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Original Contribution

DETERMINATION OF INTEGRATED ENVIRONMENTAL INDICATORS OF THE IMPACT OF POLLUTANTS INTO WATER BODIES

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Abstract: *The advantages and disadvantages of the current limit concentrations (PDC) have been analysed as they do not fully reflect the impact of alien substances on water in aquatic ecosystems. A relatively simple method for determining integral doses in multifactorial contamination of water bodies has been proposed.*

Key words*: limit concentrations, integral dose, water pollution*

Introduction

Currently, water bodies are characterized by multifactorial contamination, suggesting diverse content of mineral and organic substances, mixtures and/or elements. The hydrosphere has turned into a collector of waste generated by people and businesses. Its vulnerability to chemical contamination is determined by the continuous circulation of water in nature (precipitation, evaporation, cross-border movement, surface and underground flows) where any pollutant into the atmosphere or in the soil, eventually gets into water bodies. Pollution affects mainly fresh water bodies such as rivers, lakes, reservoirs, inland seas etc. This requires a specific methodological approach through which diverse hydrochemical information to quantify a single dose effects on living organisms. It is complicated to take into account both direct and indirect effects, interactions between technogenic substances imported into the aquatic environment, which form the hazardous properties of water. Water pollution is the most complex. It is associated with eutrophication and changes in the salt regime. Acidification of water accompanies leaching of toxic elements from substances and mixtures. This process is especially dangerous for hydrobionthic species at low pH values.

At present the core dimension of ecological standardization of harmful chemicals in the environment components is the concentration limit. It is a harmful substance which practically does not affect human health and does not cause adverse

changes to the progeny. Its effect on animals, plants, microorganisms, and natural communities as a whole is considered in determining its values.

Limit concentrations are contingent variables that differ significantly in the countries, despite the attempts for standardization of the methods for their estimation.

They do not take into account the natural conditions of the water body in which the toxic substance is spread and acts [1,2,3]. Moreover, they do not consider the interaction between the elements in the complex water pollution, in which case it is possible the toxic properties of the substances to be mutually reinforced (synergism) [4].

The modern system of limit concentration does not take into account the effects of the joint action of mixtures of chemical substances or other toxic compounds of the same chemical element with different concentrations. The effects caused separately by each of them are known in most cases, but it is not possible to identify all possible combinations of the joint action of substances, particularly when they are in different concentrations [5]. It has been practically proved that the effects of many types of pollution occur decades after the contact with them. There are genotoxic substances causing somatic mutations that occur as inherited mutations later in the years or in the next generations. In recent decades, there has been stronger influence of the chemical compounds of technogenic origin, which have no natural analogues (xenobiotics).

For the majority of them neither the toxicity, nor the time required for its development are not completely developed. Limit concentrations cannot be used as a means of assessing the late effects (gonadottropic, embryotropic allergic, teratogenic, mutagenic, carcinogenic) to the human and warm-blooded animals caused by the influence of xenobiotics on them.

The effects of increased toxicity and bioaccumulation of contaminants in the transition from one trophic state to another are not studied in detail. We should not ignore the fact that water bodies, like terrestrial ecosystems, have the ability of self-purification.

This would imply that the system of limit concentration should be considered as one of the possible indicators and even as a way of predicting and evaluating the rapid impact of xenobiotics on living organisms [5]. In any case, specific physical and chemical characteristics of natural water should be considered in the standardization of contaminants' content.

The integral index of water pollution can be determined depending on the type of contaminants identified.

When these contaminants have similar toxicological indicators for the degree of harm they cause (i.e. they are from the same Toxicology group), the integrated index can be easily represented as a sum of the concentrations measured for all toxic

chemicals normalised to LC (limit concentration).

$$I_{t1} = \sum (C_i / LC_i)$$

Notwithstanding all the reserves given above, LC provides a real picture of LC the relative risk of various substances and allows for standardisation of components and substances according to the degree of danger for the living organisms. When two or more highly toxic elements such as lead, cadmium, chromium and uranium are found in the water, their total concentration, calculated using the appropriate formula, should be less than or at most equal to one [5]

$$\frac{C_1}{C_1^{LC}} + \frac{C_2}{C_2^{LC}} + \frac{C_3}{C_3^{LC}} + \frac{C_4}{C_4^{LC}} = 1 \qquad (1)$$

where: C_1 C_2, C_3, C_4 - the concentration of the components in the test water in mg/l,

More correct would be the summation of concentrations exceeding the thresholds to their Cp influence on aquatic organisms.

$$I_{t2} = \sum (C_i / C_{pi}) \qquad (2)$$

However, such data is available in the scientific literature only for some of the substances. Most often it is assumed that toxic substances have additive effect. You can introduce Coefficients for synergism or antagonism can be introduced, if there is evidence of such effects.

When a body of water is contaminated with a large group of metals, which are imported by flow of wastewater, their toxicity, to a large greatest extent, depends on the metal ion forms. In this case one should take into account the ratio of labile and unlabile forms (associated with organic ligands) in the water body. Based on the studies of Rodyushkin (1995), Moiseenko (1999) for complex-forming ability of water, some quantitative data has been obtained on the ability of natural dissolved organic matter, which can deactivate different metal ions. Their position has been determined in the competitive order of connecting organic ligands.

$$I_{t3} = \sum \left(C_{Ni^{2+}} / LC_{Ni^{2+}} + C_{Hg^{2+}} / LC_{Hg^{2+}} + ... \right) \qquad (3)$$

$$I_t = I_{t1} + I_{t2} + I_{t3} \qquad (4)$$

Assuming that the toxic properties of the aquatic environment are the result of metal ion mixtures, then the normalization according to the toxicity may be carried out according to PDC (limit concentration). Toxic properties of water can be different in the presence of the same metals depending on their origin. When they are the result of human activities, most often they are found in the form of ions, while in natural acidified water metals are deactivated by humic acids. Similar phenomena have been observed in the small lakes of Kola North. [6]. The greatest risk is posed by heavy metals, which have high biological activity.

Their action depends on the nature of the metal, the type of compound, under which it exists in the aquatic environment and of course its concentration. On Figure 1 the arrow shows the direction of decreasing toxicity of the forms in which metals are found in the aquatic environment. [6]

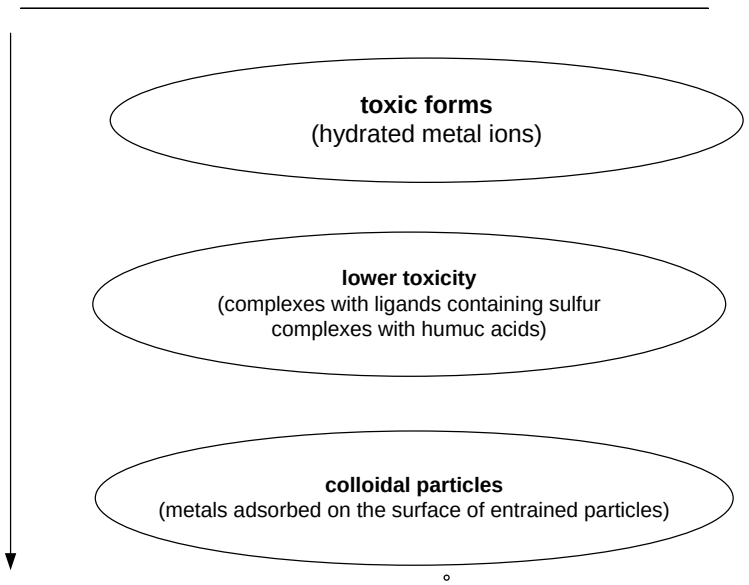

Fig.1. Different forms of metals in water bodies

Like all other values of LC (limit concentrations), the values for the metals are quite different in the different countries (Table 1). The ratio between the maximum and minimum value ranges from 56 for arsenic to 160 for copper. This is due to different methodological approaches in establishing the LC.

Table 1. LC for surface water of some heavy metals

Country	Hg	Cd	Pb	Cu	As
Bulgaria	0,2	5	20	50	20
United Kingdom	-	-	4-25	0,5-12	50
Germany	0,8	1,2	100	80	-
Denmark	1	5	3,2	12	4
Russia	0,01	5	6	1	50
the Netherlands	0,23	0,34	11	1,1	24
Czech Republic	0,5	5	50	50	50
Sweden	-	0,09	1,2	2,1	0,9
Japan	0,5	10	50	3	10
PDC_{max}/PDC_{min}	100	111	100	160	56

In those cases when water bodies are contaminated by many toxic substances and eutrophication is observed, a change occurs in their

physical and chemical characteristics - turbidity, salt composition, pH. etc. If several processes with different ecological significance run simultaneously in the aquatic environment, determination of the cumulative index of contamination is much more difficult.

In eutrophication inactivation of metals is observed due to their biological uptake, associated with turbulent growth of algae. At the same time, however, release of metals can be performed from bottom sediments.

Criterion for this process may be the degree of excess phosphorus above background values (Cp). The ratio of total nitrogen to total phosphorus in a water body characterises the degree of eutrophication of the aquatic ecosystem. For highly humuficated inland reservoirs Ntotal/Ptotal $\geq$ 100, clean oligotrafic and mesotrophic lakes - 30-40, for eutrophic reservoirs (under strong anthropogenic influence) 15-25, while for hypertrophic reservoirs - from 18 to 3.

Therefore trophic status of the reservoir should be considered. In mesotrophic state eutrophication index doubles, and in eutrophic state it triples:

$$I_e = (C_P / C_{Pbaskground} 1)x2 \quad (5)$$

$$I_e = (C_P / C_{Pbaskground} - 1)x3 \quad (6)$$

Concentration of chlorophyll a ($C_{35}H_{72}N_4Mg$) is most often used as a direct indicator of trophic status. It is a major photosynthetic pigment and therefore the values of its concentration in water samples are representative indicator of algal biomass. The pigment is an accurate and useful measure of the degree of eutrophication of water bodies.

The main criteria characterizing the process of eutrophication of water bodies are the following:

- Decrease in the concentration of dissolved oxygen in depth;
- Increase in the concentration of nutrients;
- Increase in the number of involved particles, especially of organic origin;
- Reduced penetration of light (self-darkening, increased water turbidity);
- Increase in the concentration of phosphorus in bottom sediments;
- Continuous change of the algae populations with priority of blue-green and green algae;
- Significant increase in the mass of phytoplankton, while simultaneously reducing species.

The main components of the aquatic biota are reducents, which decay organic matter, phytoplankton, zooplankton, benthos, microvials, amphibians and more. Phytoplankton activity decreases at pH $\leq$ 6, but serious adverse effects are observed at pH $\leq$ 5, including sharp decrease in the population of fish [7].

The indexes of other physical and chemical parameters of water can be similarly determined. Those indexes, which have the largest contribution to the changing conditions of the aquatic organisms'

habitat, are reported. The integrated index of physical and chemical contamination can be represented as follows:

$$I_{fiz-him} = \sum \left(C_i / C_{baskgroundmax} - 1 \right) \quad (7)$$

The total integral indicator of water contamination is defined as the sum of partial derivatives:

$$I_i = I_t + I_e + I_{fiz-him} \quad (8)$$

In the methodological scheme for the study of pollutants, which enter water bodies, besides all of the studies mentioned above and the values of environmental and hygiene regulations, studies should be conducted to assess the health of the population living in areas with potential adverse effects of the studied compounds in water bodies. This is related to: -
development of harm criteria in the assessment of toxicity and danger of chemical water pollution;

- development of accelerated methods for toxicological justification of PDC (limit concentrations) of harmful substances in the water;
- forecasting the individual effects of water contaminants;
- development of principles and methods for establishing regulations for substances causing mutagenic, carcinogenic, allergenic, embryotoxic and gonade toxic late effects;
- development of methodological practices for environmental and hygienic evaluation and forecasting of transformation products of chemical reagents in water;
- improvement of the quantitative methods for assessment of the combined effect of the substances.

Conclusions:

LC (limit concentrations), which are currently used, do not fully reflect the impact of extrinsic water substances in the aquatic ecosystems. It is necessary to develop ecological PDC. Furthermore, assessment of natural water should be made reporting not only the organoleptic, chemical, hygiene and sanitation indicators, but also the biochemical and microbiological indicators that reflect the status of hydrobionthic species.

The method for determining the integral dose index in multifactorial water contamination is relatively simple, but it quite adequately reflects the hazardous properties of water. In the absence of contaminating substances Ii should be zero. Moreover, this method can identify the leading factor in the formation of dose effects and to consider its environmental hazard.

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