Assessment and forecast of technogenic pollution impact on the mineral composition of surface waters of Ukraine

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ABSTRACT

The assessment and forecasting of the quality of water sources that can be suitable for public water supply and the implementation of the principles of the Water Framework EU Directive 2000/60 / are of great importance on the threshold of the third millennium. The rationale of the research stems from the fact that at the current stage of development of commercial public water supply systems, 70% of water use in Ukraine is provided from surface sources (the EU average is 20%). According to existing standards, all major rivers of our country, as well as their main tributaries, are considered to be "polluted" and "very polluted". It became extremely urgent to
study the stages of long-term changes in the mineralization index in the aquatic ecosystem under the influence of external factors and to obtain dependencies to determine the maximum value of the mineralization index, which can be accumulated in the aquatic ecosystem, and time needed for the lake or river system to achieve the new stage of technogenic equilibrium.

The determined regularities may form the basis for justification of the maximum allowable water loads for different regions of Ukraine to ensure their adequate level of environmental safety, and to improve the work efficiency of water treatment facilities. The assessment and forecasting of the technogenic pollution impact on the mineral composition of surface waters of Ukraine is carried out.

1. Introduction

A number of authors: Hopchenko E.D., Severna N.I., Korzh A.M have been actively engaged in the study of changes in the mineralization of surface waters in the area of drinking water intake in the city of Bolgrad since the early 1970's. Based on the results of the research conducted, it has been concluded that the quality of water in the Yalpugh Lake, especially in the area of the Bolgrad water intake, is characterized by the dependence on the natural factor - the mineralization of groundwater, discharged into the lake basin rather than by the dependence on anthropogenic loads. According to the results of chemical analysis from wells, evenly spaced along the perimeter of the Kugurlui and Yalpugh lakes, it makes on average of 2.6 g / dm3.

Several aquatic ecosystems were selected to do research in various natural and climatic zones of Ukraine: the dry arid zone of the steppe - Lake Yalpugh, the Bolgrad water intake; Polissya Zone - the Irpin river, Mostysche village and the Desna River; Letky village; the western forest steppe zone - Poltva river, the city of Busk; Donetsk-Dnipro region – the Samara river, Novomoskovsk; Kaluski Mining District, Pre-Carpathian Region – the Limnitsa river.

It is determined that although the increase in technogenic changes is due to the influence of various load factors (irrigation in the arid Steppe area, mining pits closure and the reduction of water pumping in high salinity mines in Donbass, etc.), the nature of these factors is the same (Figure 1) and is adequately described by the asymmetric distribution curve of Pearson III genus.
Fig. 1 Dynamics of changes in the surface water mineralization values in different natural and climatic zones of Ukraine.

It is determined that the equation of surface water mineralization growth with account of the component of the level of disturbance of the stable functioning for a particular year \( t_i \) is most accurately described by the law:

\[
\frac{\partial C}{\partial t} = \frac{C_i \left( t_i + d \right)}{t_0 + \gamma t_i},
\]

(1)

where \( C_i \) - average annual surface water mineralization in the \( i \)-th year in the section considered;

\( t_0 \) - beginning of observations in the cycle of long-term observations;

\( d \) - modal abscissa of the time interval between the maximum observable concentration and the distribution center, or - the ordinate of the radius of the asymmetry of the distribution curve.

The section contains a mathematical model to determine the relation between water system mineralization level and the indices that characterize the degree of disturbance.

In an integral form, the equation (1) is represented by the dependence:
where \( C_d \) is the level of mineralization for the modal point;

\( t_m \) - a year of maximum salt concentration throughout the observation period;

\( C_{\text{max}} \) - the maximum mineralization level observed in the system

The above-limit value of the predominant mineralization level, which has occurred at least in the last ten years in the considered point over the initial one \( C_i \) is taken as the level of aquatic system mineral composition disorder and the ratio \( \frac{C_{\text{max}}}{C_i} \) is proposed to be determined as excess resource capacity of ecosystem considered.

The disturbance component has been determined as the difference of the integral over \( C_i \) according to equation (2) and the average value \( C_0 \) of the surface water mineralization in previous years of observation (when the system does not experience significant anthropogenic impact and has hydrochemical parameters close to the natural background). For rivers that have already acquired the stage of anthropogenic equilibrium, the value of the mineral composition disturbance component can be determined according to the equation:

\[
R = \frac{t_2}{t_1} \left( C_i \cdot e^{-\frac{t}{d}} \left( 1 + \frac{t}{t_0 - t_m} \right) \frac{t_0 - t_m}{d} - C_0 \right) dt.
\]

\[
C_r = C_i \cdot d \exp \frac{t_2}{d} \left( 1 + \frac{t_2}{t_1 - C_{\text{max}} - C_0} \right).
\]

Equation (3) is to be written in the form:

\[
R = C_d \left( e^{\frac{t_2}{\Delta t_n}} \int_{u_2}^{u_2} e^{-\frac{t_2}{d}} du - C_0 (t_2 - t_1) \right).\]
When calculating the value of the component of the level of technogenic contamination disturbance on the mineral composition, the Simpson method was used as one of the most accurate approximate methods.

Calculated using the formula (4), the annual average component of change in the surface water mineral composition \( \bar{R} \) was compared to the value received by the method of long-term statistical observations treatment. Error in the calculations was 9%, which is within satisfactory limits.

The influence of subsurface water flow on the degree of land surface water disturbance under the conditions of the level of technogenic load on violation of water bodies sustainable development has been determined.

The functional relation between the values of relative mineral composition disorder \( \bar{C}_T \), value of the coefficient of subsurface water flow \( M \), the relation of total river flow \( W \) with extreme values of water content is proposed to be determined by correlation dependencies that reflect the direct impact of groundwater inflow on the increase in the level of technogenic load to the sustainable functioning failure of the river basins of the regions:

\[
\begin{align*}
\ln C_T &= 1.533 \ln W_{\text{min}} - 0.76, \\
\ln C_T &= 0.786 \ln W_{\text{max}} - 1.27, \\
\ln C_T &= 0.492 \ln M_{\text{min}} - 2.037, \\
\ln C_T &= 0.886 \ln M_{\text{max}} + 2.516
\end{align*}
\]

where \( M_{\text{min}} \) and \( M_{\text{max}} \) and \( W_{\text{min}} \) and \( W_{\text{max}} \) are the minimum and maximum values of subsurface waterflow coefficients and the values of the minimum and maximum relation of the total river flow respectively, which characterizes two periods - flood and bound one.

The value, which is determined by the formula (5):

\[
\bar{C}_T = \frac{C_r - C_i}{C_i}, \quad (5)
\]

is taken as the value of relative mineral composition disturbance of surface waters.

where \( C_r \) is the predominant over the initial one level of mineralization which has occurred at least in the last ten years in the section considered \( (C_i) \).
The author offers to describe stages of the mineralization index growth for various water bodies by general system of equations:

\[
\begin{align*}
C_i &= C_o + K_n \cdot t \\
C_i &= C_{\text{max}} - K_3 \cdot t
\end{align*}
\]

where \(C_i\), \(C_o\), and \(C_{\text{max}}\) are surface water mineralization of the object at some point and, prior to the technogenic impact, the maximum mineralization index before new stage of sustainable development of the system mg / dm3, respectively;

\(K_n\) and \(K_3\) - coefficients that characterize the rise and decrease of the total of ions in water, respectively (mg / dm3) / per year.

Stages of long-term changes of the mineralization index in the aquatic ecosystem under the influence of external factors are as follows:

According to the results of the research, the dependencies presented in Fig. 3 and 4.

\[K_n = f(P)\] and \(K_n = f(K_\beta)\) have been formed.

![Fig. 3 Dependence of the coefficient Kn on precipitation for specific river basins of Ukraine](image)
This approach will allow to determine the equation of mineralization content rise in the surface water for different natural and climatic zones using a long-term database of hydrochemical indices:

\[
\begin{align*}
C_i &= 375 + 76 \cdot t & \text{for the zone of arid Steppe (Lake Yalpuh);} \\
C_i &= 400 + 9.5 \cdot t & \text{for the area of Polissya (the Irpin river);} \\
C_i &= 600 + 39 \cdot t & \text{for the zone of the western forest-steppe (the Poltva river);} \\
C_i &= 1800 + 318 \cdot t & \text{for the Steppe zone (the Samara);} \\
C_i &= 380 + 13 \cdot t & \text{for the area of Polissya (the Desna river)}
\end{align*}
\]

Simultaneous solution to the equations of the written system will allow us to find \( t_m \), that is, time when water system acquires the value of maximum external impact:

\[
t_m = \frac{C_{\text{max}} - C_0}{K_n + K_3}
\]  

(7)

Ecosystem stabilization time \( t_k \) after reaching its maximum limit of impact is determined by the formula:

\[
t_k = \frac{C_{\text{max}} - C_r}{K_c}
\]  

(8)

From the above reasoning and proposed quantitative dependencies to determine the degree land surface water stable functioning failure, it is logical to introduce self-regeneration index, the quantitative value of which falls within the limits from 0 to 1, and is to be determined by the formula:

$$K_{	ext{self-regen}} = \frac{C_{\max} - C_r}{C_{\max} - C_0}$$

(9)

The results obtained allowed to calculate the degree of disturbance of water-surface ecosystem sustainable functioning in different climatic zones according to the mineralization index, the time when it reaches the maximum value of the mineralization index and the technogenic level of hydro chemical stabilization. It is proved that the maximum value of the latter index depends on the main regime forming and resource factors rather than on the weakening of anthropogenic load on the system.

**Conclusions**

1. The of changes in the mineral composition of land surface waters have been assessed and forecast, depending on the anthropogenic load on various natural and climatic zones of Ukraine.

2. The research has been carried out in the area of public water intakes of the lake of Yalpugh - Bolgrad water intake and the Desna river in Letki village, which showed that an increase in the mineralization level by sanitary-hygienic standards for drinking water intakes DSANPiN No. 136/1940, DSTU 4808: 2007 was observed in the surface waters near the city of Bolgrad (Lake Yalpuh), in 2001-2003. The author states that since 2001 the ecosystem of Yalpugh lake has been in the stage of a new technogenic equilibrium with an average annual level of mineralization of surface waters being 1200 mg / dm3.

3. The long-term dynamics of surface water mineralization for typical water bodies in the main natural-climatic zones of Ukraine with different levels of water supply and water use as an indicator of technogenic impact on them has been established. It is shown that this dynamic can be described by the asymmetric distribution curve of Pearson of the third genus.

4. New generalizations on the influence of ground water inflow and the ground water runoff component on the level of the surface water mineral composition disorder have been made. It has been proved that ground water runoff plays an essential role in restoring sustainable development of the system. The statistical dependencies between the level of disturbance of water-surface ecosystems sustainable development under extreme values

of water content for different natural-climatic zones of Ukraine and the values of the ground water runoff of the territory (M) and mutual coupling factor of surface and groundwater (Ka) are proposed.

5. The dependencies to achieve the time of maximum value of the total mineralization index by the land surface water and the time of the new technogenic stage of the ecosystem stabilization were determined. It is proved that the maximum value of the latter index depends on the natural regime forming factors rather than on the weakening of anthropogenic pressure on the system.

References
