes was used, on average, 580 million m³ or over ¾ (76%) of the total volume of water used, for household purposes – 111 million m³ (15%), and for agricultural purposes – only 66.1 million m³ (8.7%), including for irrigation – 41.1 million m³ (5.4%). On the right side of Dniester HD, in agriculture were used, on average, 26.5 million m3 of water (30%), including 8.4 million m3 (10%) for irrigation, and for industrial purposes – 11, 7 million m3 (13%). Agriculture predominates detached in the Botna (79%) and Răut (68%) river basins, and in the Bâc river basin – 44%.

In the 2003-2020 years, the total volume of water used registers an oscillating dynamic, caused both by the annual regime of atmospheric precipitation and by the demographic and economic evolution, as well as by the data from the left side of the Dniester. The maximum values of water use in the 2007 and 2020 years are due to the manifestation of stronger and longer droughts in these years. In the 2008-2016 years, there is a strong negative trend, and the total volume of water used has decreased by 1.4 times. In the 2017-2020 years, there is an increase of the water use, including in the Răut, Bâc and Botna river basins.

For future research, we propose to analyze the trends of water demand and water use in correlation with climate change and its effects on the Dniester river flow, on the water supply capacities, and on the development of riverside tourism.

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