

Water supply and water discharge: challenges and concept of responses – context of climate change and exhaustions of water resources

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Abstract

For a long time the natural water resources of Ukraine experienced a heavy anthropogenic pressure resulting in the negative environmental changes. The examples of such changes related to forecast of impact of possible tendencies of climate change are considered in this article.

In 2015 year the general hydrological situation in the basins of the Ukrainian rivers and reservoirs was rather dangerous due to the smallest volume of water in the reservoirs over all the period of their exploitation. Such situation occurred due to the complicated climate conditions (climate aridization), and consequent increased water consumption.

The intensive water pollution by wastewater from industrial enterprises and municipal companies, wastewater from animal farms, surface run of snow melting as well as by rain waters contaminated by the different pollutants from the agricultural and urban areas, and exploitation of water transport make the situation in Ukraine even more complicated (*DEFRA, 2010 Europe; European; Feyen, 2009*).

For the analyses of the long-term regional changes of climatic fields in Ukraine the empirical data of observations obtained from the network of meteorological stations were used. The semi-empirical models of transformation of annual and seasonal courses of climatic conditions (surface temperature change and precipitation) in Ukraine under the influence of global warming were developed. For comparison the climatic field of the annual and seasonal temperatures and the annual sum of precipitations for the Holocene Optimum were also used. The expected features of climate change and consequences for Ukraine were forecasted. The coastal regions of the Black Sea and the Sea of Azov, the Carpathians, mountains of Crimea and steppe were recognized as the territory of Ukraine the most vulnerable to climate changes.

The answer to this challenge should be a change in attitude to water: maximum economy, adequate pricing, termination of pollution, groundwater use, maximum

treatment and swivel water use, recovery of natural rivers, lakes, flood plains, deltas, coastal zones, swamps and wetlands, reduction of the surface area of reservoirs. As new legal instrument the updated Water Code of Ukraine lined up to the European Union water legislation and the Protocol on Strategic Environmental Assessment should be applied widely.

Keywords

Climate change, water resources, water supply, wastewater discharge, forecast and trends of the state of water resources, measures towards water policy in municipal sector

1 Introduction

The natural water resources of Ukraine for many years experienced a heavy anthropogenic pressure, resulting in the negative environmental changes and the consequent economic losses. Examples of such changes related to the possible scenarios of climate change impacts are presented in this article.

To some extent the climatic conditions may result in decrease in the water volume in the water bodies due to increased evaporation caused by of the elevated surface temperature and reduced precipitation (*Feyen, 2009*).

In 2015 year the general hydrological situation in the basins of many rivers and reservoirs of Ukraine was characterized as dangerous due the lowest volume of water during the total time duration period of their exploitation. Such situation occurred due to a very hot and dry weather conditions (climate aridization), and the consequent increase in the water consumption.

These factors resulted in the reduced water discharges from reservoirs to the minimal allowable sanitary and environmental values and significant drawdown of the Dnipro reservoir cascade (6 reservoirs) and the Dnister reservoir. Free volume of the Dnipro reservoir cascade in September of this year was equal to 5.1 km³ where during the last few years it did not exceed $2/75 \pm 0./25$ km³. The water discharge of the Dnister reservoir decreased to 105–110 m³/sec when the minimal environmentally allowable was equal to 100 m³/sec (Fig. 1). Water volume of the Southern Bug river in August and September 2015 was approx. 12–15% lower than the monthly average.

The intensive water pollution by the various sewage from industrial enterprises and municipal companies, wastewater from animal farms, run of snow melting and polluted storm water from the agricultural and urban areas as well as exploitation of water transport complicate the situation.

Climate changes

- Increase of average annual temperature
- Decrease of precipitation amount
- Warmer cold periods



Decreased water level in the estuary of the Smotrych river, September 2015

Water resources

- Decrease of water level in water reservoirs, and increase of water consumption
- Intensive sewage pollution of water bodies
- Increase of temperature of water surface of water bodies
- Excessive alga bloom



Decreased water level in the river Dnister, September 2015

Fig. 1. Consequences of climate changes, and its influences on water resources

2 *Materials and Methods*

For the analyses of long-term regional changes of climatic fields in Ukraine the empirical data of observations obtained from the network of meteorological stations were used. The applied meteorological stations were chosen to meet the following requirements (*Boychenko, 2007; Voloshchuk, 2002; Voloshchuk, 2003*):

- observations by meteorological stations were started not later than 1900;
- missing observations by meteorological stations do not exceed 30% for the period 1900–2000.

Only 25 of such stations operate at the territory of Ukraine. It is supposed that the main reason of the regional changes of climatic conditions in the territory of Ukraine for last 100 years is the global warming because of anthropogenic global atmosphere pollution by “green-house” gases. The analyses of dependence of meteorological parameters on time (seasonal fluctuations) and on the altitude above sea level, and also their geographical distribution at the territory of Ukraine was performed in this paper. Such complex research represents the special interest of Ukraine related to its sharply expressed orography (for example, Ukrainian

Carpathians, Crimean Mountains, Volynsk and Donetsk elevations) and also with the features of distribution of anomalies of atmospheric precipitation at its territory.

The climatic field of annual and seasonal temperatures and the annual sum of precipitations for the Holocene Optimum ($\Delta T \sim 1 \text{ }^\circ\text{C}$) were also used in our studies (Oliver and Fairbridge, 1987; Velichko, 2002).

3 Results and Discussion

3.1 Water supply and wastewater discharge in Ukraine: practice and state of art

The municipal and industrial water demands in Ukraine are satisfied presumably by surface water, the total share of which in water supply constitutes approx. 80% (Міністерство, 2013). Surface water is more affordable in comparison to groundwater but – much more vulnerable to the technogenic pollution. Even in the areas of unfavorable natural conditions for use of surface water due to extremely scarce water resources and their high mineralization (East and South of Ukraine) water pipes for water supply were constructed from the large rivers, mostly – from the Dnipro river.

Volume of water sampling from natural water objects during 2010-2014 years

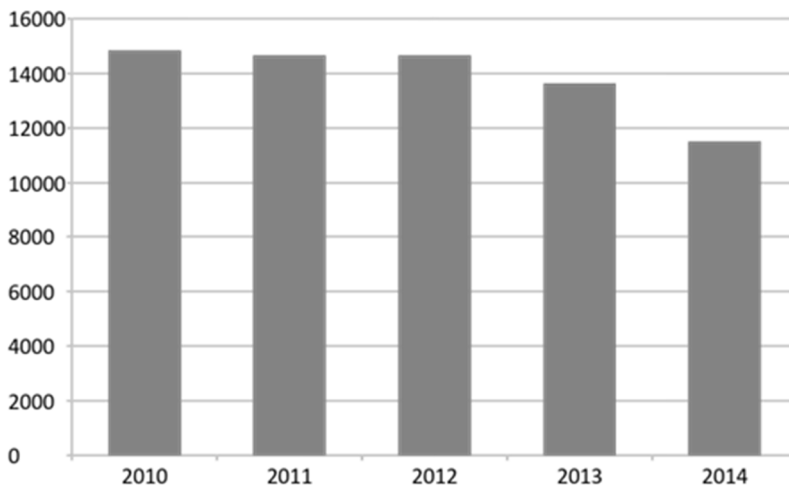


Fig. 2. Volume of water intake from natural water objects during 2010–2014 years

The intensive use of surface water for the purposes of consumption and energy generation is accompanied by the regulation of river flow (volume of water intake from natural water objects during 2010–2014 years was presented in Fig. 2).

As a result, the water reservoirs and pounds accumulated approximately 58 billion m³ of water. This volume exceeds the annual flow from all rivers of the country. Regulation of most of rivers reached or even exceeds the upper economic and environmentally sound water-allowable limit up to the point of environmental destruction (above 75% of total length of channels at optimum 25–30%) – dramatically reduced and often totally destroyed the self-purification capacity of rivers (*DEFRA, 2010; Державна, 2014, 2015; Feuyen, 2009; Національний*). Indicators of the general water drainage during 2010–2014 years were showed in Fig. 3 (*Державна, 2014, 2015*).

Indicators of general water drainage during 2010-2014 years

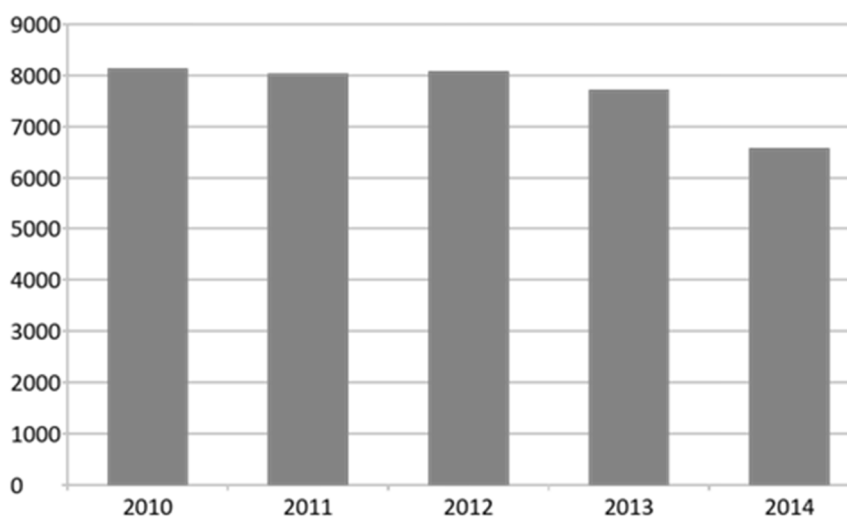


Fig. 3. Indicators of general water drainage during 2010–2014years

State of both types, the small and large rivers of Ukraine steadily continues to deteriorate.

The chemical and radiological indicators (information of state monitoring system in 2013) show that the quality of surface water is unsatisfactory. In more than 90% of the control points the standard allowable concentrations of pollutants or indicators of physical and chemical state of surface water were exceeded. In most cases these indicators were: chemical oxygen demand and biochemical oxygen demand, total iron and color. Manganese, dry residue, hardness, sulfates;

petrochemicals also exceeded the maximum allowable concentrations (*DEFRA, 2010; Feyen, 2009; Міністерство, 2013*). In addition, the phosphates, presence of which is a result of influence of sewage waters at river systems, were detected in the tested surface water.

Volume of dumped sewage water during 2010-2014

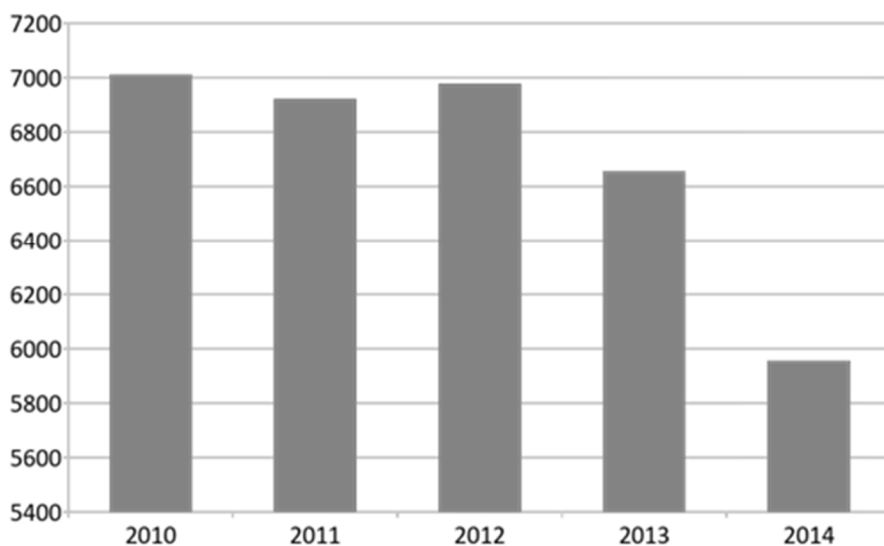


Fig. 4. Volume of dumped sewage water during 2010–2014 years

The official statistics says that 440 million m³ of wastewaters were discharged into surface waters in 2013. Including the polluted water constituted 1717 million m³ (23%), normatively treated – 1477 million m³ (20%), normatively cleaned without treatment – 4246 million m³ (57%) (*Міністерство, 2013*). The 881 enterprises discharge wastewaters into the surface water bodies. Sources of municipal and industrial wastewater discharge into water bodies or through a system of urban sewage. In 2013 (according to the official data) 45.2 thousand tons of suspended solids, 375.6 tons of petrochemicals, 1006 thousand tons of sulfates, 782.5 thousand tons of nitrites, 253.4 tons of synthetic detergents, 760.5 tons of iron, 7.8 thousand tons of phosphates, etc. were discharged with wastewaters into the surface water bodies (*Державна, 2014, 2015*). Volume of dumped sewage water during 2010–2014 was shown in Fig. 4 (*Державна, 2014, 2015*).

In addition, the quality of surface waters is also negatively affected by discharge of pit mine water discharged almost without any treatment into surface water bodies in the annual volume of 661 million m³.

3.2 Climate change and consequences for Ukraine

The analysis of data of instrumental observations of a network of meteorological stations of Ukraine for last 100–130 years showed that its climatic conditions reacted to the global warming as follows (*Boychenko, 2008; Boychenko, 2015; Voloshchuk, 2003; Voloshchuk, 2010*):

- the annual temperature increased by 0.6 ± 0.2 °C/100 years which approximately coincides with estimations of a level of the global warming (Fig. 5);
- the process of alignment of an annual temperature field was revealed: in northern and north-east regions the annual temperature increased by 1.0 ± 0.2 °C/100 years; in southern and south-west regions of Ukraine – only by 0.5 ± 0.1 °C/ 100 years;
- decrease in the amplitude of a seasonal course of temperature by ~ 0.4 – 0.5 °C (effect of continentalization): significant warming in the cold period of year (1.0 – 2.0 °C/100 years), for spring (1.5 – 2.0 °C/100) years; warming was insignificant in summer months;
- insignificant increase in the annual sums of precipitations (5–7% for 100 years) (Fig. 6);
- general alignment of a climatic field of the annual sums of precipitations was revealed. In northern and north-west regions of Ukraine, where the annual sum of precipitations was relatively high (650–750 mm/year), it decreased approximately by 10–15%; in southern and south-east regions, where the annual sum of precipitations was relatively low (350–450 mm/year), it increased approximately by 10–15%;
- decrease in the sum of precipitation for some months: spring – May, summer-autumn – August–September;
- increase in the repeated anomaly of high temperatures in May for the period 1891–2011 (in XX century – $16/5$ – $17/5$ °C and in XXI – $18/0$ – $18/8$ °C).

Surface temperature and precipitation changes in Ukraine were used for elaboration of the regional scenarios:

1. Scenarios of the global surface temperature change for the end of the 21st century (*Climate, 2013*):

- it is likely that not to exceed 2°C for RCP4.5 – ($\Delta T \sim 2.0$ °C);
- it is likely to exceed 2°C for RCP8.5 – ($\Delta T \sim 4.0$ °C).

2. Semi-empirical models of transformation of the annual and seasonal courses of climatic conditions (surface temperature change and precipitation) in Ukraine under influence of the global warming (*Boychenko, 2007; Boychenko, 2008; Voloshchuk, 2003; Voloshchuk, 2004; Voloshchuk 2010*).

3. Climatic field of annual temperatures and the annual sum of precipitations for the Miculino ($125 \cdot 10^3$ years, $\Delta T \sim 2/0-2/5^\circ\text{C}$) and Pliocene Optimum ($2.3-3 \cdot 10^6$ years, $\Delta T \sim 3/0-4/5^\circ\text{C}$) (*Oliver and Fairbridge, 1987; Voloshchuk, 2002*).

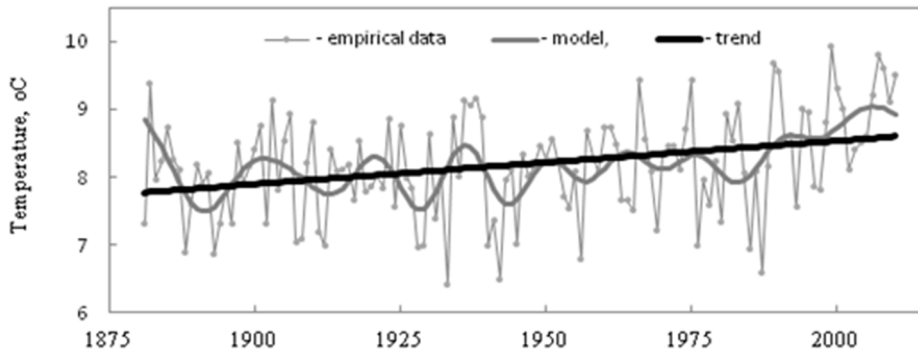


Fig.5. Century course of fluctuations of annual temperature in Ukraine for the period 1881–2010

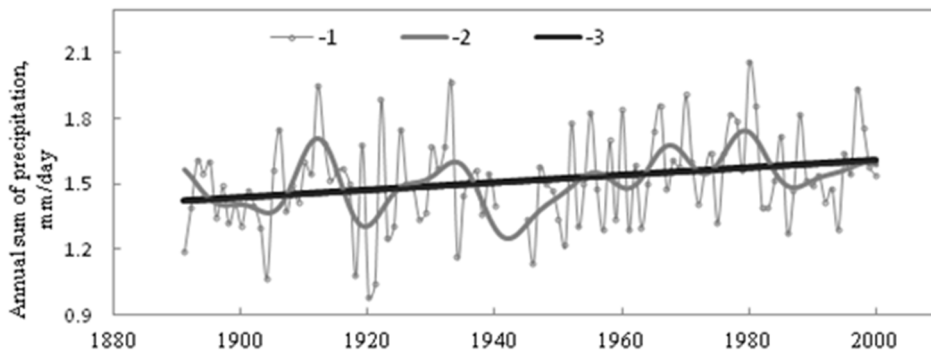


Fig.6. Century course of fluctuations of annual sum of precipitation in Ukraine for the period 1885–2005

Thus, the regional scenarios of surface temperature change in Ukraine for the 2050 (Fig.7) are the following (*Boychenko, 2008; Boychenko, 2015; Voloshchuk, 2003; Voloshchuk, 2010*):

- scenarios 1: it is likely than not to exceed ($\Delta T \sim 1.4 \pm 0.2^\circ\text{C}$);
- scenarios 2: it is likely to exceed ($\Delta T \sim 2.4 \pm 0.3^\circ\text{C}$).

The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be some regional exceptions (Climate, 2013; Jones, 1999; Voloshchuk, 2004). Therefore, regional scenarios of precipitation change in Ukraine for the 2050 the following is expected (Boychenko, 2007; Boychenko, 2015; Voloshchuk, 2010).

Scenarios 1: increase in the annual sums of precipitations on $10\pm 5\%$ and aridity of climate in the warm period of year (May and August).

Scenarios 2: differential spatial distribution of annual sums of precipitations, namely increase in the northern, northwest and northeast regions by $15\pm 5\%$ and decrease in the southern, southeast and southwest regions by $15\pm 5\%$.

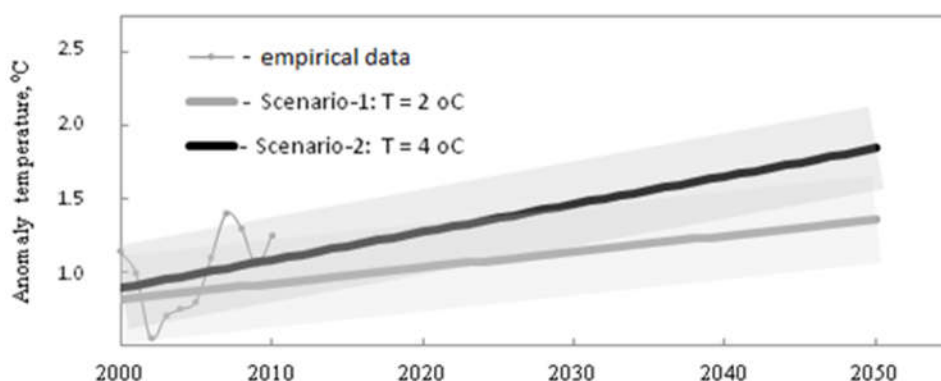


Fig. 7. Regional scenarios of surface temperature change in Ukraine for the 2050

The following features of climate change and consequences for Ukraine are expected (Boychenko, 2008; Kobak, 1992; Tkachenko, 2014; Velichko, 2002):

- effect of the approximate synchronization of fluctuations of levels of the Black Sea and the Sea of Azov with fluctuations of the World Ocean. Century course of a level of the Black Sea and the Sea of Azov for the period 1923–2007 increased by 12–15 cm/100 years and in the scenario for period 2050 a level of sea will increase till 25–30 cm – $\Delta T \sim 2\text{ }^{\circ}\text{C}$;
- activation of catastrophic shifts and deformations in mountain regions of the Carpathians mountains and the Crimea through changes of a regime of humidity, water balance, ground and subsoil waters;
- increase in the repeatability of catastrophic floods in region of the Ukrainian Carpathians mountains caused by an intensification of heavy rains and intensified by deforestation;
- intensification of meridional circulation of an atmosphere which will result in the increase in the repeatability of some anomaly synoptic formations above Ukraine;

- structural drift of steppe phytosystems in Ukraine under the influence of climate changes and in line with the scenarios for first half of the XXI century. The analysis of ratio of the basic ecobiomorphological components in phytocoenosis of the Ukrainian steppes at the second half of the XX century and in the beginning of the XXI century revealed the tendency of degradation of xero-morphic component by $30\pm 10\%$ and the reverse tendency of increase of mezo-morphic component by $10\pm 5\%$ and lignostic components by $20\pm 10\%$.

So, the most vulnerable to climate changes in territory of Ukraine are the coastal regions of the Black Sea and the Sea of Azov, the Carpathians and mountains of the Crimea and steppe.

4 Summary and Conclusions

Systematic analysis of the current trends in climate change, environmental state of the river basins of Ukraine and peculiarities of management and protection of water resources showed that most urgent problems are as follows:

- increase in the temperature at water surface of water bodies;
- reduction in the water content of water bodies due to the increased evaporation upon increased surface temperatures and reduced rainfall, especially in the upper and middle part of the basins; processes of soil degradation resulting from the intense ravine and planar erosion, subsidence of loess rocks, water logging and raising water table of groundwater;
- increase in the frequency and intensity of the steamy fog around the reservoir which forms due to difference between ambient temperature and temperature above water in cooling pond;
- intensive alga blooms and, consequently, occurrence of fish mortality due to the reduced oxygen content in water, slow water exchange and the formation of stagnation zones;
- intensification of river pollution during the low water level periods – due to wastewater discharges by municipalities and industries without the adequate treatment, inefficient treatment plants or no treatment.

The increased irreversible losses of water and the reduced water volume of watercourses with a gradual temperature increase and rainfall decrease are observed in Ukraine. The answer to this challenge should be a change in the attitude to water: maximum economy, adequate pricing, termination of pollution, groundwater use, maximum treatment and swivel water use, recovery of the natural rivers, lakes, flood plains, deltas, coastal zones, swamps and wetlands, the reduced surface area of reservoirs. Accordingly, the adequate revision of the Water Code, and the

national strategies in water management, education of water users and sustainable water consumption. Ratification of the Protocol on Strategic Environmental Assessment introduced the new legal instrument to be applied *inter alia* to the water management schemes and plans. The necessary revision of the draft law on Environmental Impact Assessment, its expert discussion and approval by the Verkhovna Rada of Ukraine currently shall be accelerated in Ukraine to fully extent address to water saving issue in the each investment project.

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