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Ukrainian hydro-economic complex under conditions of sustainable development

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Abstract This paper describes the Ukrainian hydro-economic complex in the context of sustainable development. Criteria such as the supply of renewable water resources of satisfactory quality (I_g), the efficiency of water resources use (I_e), and the index of water resources risk (I_d) were used to determine sustainable development.

Key words sustainable development; water resource use; water resource risk; Ukraine hydro-economic complex

INTRODUCTION

As a planetary ideology with a new system of values, sustainable development must have accurate criteria of behaviour with estimates of acceptable deviation. This can be realized for humanity as a system, while development of subsystems (countries, regions) will be an element of sustainable development. The main aspects of the approach to sustainable development on both regional and global scales are:

- every person in the world has a right to an equal volume of natural resources and to a healthy environment;
- the use of natural resources should not exceed the renewable ability of the Earth to satisfy the requirements of future generations.

For this, it is necessary:

- to guarantee equal rights to use of natural resources by contemporary and future generations;
- to regulate the requirements of social production for natural resources from the positions of balance, sufficient necessity, complexity, and environmental safety;
- to develop ecological requirements for conservation and sustainable use of natural resources.

Water resources, which are the main important component of the national wealth, change in time and space. In contrast to other natural resources, many aspects of water resources are continuously renewed and change their quality under the influence of inflow sources and environmental conditions. As a result of this, sustainable development of the hydro-economic complex is determined by such criteria as the supply of renewable water resources of satisfactory quality and the efficiency of water resources use.

DEVELOPMENT OF CRITERIA

The criterion of supply (I_g) is a ratio of the total volume of water resources to water consumption:

$$I_g = \frac{Q_r + Q_{gw} + Q_a}{C_p + C_t} \geq 1 \tag{1}$$

where Q_r (m^3 year^{-1}) is a rate of river runoff, Q_{gw} (m^3 year^{-1}) is a rate of groundwater runoff, Q_a (m^3 year^{-1}) is a rate of other water sources (sea water, mine water, water recycling, induced recharge of groundwater resources), $C_p = c_n N$ is a rate of public water consumption (c_p is the consumption per one person (m^3 year^{-1}), N is the size of the population), and $C_t = c_t W$ is technological water consumption by Ukrainian economic activity (both industry and agriculture). c_t is the water-capacity of a monetary unit of a gross output (m^3/monetary unit); and W is a gross output (monetary unit).

The difference between the numerator and the denominator in equation (1) is a water supply reserve (R), which must exceed the difference between water resources (both groundwater and surface water runoff) in a year with average discharge (Q_m) and water resources in a year with low discharge (Q_s):

$$R = \left[\left(Q_r + Q_{gw} + Q_a\right) - \left(C_p + C_t\right)\right] > Q_m - Q_s \tag{2}$$

The efficiency of water resource use is determined by both the minimization of gross output water-capacity:

$$c_t \Rightarrow min \tag{3}$$

and maximization of the efficiency criterion (I_e), which can be defined as the ratio of total water requirements (C_w) to the sum of transportation loss (Q_t), irrevocable water consumption (C_u), and waste discharge (Q_d):

$$I_e = \frac{C_w}{Q_\ell + C_u + Q_d} \Rightarrow max\,. \tag{4}$$

Figure 1 shows the ratio between total water inflow (ΣQ) and water consumption in time under conditions of sustainable development.

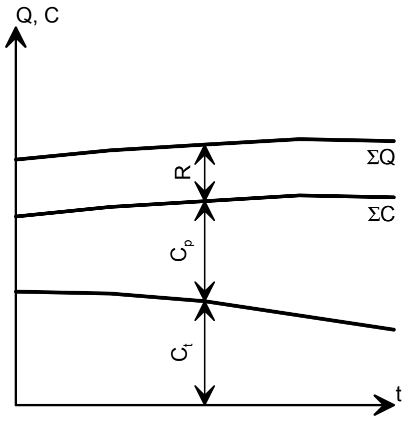

Fig 1. The water inflow–water consumption ratio under conditions of sustainable development.

Water inflow should increase under conditions of sustainable development due to an increase in water recycling or the exploitation of alternative sources. A rise in water consumption due to population upsurge and improvement of sanitary conditions should be compensated by a reduction of technological water consumption including a decrease in gross output water-capacity, technological and transportation losses, and waste discharge. These stability criteria should be determined for both the State as a whole and for separate districts, regions, river and groundwater basins.

Nowadays, a threat to human survival substantially depends on not only the availability but also the quality of water resources, which has deteriorated due to human activity. Therefore, the quality of water resources depends on the ecological state of the territory as a whole. First of all, water resources suffer from crude wastes entering river basins and groundwater from storage and seepage fields. Irrigation is more threatening to groundwater because it can result in contamination by nitrates, pesticides, etc. through the use of incorrect agricultural technologies.

A total threat to water resources is estimated by means of a risk index:

$$I_d = \frac{Q_{cw}}{Q_r + Q_{gw}} \tag{5}$$

where Q_{cw} is crude waste volume.

The risk index is doubled for regions where aquifers are not protected. Therefore, zoning by a risk index should be combined with zoning by both a degree of groundwater protection and the prevalent types of anthropogenic load (Fig. 2).

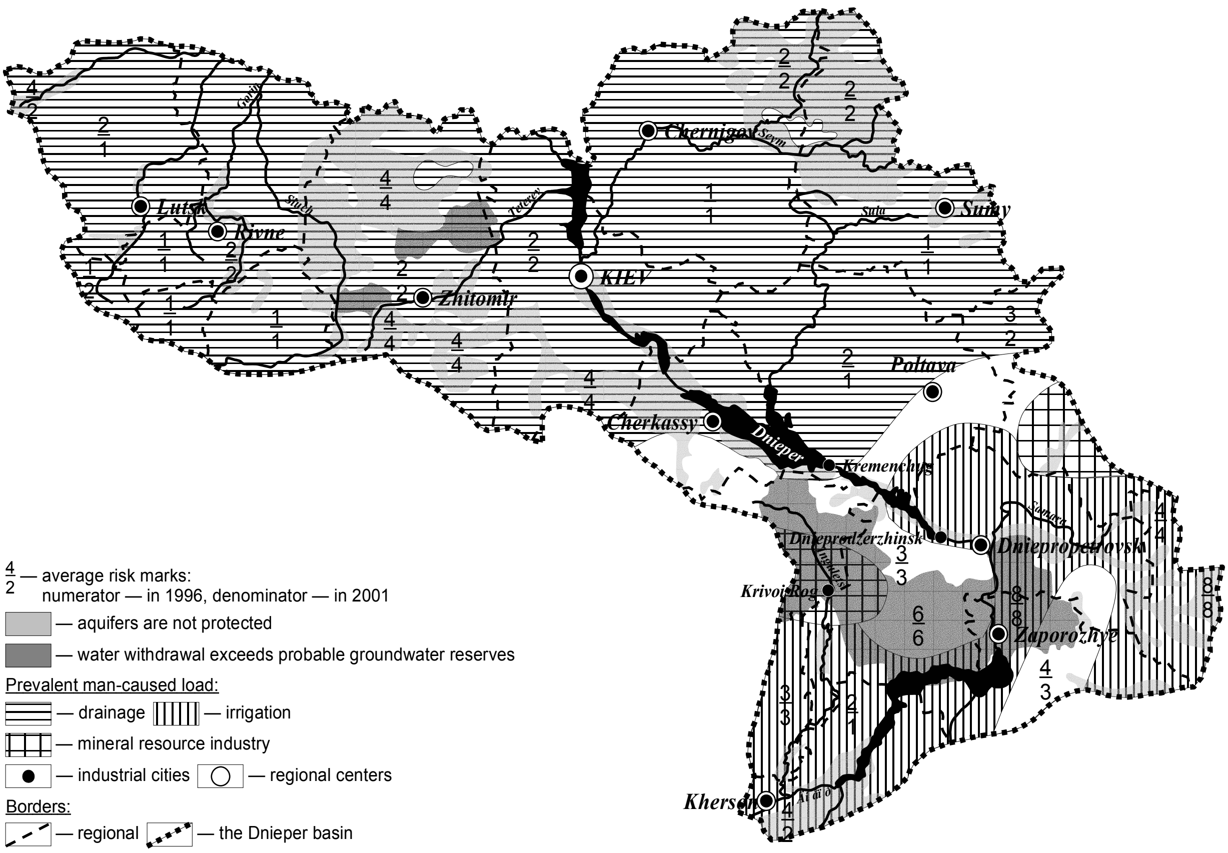

Fig. 2 The map of risk to water resources of the Dnieper River basin.

The risk index may be evaluated in marks as:

I_d		*Marks*
< 0.01	–	1
0.01–0.1	–	2
0.1–0.5	–	3
0.5–1	–	4
> 1	–	5

Sustainable development of the hydro-economic complex is connected with development of the ecological and economic system (EES) as a whole. The hydro-economic complex represents a sub-system of EES. A pathway of EES development can only be estimated by means of modelling of system state predictions and its management optimization.

A model works in two modes: prediction and planning. A general basis for both modes is a scenario approach as a reflection of multivariant purposeful social activity and the estimation of appropriate consequences at two levels: upper and lower. Predictions of EES development involve the estimation of its behaviour in case the parameters, such as the system of priorities and ecological standards, the degree of human influence on the biosphere, and population size, etc., are subject to change. This yields a range of development pathways, which do not correspond to sustainable development in most cases but they determine potential consequences of the activity.

Planning finds a pathway of sustainable development by running specified temporal and spatial characteristics of EES state in a model. An EES model includes three groups of parameters:

- relative priorities of development;
- characteristics of social activity;
- economic standards determining risk statistics.

Present ecological standards are considered critically dangerous. For example, such elements as carbon, sulphur, nitrogen and phosphorus are not included in ecological standards because they threaten ecological catastrophe in a few centuries. Therefore, it is necessary to prepare ecological standards for sustainable development, including a gradation of load levels and an estimation of the consequences of choosing optimal levels in order to determine development pathways. Realizing the necessity of sustainable development as a non-alternative planetary ideology, humans must accept it and learn to estimate their behaviour exactly and safely.

The Ukraine situation

In the Ukraine, water resources consist of surface water and groundwater. Potential resources of surface water are estimated at 209.8 km^3 (Danilishin *et al.*, 1999) including 25% (52.4 km^3) within Ukraine itself as opposed to flows from neighbouring countries.

In low-water years, surface water resources are 29.7 km^3, a decrease of 1.8 times, and the Ukraine takes one of the last positions in Europe (after Hungary and Moldova) in terms of local river runoff resources per head. A value of 1000 m^3 year^{-1} per head for Ukraine compared with 4600 m^3 year^{-1} per head for Europe indicates an extremely low supply from river runoff supply. It is only in the Transcarpathian region where river runoff is higher and nearer to average European levels.

Probable groundwater reserves are estimated at 22.5 km^3 year^{-1} (61.7 × 10^6 m^3 day^{-1}), of which 66.7 % are renewable. Average probable groundwater reserves are 440 m^3 per head per year and 989 aquifers containing 15 800 m^3 year^{-1} of groundwater resources have been explored. Water withdrawal from probable reserves has decreased since 1980 and was 7 727 650 m^3 day^{-1} by the beginning of 2001 (Hydrogeological YB, 2004),resulting in 53.76 × 10^6 m^3 day^{-1} of probable groundwater reserves including 12.62 × 10^6 m^3 day^{-1} operating resources. The Ukrainian multipurpose hydro-economic complex requires large volumes of water. Figure 3 shows the dynamics of water consumption according to Derzhcomvodgosp data (2001, 2004). The gross water requirements in 1990 totalled 103.3 million km^3 and approach the total water resources of an average water year. However, they decreased by 35% to 67 × 10^6 km^3 by 1997 due to Perestroyka and the associated economic recession. In particular, water consumption for irrigation and for industry reduced by 65% and 55%, respectively. After 1997, total water consumption continued to decrease and total water requirements were 58.9 km^3 year^{-1} in 2001. This resulted in a 93-km^3 reserve, which exceeded the required reserve of 31.8 km^3.

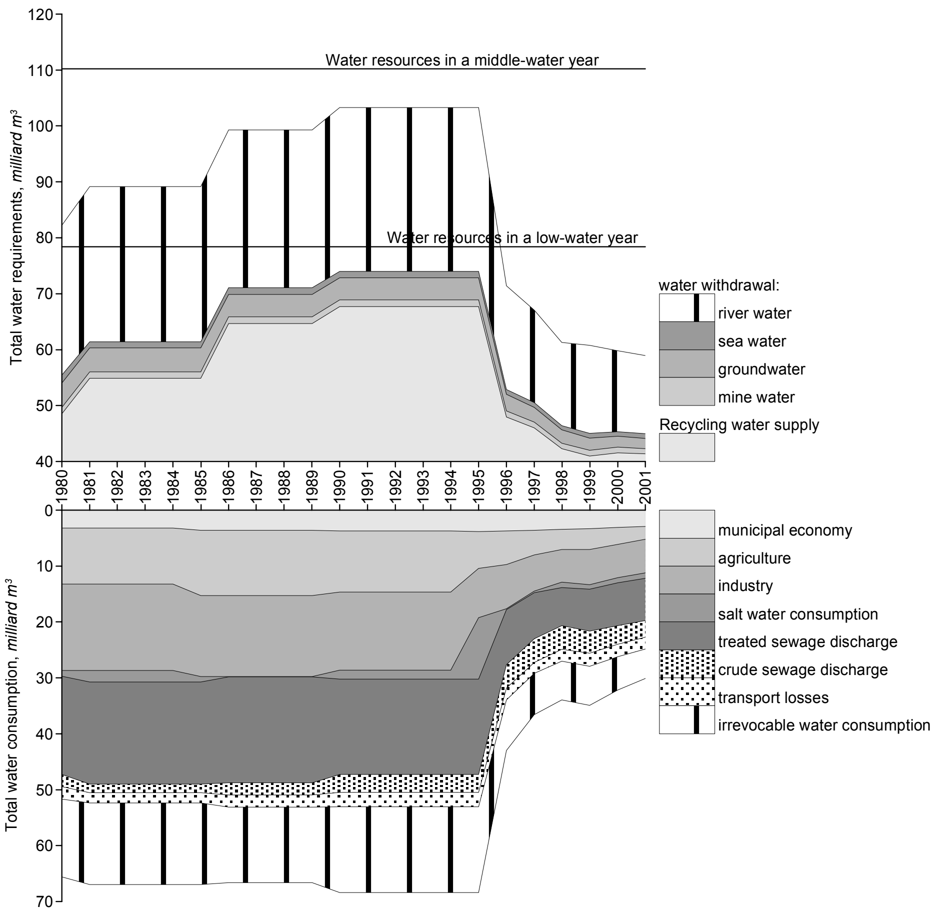

Fig. 3 Dynamics of water consumption in Ukraine.

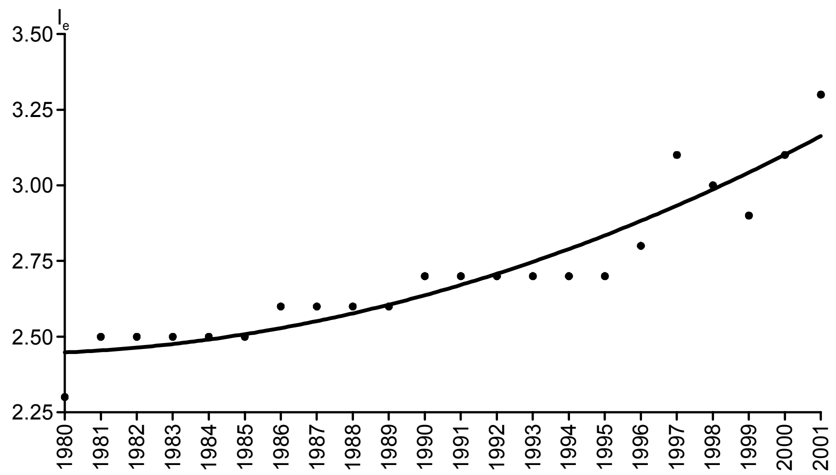

Fig. 4 The efficiency of water resources use.

Figure 4 reveals a change in the efficiency of water resources use computed by equation (4). It is clear that the I_e criterion has continued increasing from 1980 until 2004, which indicates the occurrence of sustainable development of the Ukrainian hydro-economic complex. A continuous decrease in gross output water capacity, which was 0.09 m^3 per monetary unit in 2001, also provides evidence of sustainable development of the hydro-economic complex. Drinking and domestic requirements have not changed considerably and are 4 km^3 $year^{-1}$ (10 960 m^3 day^{-1}) which includes 3.2 km^3 $year^{-1}$ (284 m^3 day^{-1}) per head in the municipal economy. This water from superficial sources is generally contaminated. More than 240 settlements currently use water unfit to drink.

The main source of surface water contamination is waste discharge in a volume of 11.7 km^3, which includes 3.5 km^3 of insufficiently purified water and 0.8 km^3 of crude wastewater. Industrial wastewater contains 846 t of iron, 65 t of copper, 43 t of zinc, 27 t of nickel, 12 t of chrome, 42 t of nitrate, 1200 t of petroleum products, etc. Nearly everywhere surface water is exposed to contamination.

Most of the potential groundwater reserves (84%) are protected from contamination, and changes in groundwater quality are observed in only a few isolated instances. Therefore, in the Ukraine, drinking and domestic water supply from plentiful groundwater resources seems more attractive than using surface water. In addition, about 60% of local runoff is being abstracted so water consumption volumes in river basins have reached the upper limit. If surface water quality is not improved, pollution at the surface is not reduced and monitoring, withdrawal and conservation of groundwater resources are not managed, and in the near future large groundwater volumes will be unfit for drinking, which will be a national catastrophe.

The Donetsk and Zaporozhye regions, where the volume of wastewater has exceeded a half of surface and groundwater runoff, are in the worst condition regarding the threat to groundwater (Fig. 2). The Sumy, Chernigov, Ternopol, Khmelnitski, and Rivne regions are in a better condition. Here the volume of wastewater is less than 0.01% of the volume of surface and groundwater runoff. From 1996 to 2001, the extent of risk decreased in the Lutsk, Poltava, and Kherson regions.

CONCLUSIONS

Zoning of the territory of Ukraine with respect to pollution types and their consequences must be a basis to plan and realize the strategy of sustainable development of the hydro-economic complex. A large circle of water management problems, which require co-operation of different branches and regions as well as government support, can be solved by development and realization of the special government programme. Balanced development of the water industry requires inclusion of environmental conservation priorities into all branches of the socially directed market economy. The governing principles of sustainable water supply are as follows:

– to establish the priority of the social sphere for water use and to provide human rights to drinking water of good quality and a satisfactory aquatic environment;
– to control water-management and water-protection activity by a basin principle in co-operation with other components of the environment;
– to develop economic potential of regions based on the estimation of current water resource state and predicted changes;
– to realize forms of economic development that preserve water;
– to foster the co-operation of national, regional and local interests in taking into consideration a self-renewable potential of water resources;
– to realize an integral method of planning, predicting and organizing water management;
– to establish the priority of economic governance of water use and water protection in co-operation with organizational and legal methods;
– to follow the international legal standards of water use and protection and to co-operate in the field of transboundary water systems.

Realization of these principles requires the following:

– improving the standard base of water consumption by licenses and quotas;
– improving the quality of monitoring, government control of water use, and conduct of the State water authorities;
– introducing flexible economic methods for water-use regulation.

All this should be based on the following research:

– development of energy-conservation and resource-economy technologies to prevent groundwater contamination;
– development of modern equipment and treatment plants for safe and controlled water use;
– modernization of methods for the estimation of water status, monitoring and prediction;
– development of scientific methods to protect groundwater from contamination by industrial waste and agricultural and urban land run-off.

All this requires a realization in political spheres of the importance, not of providing material comforts, but of providing long and healthy and safe lives with a secure social status and the opportunity for self-development and self-affirmation.

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