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To cite this article: A I Vtorova *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **321** 012025

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# External water exchange of reservoirs of South Ural

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**Abstract.** Reservoirs are building worldwide for the rational usage of water resources. Engineers create reservoirs for redistribution of runoff both in seasonal and multi-annual regime. The duration of stay of river water in slow water exchange condition is one of the major factors which influences the transformation of the river water and the formation of water resources, which are specific to reservoirs. External water exchange of reservoirs is one the major hydrological and hydro-ecological characteristics. Value of water exchange defines the formation of water mass with determinate properties. Identification of the characteristics intensity of external water exchange of reservoirs allows to make an estimation of the processes under way in the system “river-reservoir” and to decide limnological tasks taking into account the change of climate. The definition of the typical differences taking into account anthropogenic interference in these conditions is especially valid.

## 1. Introduction

Purpose of reservoirs on use in them the accumulated water can be a miscellaneous, but are created mainly for the purpose of accumulation of storage and the subsequent use of reserves of the water accumulated in them. Reservoirs belong to young water objects. Studying of their hydrological mode and processes in them occurring is a subject of studying by scientists of Russia[1-9] so scientific foreign countries[10-13]. Characteristics of intensity of external water exchange for full and net volume and also water exchange coefficients: on a drain and inflow, the average coefficient of water exchange and the period of water exchange are the major factors influencing transformation of river waters and formation of water masses characteristic of reservoirs.

## 2. Material and methods

Water supply of the industry and citizens happens predominantly by the surface water. Natural regime of runoff changes under the impact of work of seasonal and multi-annual regulation of reservoirs. Chelyabinskaya oblast is situated in the south Ural, the region which is located on a border between two parts of the world. Territory of the region is 88,5 thousand square kilometers, population is 3689,7 thousand people. In orographic regard, territory is located on the border of upper river basins: Ural, Kama, Tobol, hence it is divided into three parts. Therefore there is no water body what could provide



non-stop water supply for objects of regional economy. Irregularity of annual distribution of the river runoff and territorial differences in location of water resources defines requirements in the regulation of the surface runoff through the creation of ponds and reservoirs.

**Table 1.** Ranking of volume of reservoirs and ponds

Indexes	Total
Numerals waterworks	341
Including basins	
-Ural river	53
-Tobol river	246
-Kama river (Volga river)	42
Distribution of capacity of reservoirs and ponds	
over 100 million m <sup>3</sup>	12
от 50 до 100 million m <sup>3</sup>	5
от 10 до 50 million m <sup>3</sup>	15
от 1 до 10 million m <sup>3</sup>	96
от 0,5 до 1 million m <sup>3</sup>	54
от 0,1 до 0,5 million m <sup>3</sup>	96
less 0,1 million m <sup>3</sup>	63

The total water content of main reservoirs is 5,05 cubes kilometers, their beneficial yield is 3,45 cubes kilometers. Control over a scheme of exploitation is carried out in 31 reservoirs, 11 of which are with multi-annual and 20 respectively with the seasonal regulation.

In the paper we use the base of dates on reservoirs of Chelyabinskaya oblast from the information resource AIS GMWO (Automatic information system of Government monitoring of water objects).

From basic material (daily data) monthly average and annual average data have been computed: discharges of water (inflow and outflow), volumes, levels and areas of water surface of reservoirs.

For calculation of the external water exchange of reservoirs we used annual average data about discharges of water (inflow and outflow) of 19 reservoirs.

When studying of external water exchange of reservoirs average index of water exchange have been computed not only to full, but also the beneficial volume while annual average values.

In order to characterize the intensity of external water exchange of reservoirs we used some indexes, each allowing to estimate the kind of processes which under way in system “river-reservoir” and to decide limnological tasks. These indexes are based on solution of equation of the balance of water. Most commonly used coefficients of water exchange to inflow ( $K_{E\ IN}$ ) or outflow ( $K_{E\ OUT}$ ):

$$K_{E\ IN} = W_{IN}/W_0; \quad K_{E\ OUT} = W_{OUT}/W_0, \quad (1)$$

Where  $W_{IN}$  and  $W_{OUT}$  is respectively total inflow of water to reservoir and outflow in downstream of reservoir;  $W_0$  is volume of water in reservoir over the same period.

Moreover for reservoirs coefficients of water exchange beneficial volume ( $W_{B.V.}$ ) in reservoir over the same period are applied:

$$K_{E\ IN} = W_{IN}/W_{B.V.}; \quad K_{E\ OUT} = W_{OUT}/W_{B.V.}, \quad (2)$$

Average coefficient of water exchange ( $A_E$ ) is equivalent to:

$$A_E = (W_{IN} + W_{OUT})/W_0 = (W_{IN} + W_{OUT})/W_{B.V.}, \quad (3)$$

**Table 2.** Outcomes of calculation of external water exchange are shown in the table form.

Reservoirs and rivers	Regulation	Area of basin, km <sup>2</sup>	W, mln m <sup>3</sup>			K <sub>E,OUT</sub>		K <sub>E,IN</sub>		A <sub>T</sub>
			W <sub>FULL</sub>	W <sub>beneficial</sub> volume	Average runoff of year million m <sup>3</sup>	W <sub>OUT</sub> /W <sub>0</sub>	W <sub>OUT</sub> /W <sub>B.V.</sub>	W <sub>IN</sub> /W <sub>0</sub>	W <sub>IN</sub> /W <sub>B.V.</sub>	W <sub>MULTI</sub> /W <sub>IN</sub>
1	2	3	4	5	6	7	8	9	10	11
Argazinskoe Miass River	Multi	2750	980	852	300,54	0,39	0,5	0,39	0,53	1,87
Bredinskoe Sintashty River	Multi	639	45,5	42,8	18,29	0,6	0,7	0,1	1	1,1
Verkhneufaleyskoe Ufaleyka River	Season	170	8,3	4,4	45,72	5,3	16,5	5,3	17,1	0,04
Verkhneuralskoe Ural River	Multi	4280	601	569	340,8	0,6	0,64	0,7	0,74	1,78
Dolgobrodskoe Ufa River	Multi	1000	333	273	189,22	0,87	1,25	0,91	1,29	1,03
Zyuratkul'skoe	Multi	215	73,7	57,7	56,76	5,9	8,7	5,9	8,9	0,2
Iremelskoe on Verkhniy Iremel	Multi	264	37,6	35,1	29,01	1,43	1,57	1,6	1,76	0,96
Kateninskoe Karataliyat River	Multi	1018	16,23	15,7	22,71	1,74	1,83	2,66	2,81	0,43
Kyshtymskoe Kyshtym River	Multi	238	9,2	3,7	12,33	1,3	4,5	1,3	7,6	0,1
Magnitogorskoe Ural River	Season	6437	189	32	498,1	2,3	23,3	2,8	28,1	0,05
Malosatkinskoe Malaya Satka River	Season	243	19,2	17,2	81,29	5,13	4,81	5,13	5,89	0,2
Miass pond Miass River	Season	790	12,2	5,4	51,4	1,9	3,5	1,9	4,4	0,4
Nizhneufaleyskoe Ufaleyka River	Season	782	24,3	15	139,59	6,7	12,6	6,7	12,6	0,09
Nyazepetrovskoe Ufa River	Multi	2890	153	138	348,79	3,8	3,8	3,8	4,2	0,3
Polikarpov pond Miass River	Season	1330	10,5	8,5	138,44	8,8	11,4	8,8	11,4	0,3
Satkinskoe river Bolshaya Satka	Season	264	12,5	5,5	73,164	6,2	16,2	6,2	16	0,1
Troitskoe Uy River	Season	15100	45,1	22	575,95	9,44	23,4	9,44	19,3	0,06
Shershnevskoe Miass River	Multi	2610	176	106	124,44	1	2,2	2,4	5,3	0,14
Yuzhnouralskoe Uvelka River	Multi	4750	75,45	65,1	183,8	3	3,6	3	4,1	0,2

Value that inverse to coefficient of water exchange is a period of water exchange and characterizes the duration full change of water in reservoir. Conditional quantity of years  $A_T$  for a change of water in reservoir are calculated upon the formula:

$$A_T = W_{\text{MULTI}} / W_{\text{OUT}} = W_{\text{MULTI}} / W_{\text{IN}}, \quad (4)$$

Where  $W_{\text{MULTI}}$ ,  $W_{\text{OUT}}$  and  $W_{\text{IN}}$  is respectively average multi-annual volume of water in reservoir and average volume of water from reservoir is flowed and average volume of water to reservoir is in-flowed.

### 3. Results

Despite schematic of averaging of the indexes, the authors consider that these are basic in comparative studying of reservoirs in particular geographic conditions. Practical convenience of this feature is conditioned data availability in AIS GMWO about of water in reservoirs, their volumes, value of inflow and outflow. Multi-annual data allows defining the external water exchange for a required year probability.

### 4. Discussion

The results of the calculation of the external water exchange in the main reservoirs of south Ural do not give the answer to a number of important questions. For instance, the percentage of impact of climate and underlying surface in formation of water exchange. Conditional coefficients customarily employed in hydrological investigations to characterize the external water exchange of reservoirs do not take into an account the dependency from physico-geographical factors. At the same time different structure of system “river-reservoir”, their location define various involvement of climate (active) and morphometric (adaptive) factors in formation of the water exchange. Thus, there arises a need to construct such an integrated index which would take into account the diversity of factors and synthesizes to unified summary estimation with account of separate influence of active and adaptive factors. These allow to define most sensitive factors value of water exchange with anthropogenic interference is impacted.

### 5. Conclusions

Coefficients of external water exchange are conditional since these are considered with assumption that water in reservoir is fully renewed, i.e. forced out of reservoir without being mixed. However, despite this schematic form, coefficients of water exchange are most in the comparative studying of reservoirs located in different physico-geographical zones.

Coefficient of water exchange under the inflow defines terrigenic or limnical processes in reservoir. In this small values of coefficient of external water exchange under the inflow points to priority of limnical effects. With an increased coefficient of external water exchange under inflow the role of the terrigenic processes rises. Coefficient of water exchange is characterized by transit-accumulative features of reservoirs under outflow, it defines the type of limnogenesis.

Huge variation in the values of coefficients of external water exchange under inflow and outflow and their significance for studying of reservoirs requires classification of reservoirs under these indexes.

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