ECOLOGICAL-ECONOMICAL ASPECTS OF WATER MANAGEMENT BASED ON HOLISTIC MODEL

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Global "Millennium Summit" in Johannesburg pointed on water resources to be the one of determinative factors in sustainable growth concept formation. Freshwater becomes the scarcest resource, and providing of its quality is one of the society's global challenges. Irrational freshwater usage and pollution leads to degradation of water ecosystems and cause significant economic damages, connected to ill health of the population particularly. Transition to the sustainable water usage involves primarily improving of organizational-economic mechanism of water resources.

In spite of Ukrainian scientists' (such as M.A. Khvesyk, A.V. Yatsyk, L.G. Melnyk, V.A. Golyan, etc.) considerable contribution in research in this field, the issues of organizational-economic mechanism of water resources are not resolved yet. As well as the complex of economical instruments to provide well-balanced usage of water resources is not developed enough yet. The purpose of transition to the administrative and market control of water usage process is the anthropogenic load reduction and negative ecological-economic consequences reduction as a result.

To transition to above-mentioned model of water management it's necessary to explore options for development ecological-economical interactions within the water basin in system. For this purpose we select controlling parameters of interactions in the water usage process and major positive and negative connections between them. The interconnections of these parameters are presented through feedback mechanisms (figure 1). The scheme is based on feedback mechanisms, so it's possible to model homeostasis parameters of the territory.

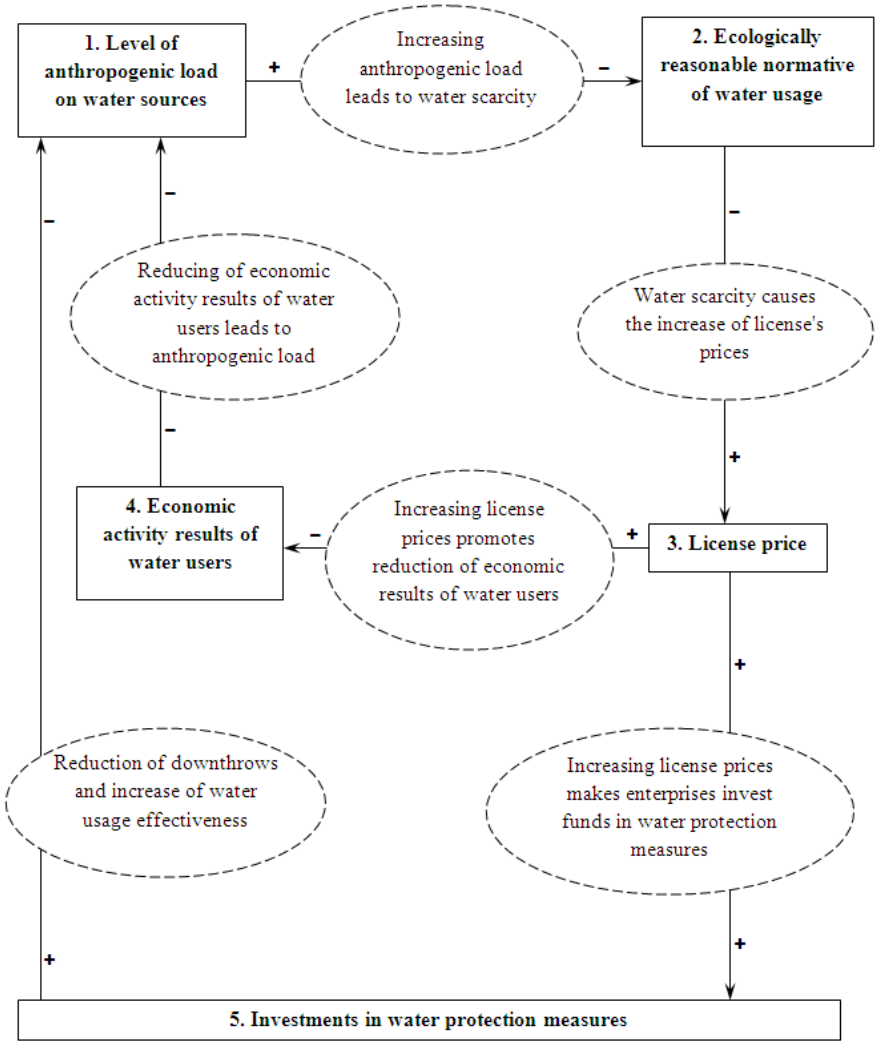

Figure 1. Functional scheme of ecological-economical interactions in water usage process («+» positive and «-» negative feedbacks)

The effective instrument of distribution of anthropogenic load on water sources is introduction of quotas and licenses on water intake and downthrow and trade these quotas and licenses. Proposed holistic model (1) enables to forecast scenario of ecological-economic development of regional water usage processes based on administrative and market control of demand and supply on licenses. Content and controlling parameters of the model are given below.

$$\begin{cases} \dfrac{dk_a}{dt} = (\alpha_1 \cdot k_a + \alpha_2 \cdot I) - \alpha_3 \cdot k_a \cdot I(t-\tau_1) \cdot (C - C_{ok}) + \alpha_4 \cdot I(\tau_2), \\ \dfrac{dC}{dt} = \beta_1 \cdot {k_a}^2 \cdot C - \beta_2 \cdot C \\ \dfrac{dI}{dt} = \gamma_1 \cdot k_a \cdot I \cdot (C - C_{ok}) \end{cases} \quad (1)$$

where

- *controlling parameters:*

k_a – anthropogenic load coefficient;

C – relative price of water, UAH/m^3;

I – average specific investment level on water economy, UAH/m^3;

- *normalizing coefficients and parameters:*

α_1 – growth rate of high water containing production;

α_2 – growth rate of investment in low water containing technologies, wastewater treatment plants, water protection measures;

α_3 – coefficient that determines the average probability of anthropogenic load reduction due to rise in water prices or water saving technologies;

α_4 – average depreciation rate of fixed assets of water complex;

β_1 – coefficient of water resources deficit;

β_2 – probable average inflation rate;

γ_1 – coefficient of "investment demand" in wastewater treatment plants, and low water-containing technologies;

C_{ok} – water price, at which investments in wastewater treatment plants or water protection measures are profitable, UAH/ m^3;

τ_1 – average time of the introduction of fixed assets in water complex, months;

τ_2 – average time of depreciation of fixed assets in water complex, months.

The basis of the proposed model (1) is the principle of feedback, i.e. increase prices of water resources and polluted water causes reduction of anthropogenic load on water objects with some delay, and contrary – forced anthropogenic load reduction due to licensing restriction leads to increase water resources price.

To achieve a sustainable transition of water use is necessary to determine impacts of feedbacks caused by administrative or economic management. Initiating administrative decisions on anthropogenic load reduction or water prices increase based on proposed normalizing coefficients, it is possible to predict dynamics and equilibrium values of water system's controlling parameters.

Thus, proposed model allows predicting water resources price, anthropogenic load on water systems and investment dynamics within the water basin. In general model allows to:

- predict scenarios of water management processes development based on feedbacks during the transition to market methods water use regulation;
- determine equilibrium values of water prices at ecologically reasonable level of anthropogenic load;
- promote sustainable development of water use processes;
- explore and predict the behavior of the controlling parameters from any time interval;
- promote the initiation of appropriate management decisions based on monitoring, thus providing feedback;
- observe the investment movement in time;
- estimate time for system to return to equilibrium state;
- consider all cycle phases in time.