

NATURAL AND ANTHROPOGENIC FACTORS OF WATER RESOURCES CHANGE IN RUSSIA, UKRAINE AND BELARUS

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Water resources change is caused by different natural and anthropogenic factors. The main reason is climatic, first of all warming during cold seasons and augmentation of rainfall in winter and in summer. During the last 15 years on the territories of Russia and Belarus the rise in river runoff has been observed. Changes in the river runoff in Ukraine were not so certain in the ninetieth but at the very end of the 20th century the raise was also seen.

Change of the climatic conditions coincides with the human impact on water resources. After the collapse of the Soviet Union there were great changes in political, social and economic spheres of the new formed states. The economic recession as well as the economic rise since the last years of the 20th century has affected the state of water resources. During the last 15 years water consumption reduction has been seen.

Keywords: water resources change, water consumption, water management

Introduction

After the collapse of the Soviet Union great changes in political and socio-economic spheres affected the state of water resources. First of all, it concerns the economic crisis including water sector in the early 90's which has not been fully overcome until present time despite economic recovery in the last years of the twentieth century. Together with the changes in climatic conditions it caused perceptible changes in the river runoff on the territory of Russia, Ukraine and Belarus. As the result, peculiar conditions for the formation and utilization of water resources on the territory of the former Soviet Union have been formed. Such changes as well as other environmental changes may become even more significant in the future that predetermines the necessity of the profound study of the question as all the conditions and changes still have not been fully explored.

One of the uncertainties of the question concerns similarities and differences in human impact on water resources during the post-Soviet period in Russia, Ukraine and Belarus - countries that have much in common, but however, going their own ways.

Knowledge of the positive and negative hydrological and water management experience allows to form the basis of future sustainable development of natural resources, including water. Thus, the main purpose is to identify main similarities and differences in the anthropogenic impact on water resources (primarily in water consumption) in Russia, Ukraine and Belarus after the collapse of the Soviet Union. The main aims are: to identify correlation of anthropogenic impact on water resources, primarily water consumption, with natural and climatic conditions; identify correlation of water consumption with economic factors; compare water consumption dynamics after the collapse of the Soviet Union; identify regional particularities in water consumption dynamics; estimate the influence of changing economic activities on the river flow and water quality; evaluate the effectiveness of water use and water protection in Russia, Ukraine and Belarus.

Methods

This investigation is one of the preparatory steps to development of long-term scenarios of water consumption in the former USSR. Methodology is based on several years' studies of Institute of Geography RAS. Scenario development for water use includes preparatory and predictive stages. Preparatory stage implies selection of forecast operational units, assessment of water resources current state and its relation to water use, determination of main tendencies in agriculture and water resources development in the recent decades. On the predictive stage different available scenarios of population change and development indices for major industries are analyzed.

The input data has been gained from various organizations and institutions in Russia, Ukraine and Belarus, library materials, cartographic and literary sources, including reference to statistical information from national reports on economics and environment, reports and information on water use, as well as the basic legal documents concerning water resources (primarily Water Codes of the States). The main method of investigation is comparative geographical method. Standard techniques of mathematical and statistical studies, processing of economic and geographic information, indicators of water use, water balance, the analysis of hydrometeo series have been used.

Findings and discussion

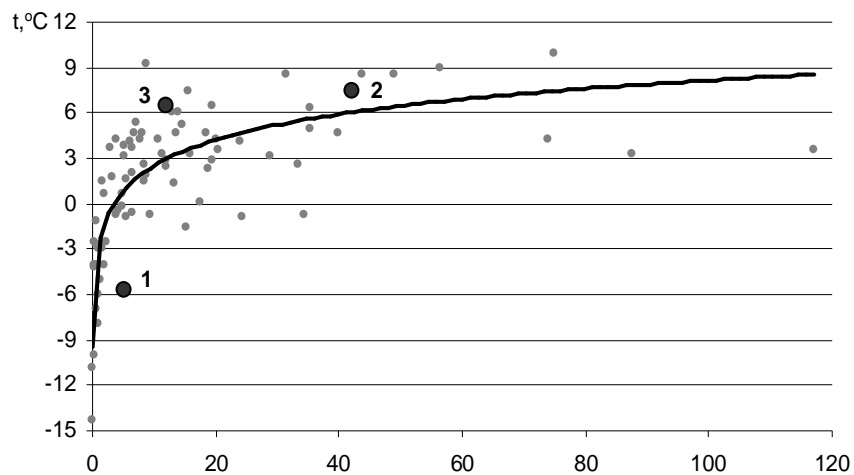
Impact of natural and climatic conditions and anthropogenic factors. While assessing the influence of natural factors on water consumption two aspects are taken into consideration: impact on the

quantity of water consumption and impact on the intensity of self-purification of wastewater and return water. Thus the indirect and direct influence on consumption can be distinguished. Indirect means that the structure of water consumption and the whole water sector as well is greatly determined by climatic conditions.

The most obvious dependence of the specific water consumption on natural factors (primarily on humidity deficit) is seen in irrigated agriculture. Such dependence is typical for other branches of Water Resources Management. Therefore one possible way to save water is to move some industries to more humid northern regions. The situation with the total water use is more complicated. Thus in the case of heat-and-power engineering and communal services the need for heat resources which grows in colder areas should be taken into account. Therefore in some sectors of Water Industry the dependence of total water use on air (and water) temperatures is not often evident.

We tried find out the dependence of some characteristics of water consumption on the average annual air temperature, as well as on its correlation with annual precipitation in the regions of the Russian Federation, Ukraine and Belarus for the different sectors of water management. It was found out, that in the regions of Russia with low air temperatures water consumption per area unit is less, than on the territories with high air temperatures. This is typical for the period of economic recession after the collapse of the USSR, as well as for the period of economic expansion during last years (Fig. 1). Besides, more severe climate in Russia causes lower water consumption per area unit, at the same time in Russia self-purification is less intensive, than in Belarus and Ukraine.

(a)



(b)

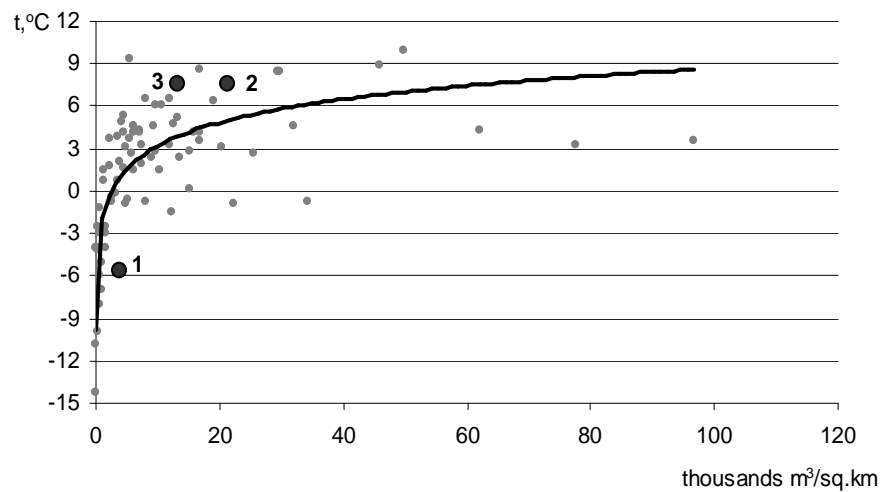


Fig. 1. Dependence of the total water consumption per area unit on the average annual air temperature. (a) - 1990 to 1995, (b) - 1996 to 2005; 1 - Russia as a whole, 2 - Ukraine 3 - Belarus. Points on the figure denote the regions of the Russian Federation.

This also concerns Caspian and Azov Basins, where the main economic potential of Russia concentrates, although they differ from Ukraine and Belarus by annual air temperature less than from Russia as a whole.

The same picture as for the general water consumption is typical for the industrial water utilization, domestic water consumption and especially for irrigated agriculture.

On the contrary calculating per head correlation of water consumption with climatic conditions is not seen, that is the reason of more considerable influence of socio-economic factors.

We also tried to find out correlation of cost-effectiveness of water use (gross domestic product per unit of used water) with annual air temperature. The result illustrates that it is necessary to take into consideration climatic conditions while investigating cost-effectiveness of water use in different countries and regions (Fig. 2).

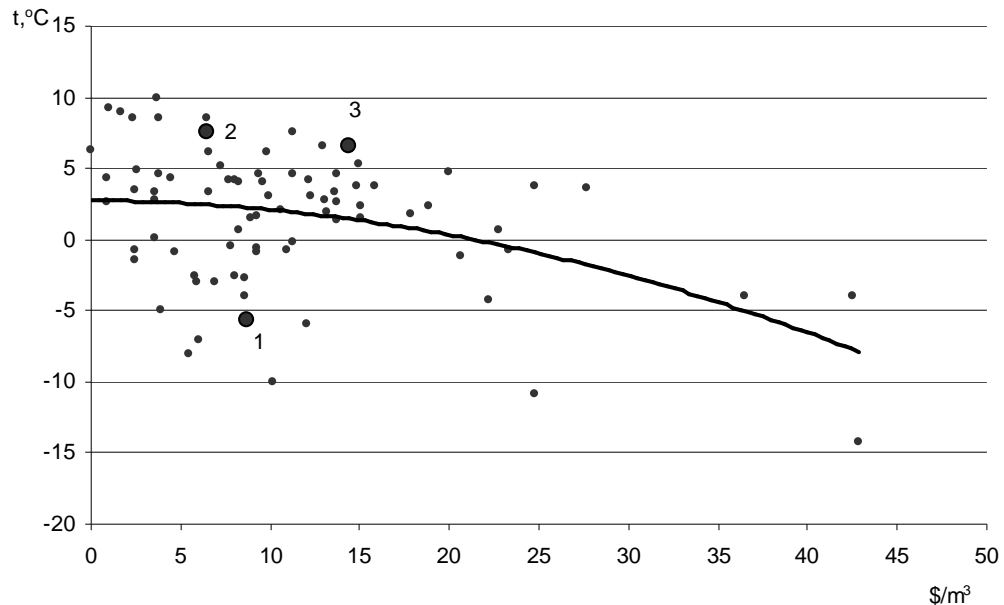


Fig. 2. The dependence of the regional gross domestic product per 1 m³ of used water on the average annual air temperature in 2000-2006. 1 - Russia as a whole, 2 - Ukraine 3 - Belarus.

Russia, Ukraine and Belarus are not equally provided with water resources. Russia excels other countries in most specific characteristics (Table. 1). Worst of all is the situation in Ukraine. Belarus occupies an intermediate position, at the same time having the highest index of groundwater sustainable flow - the most valuable runoff which does not require regulation (78 mm). The situation in Ukraine seems significantly better if considering the transit flow. However, this runoff includes Danube waters, the use of which is practically impossible for the most part of Ukraine.

Tab. 1. River runoff

Country	Area, thousands sq. km	Population, millions of people	Runoff					
			mm		km ³ /year		thousands m ³ per head	
			local	total	local	total	local	total
Russia	17075,4	142,4	236	250	4043	4270	28,4	29,9
Ukraine	603,7	48,5	87	348	52,4	209,8	1,2	4,3
Belarus	207,6	10,3	164	269	34,1	55,8	3,1	5,4

The presented picture reflects the situation in the States as a whole. Within each of these areas there are regions with good and poor water resources supply. Uneven distribution of river runoff is typical particularly for Russia. Thus, Azov and Caspian Basins, most focusing on Russia's economics, concentrate less than 8% of river flow (Waters of Russia, 1996-2000). Water resources are unevenly distributed in time too: the less their average amount is, the greater is their temporal variability.

It should be noted that in recent decades in all states there have been significant changes in mean characteristics of quantity, state and quality of water resources due to changes in climate and economic activity (Anthrop., 2003; Water resources, 2009).

Speaking about economic conditions of water consumption, the analysis of several economic indicators in these states, including gross domestic product (GDP), shows a deep economic crisis after the collapse of the Soviet Union. Less of all it affected Belarus, and the most profound it was in Ukraine. Only since the late 1990's economic recovery has begun in all three States.

This is the situation on the whole although in some regions of the States, especially in Russia, it differs significantly from the average. For example the change has not been too high in the resource-producing regions.

Water consumption in Russia, Ukraine and Belarus and its dynamics after 1990. The economic recession as well as the economic rise since the last years of the 20th century has affected the state of water resources. During the last 15 years water use and therefore water sewage reduction has been well seen.

The structure of water consumption in 1990 was characterized by following indices (Table 2). While analyzing, it should be considered that some authors exclude mining waters and some other categories of water from total water withdrawal (Dumnov, 2003). Table 2 shows the reduced amount of transportation water losses as well as the highest percentage of use of withdrawal water in Belarus. This is a result of non-considerable agricultural water use (including irrigation), where the greatest water losses take place (Demin, 2005). But the most high percentage of agricultural water use is in Ukraine (>29%).

Belarus differed by increased recycling water supply and reuse of water, which was three times more than withdrawal of "fresh" water. This is the result of the highest contribution (along with Russia) of industrial water supply, where recycling water is used. The highest share of waste and return waters (> 64%) in water withdrawal and therefore the lowest share of irrecoverable losses (36%) is in Russia. In Ukraine, the share of waste and return waters is the lowest (58%), and the irrecoverable losses (42%) are the biggest.

The economic crisis in the 1990's as well as the revival of economics during last years of XX century affected the state of water resources. During the last 15 years the water use and therefore water sewage reduction has been well seen. It is interesting to mention that the reduction of water consumption in recent years has taken place in the U.S. too, but there it is the result of water conservation measures (Dumnov, 2006; Koronkevich, 2003; Koronkevich, 2002). The largest reduction in water consumption was in Ukraine (Table 2, Fig. 3) due to the high water usage in irrigation systems and in agriculture where the greatest setback in production and water consumption after the collapse took place. It should be noted that during the same period a decrease in air humidity deficit during the vegetation period had been observed, that also contributed to the reduction of irrigation norms and water withdrawal for irrigation.

The largest reduction in industrial water use was in Ukraine, it concerns both "fresh" and reused water.

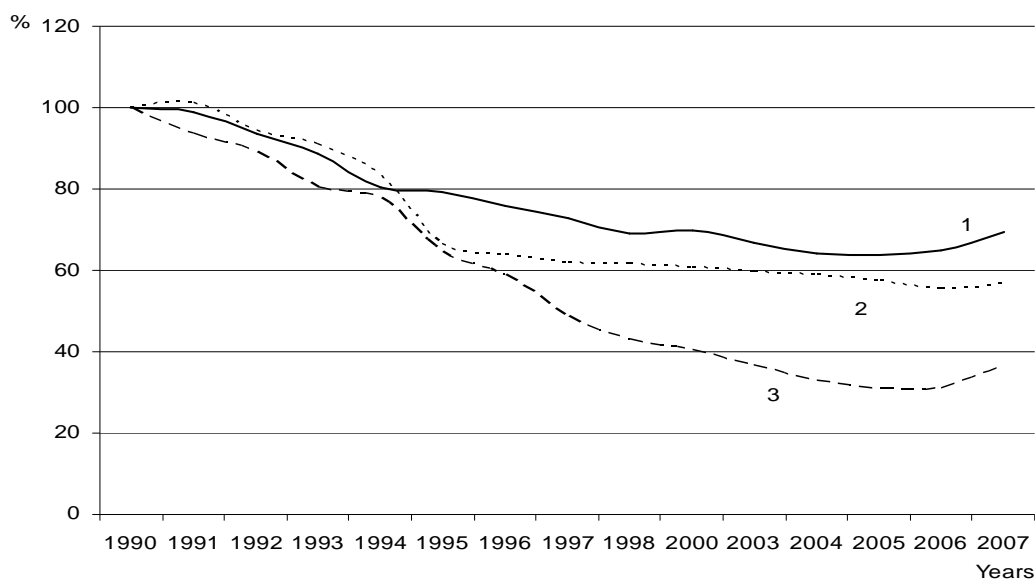


Fig. 3. Water use in 1990-2007, 1990=100 %. 1 - Russia; 2 - Ukraine; 3 – Belarus.

Tab. 2. Main indices of water consumption in Russia, Ukraine and Belarus, km³/year

Index	Year 1990			Year 2007			Year 2007 / Year 1990		
	Russia	Ukraine	Belarus	Russia	Ukraine	Belarus	Russia	Ukraine	Belarus
Water withdrawal	118	34.9	3.04	74.6	16.4	1.7	0.63	0.47	0.56
Transportation water losses	8.4	2.6	0.08	7.9	2.44	0.11	0.94	0.94	1.38
Water recycling and reuse	171	67.7	9.5	103.5	48.9	6.35	0.61	0.72	0.67
Total water consumption	96	29.6	2.7	62.5	9.8	1.49	0.65	0.33	0.55
-including domestic water consumption	14.6	4.6	0.7	11.6	2.2	0.65	0.8	0.48	0.93
-industrial water use	61	16.3	1.7	41.9	4.7	0.72	0.69	0.29	0.42
-agricultural water use	20.5	8.7	0.3	9	2.9	0.12	0.43	0.33	0.4
Sewage	75.4	20.3	1.98	51.4	8.6	1.04	0.68	0.42	0.53
-including contaminated waters	31	3.2	0.1	17.2	3.85	0.009	0.55	1.2	0.09
Irrecoverable water losses	42.6	14.6	1.06	23.2	7.8	0.66	0.54	0.44	0.62

Reduction in domestic water consumption was considerably lower than in industrial and agricultural water use, and by mid-1990 (until 2006) an increase in domestic water use in Belarus was seen. Mostly it was a result of the unproductive water losses growth, although the percentage remains the lowest among the three countries. The biggest percentage of water losses is in Ukraine.

In general the dynamics of discharge into rivers and ponds has been the same as for water withdrawal and water use with the largest reduction in Ukraine (Table 2). But there are some differences in various categories of waste and return waters in the three states caused by different approaches to the definition of these categories. The main difference concerns the growth of polluted waste water in Ukraine.

Meanwhile, in Russia and especially in Belarus the tendency to the reduction of untreated sewage and waters containing contaminants has been observed. However, the accuracy of the comparative analysis of the amount of untreated sewage depends on different methods of the division of sewage into categories (State report, 1998-2008; The natural environment, 2005; Water industry, 2000).

Inclusion or exclusion of mining waters not related to direct water consumption influence on the assessment of the dynamics of irrecoverable water losses in Russia and causes uncertainties. But in any case the greatest reduction in irrecoverable water losses has been in Ukraine, mainly in the agricultural sector.

To clarify the situation with water use, different regions of Russia, Ukraine and Belarus close by climatic conditions have been compared. In most of Russian regions the reduction in water withdrawal is than in Russia as a whole. The same situation is typical for wastewater.

Contemporary changes in the state of water resources. During last years on the territories of Russia and Belarus the rise in river runoff has been observed. Changes of the river runoff in Ukraine were not so certain but at the very end of the 20th century the raise was also seen (Fig.4). During the last 10-15 years the rise in river runoff was close to 5% (Water resources, 1967; Water resources, 2009; Water balance, 1969; The natural envir., 2005).

The main reason for this is climatic – first of all warming during cold seasons and augmentation of rainfall in winter and in summer (Shiklomanov, 1989, 2002). Along with the territories where runoff has increased, there are those where it hasn't increased or even decreased (Bolgov, 2005; Lvovich, 1974). But in all three states the changes have been partly caused by the reduction of water withdrawal and irrecoverable water losses (Fig. 5). Decrease in water losses in Ukraine is more noticeable because of considerable reduction in agricultural water usage.

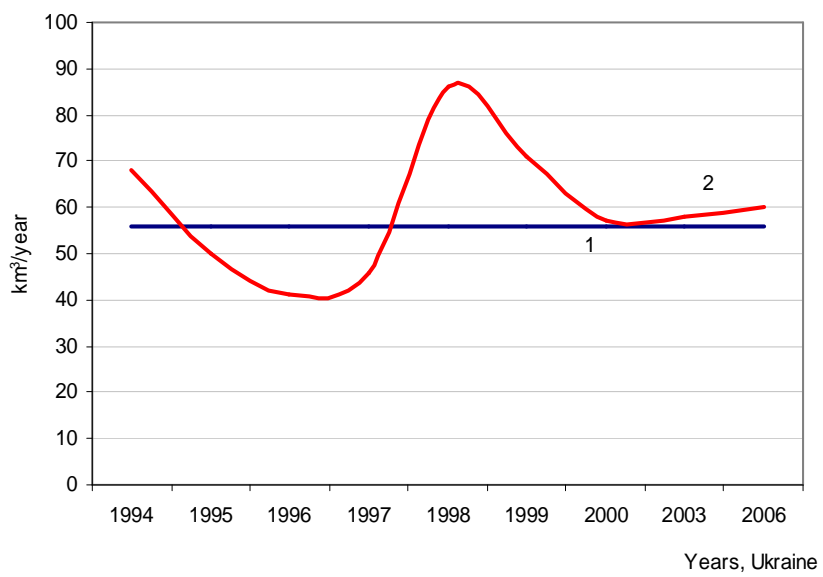
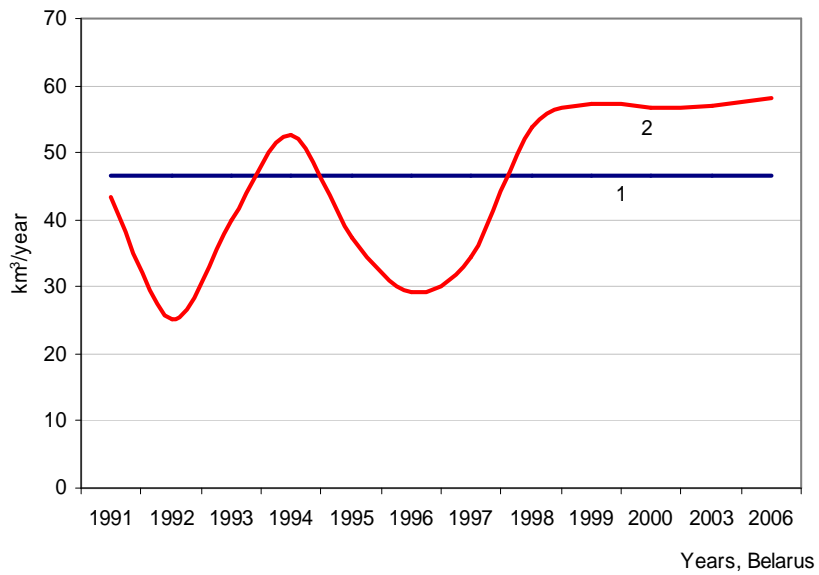
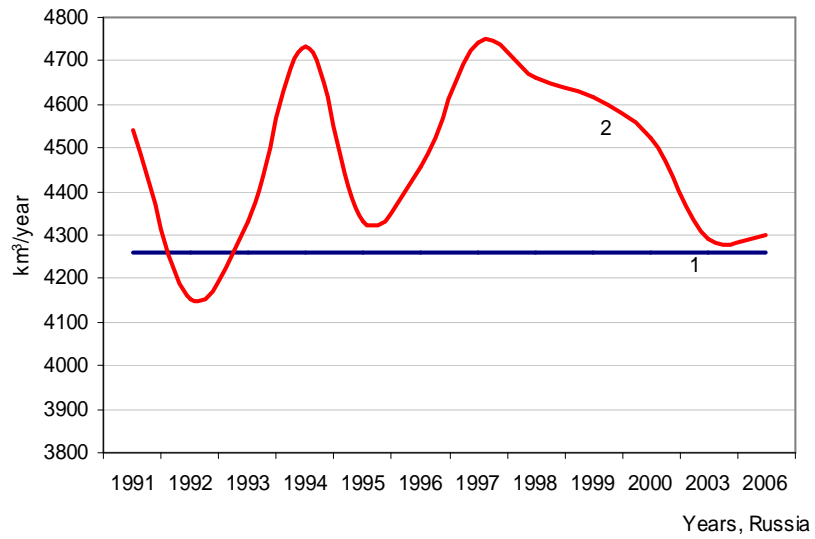


Fig. 4. Runoff fluctuations in 1990-2000. 1 – average long-term runoff, 2 – real long-term runoff.

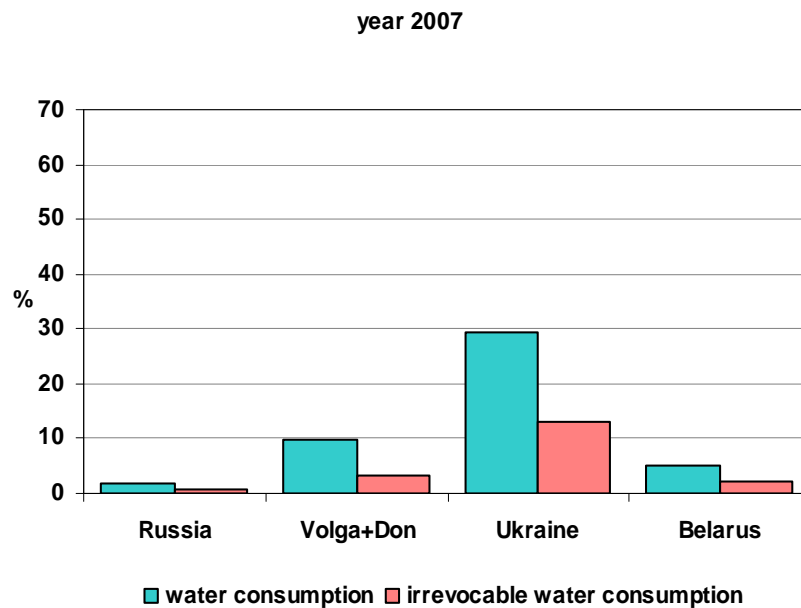
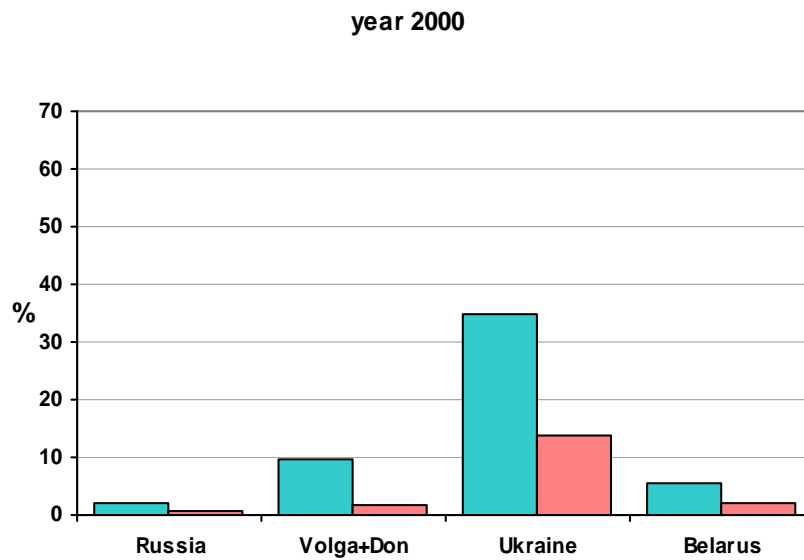
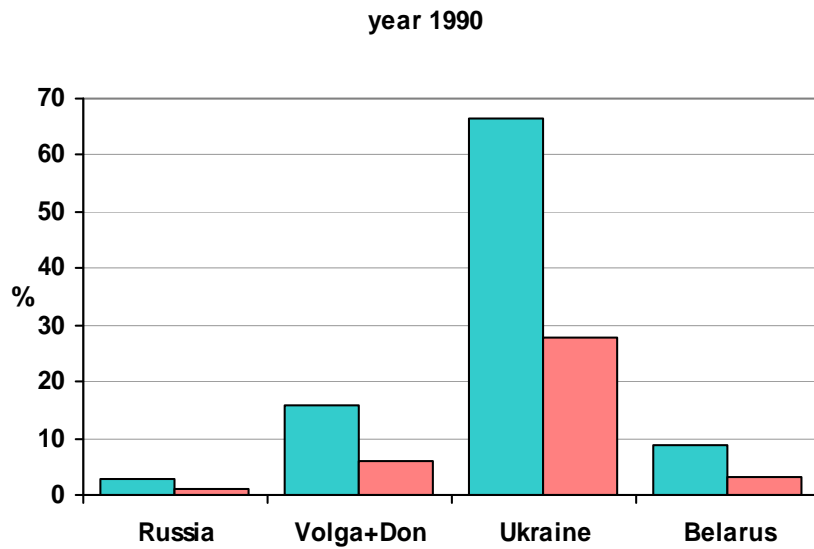


Fig. 5. Water consumption and irrevocable water consumption against average long-term runoff.

Despite the economic recession and therefore the total reduction of sewage into water bodies fundamental improvement of their quality indicators in all three countries has not been observed. (Anthropogen., 2003; Volchek, 2005; Demin, 2000; National report, 1998-2005; Overview, 2005; Trends, 2007; Environmental aspects, 2005; Yatsyk, 2006).

The problem of water quality still remains very important. In general, the situation is less critical in Russia due to the huge amount of water resources (the dilution ratio of wastewater with local river runoff - 78.7 times, the total - 83.1 times). The most difficult situation is in Ukraine. Dilution of wastewater with local runoff is about 6.1 times and by total - 24.4 times. But as it was already noted the Danube water should be taken into account with a very big reservation.

According to official statistics the most favorable situation with water quality is in Belarus, mainly because of the most rapid decrease of contaminated wastewater. By 2007 (compared to 1990) it decreased 11-fold, whereas in Russia - by factor of 1.8, while in Ukraine increased by factor of 1.2 (Table 2). However, the situation in Belarus still raises questions. Judging by the dilution ratio of the total amount of wastewater, Belarus occupies an intermediate position between Russia and Ukraine (dilution by local runoff - 32.8 times and total - 53.7). But considering contaminated wastewater the picture is surprisingly optimistic - dilution with local runoff - more than 3,780 times, and total runoff - 6200 times, that can be explained only by the difference in inclusion of waste water to one category or another.

Fig 6. reflects the changing ratio of sewage and average runoff. As in Fig. 5, the data for the river basins of Volga and Don has been represented.

In some populated areas of Russia, Ukraine and Belarus the situation with wastewater is more critical than in general for the whole states (State report, 1998-2008; National report, 1998-2005; National report, 2001-2008).

In addition to waste water and return water, washing of the contaminants from the catchment area considerable influences on water quality much.

Water use effectiveness. From the environmental point of view that human impact on water resources is better, which modifies their natural amount, state and quality less. Speaking about quantity, as it is shown in Fig. 5, 6, the lowest change in water resources was in Russia as a whole, the highest - in Ukraine. Belarus occupies an intermediate position. Similar situation concerns the impact on water quality (if we take into account the total amount of wastewater). When considering polluted wastewater Belarus is in the best position, followed by Russia and Ukraine, but as it was already noted, it depends on differences in classification of waste water.

Situation is different while assessing changes in environmental impacts on water use. Speaking about water quantity, anthropogenic influence on water resources has mostly decreased in Ukraine, then follow Belarus and Russia. Speaking about water quality the most considerable tendency to improvement is in Belarus.

Economic effectiveness of water use (partly environmental) is usually estimated by the amount of production per unit of consumed water, or inverse ratio - the amount of consumed water per unit of production. While comparing the effectiveness of water use and other natural resources N.F. Glazovskiy (Glazovskiy, 1992, 2004) widely used such economic indicator as the gross domestic product (GDP) or gross regional product (GRP). In this paper the similar approach has been used for the three states and for different regions of the Russian Federation.

Another reason, except water conservation measures, for better position of Belarus while assessing water use effectiveness can be the absence of water-retaining irrigated agriculture. On the contrary this puts Ukraine into the third place after Russia and Belarus.

In Russia, the highest water-use effectiveness is typical mainly for resource-producing regions. These are first of all the Republic of Sakha, oil-producing districts of the Khanty-Mansi Autonomous District. High water-use effectiveness is typical for the Moscow region, as well as for the whole central european part of the country (Bibikova, 2009). The worst situation with the effectiveness of water use is in the southern part of Russia. This is primarily due to the large amount of water used for low-income agricultural purposes.

In addition, the area of low economic effectiveness of water use includes some of the northern regions of Russia, e.g. the Leningrad region with the high power generation and the low percentage of water recycling.

Analising the changes in water use effectiveness (I) after the collapse of the Soviet Union we compared the indices of GDP change and water consumption change (Anthropogen., 2003) (Fig. 7).

Situation is similar for all three states. In the early 1990's. due to the crisis in the economics GDP had been reducing faster than water consumption. Therefore the specific (expended per unit of output) water consumption had grown. But then after the economic recovery this ratio increased and the specific consumption of water began to fall. First of all this happened in Belarus. Reduction of specific water consumption in recent years has been caused by restructuring of the economy, a partial "coming out to light" of the so-called shadow economy, which has always used water, but only now begins to report on the extent of production, as well as on the measures limiting water use. The biggest reduction in specific water consumption in recent years was in Ukraine.

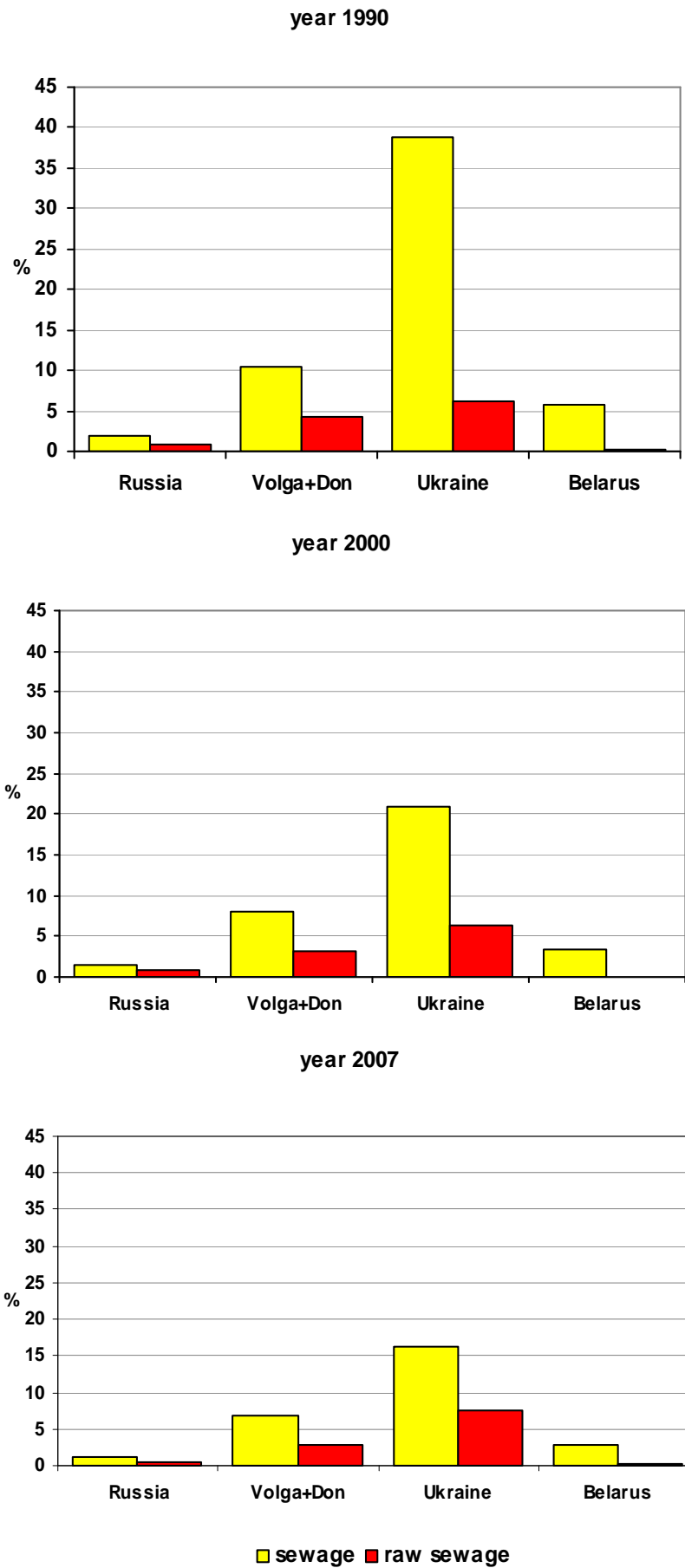


Fig. 6. Sewage and raw sewage against average long-term runoff.

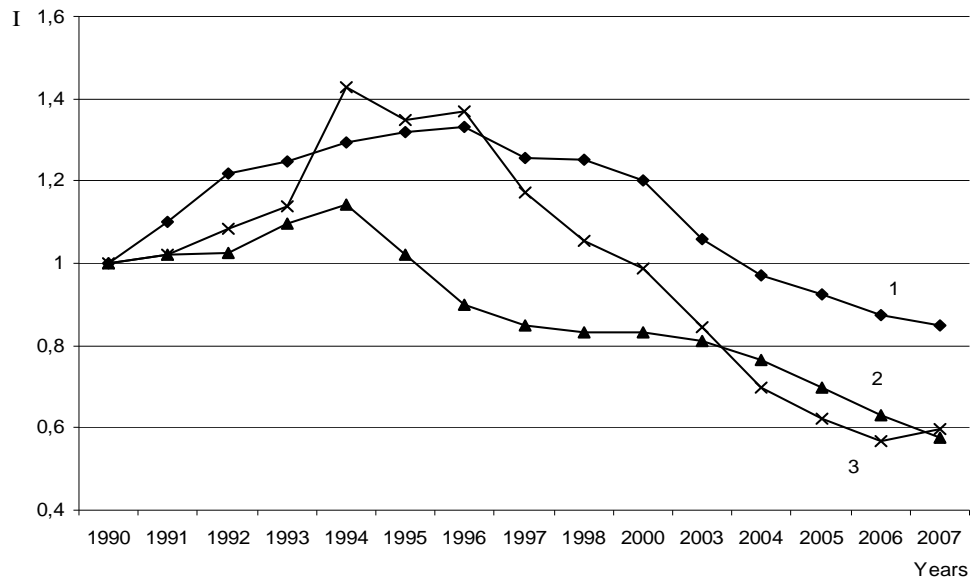


Fig. 7. Indices of change of GDP and water consumption, /, 1 - Russia 2 - Belarus 3 - Ukraine.

Conclusions

Water consumption is the main indicator of human impact on water resources in Russia, Ukraine and Belarus. Water consumption is determined by a complex of climatic and anthropogenic factors which influence both directly and indirectly.

During the post-Soviet period In Russia, Ukraine and Belarus there has been great reduction in water consumption. Compared to 1990 water use in Russia in 2007 decreased by 35%, Belarus - 45%, Ukraine - by 67%. The most considerable reduction was by mid-1990. In recent years it has slowed, and even some growth has been seen. The biggest decrease in water consumption took place in agriculture: 57% in Russia, 67% Ukraine, 60% in Belarus.

During last years on the territories of Russia and Belarus the rise in river runoff has been observed. Changes of the river runoff in Ukraine were not so certain but at the very end of the 20th century the raise was also seen.

In spite of water use and sewage reduction and rise in river runoff the problem of the quality of water resources in all three countries has not been solved. The most difficult situation with the quality of water remains in Ukraine.

Most effective use of water is in Belarus, least is in Ukraine.

In the early 1990's in all three states the decrease in GDP had been more rapid than in water consumption, therefore, the specific consumption of water had grown. Then with the "revival" of the economics, the picture changed and the specific consumption of water decreased. First this happened in Belarus. In recent years reduction of the specific water consumption has been well seen in Ukraine.

Moreover, it's necessary to have accurate homogeneous socio-economic, water management, hydrological and other data. It is not always possible for such reasons as transfer of indices from one category into another, changing the way of calculation and estimation, stations' relocation or annihilation, irregular or imperfect measurement methods and observation, rejection of observations or imprecise estimates.

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