ESTIMATION OF THE BALANCE UPSETS IN BIOSYSTEMS UNDER BOTH RADIOACTIVE AND CHEMICAL CONTAMINATION OF WATER BODIES

N.L.Shevtsova , M.I.Kuzmenko , S.M.Fedorik

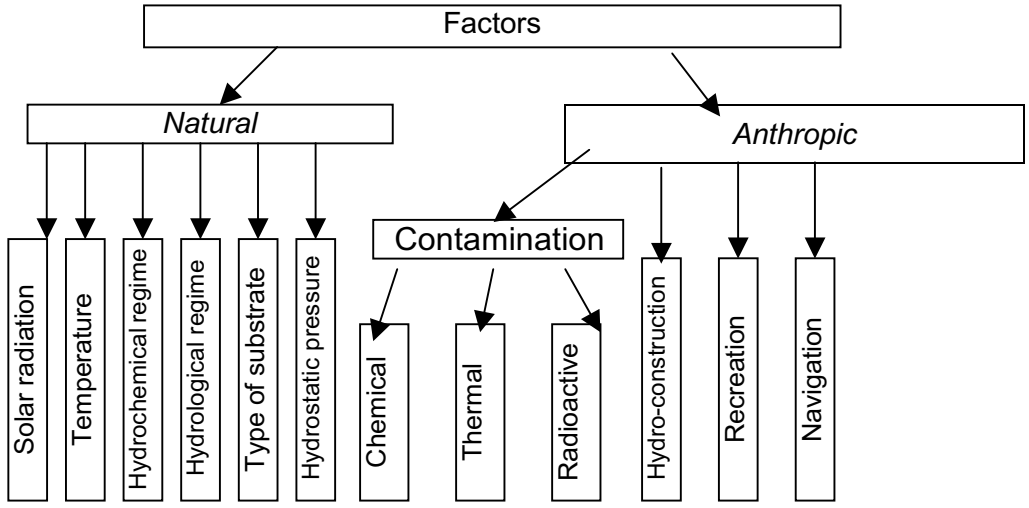
Institute of Hydrobiology, Geroyev Stalingrada Ave. 12, UA-04210, Kiev, UKRAINE,
shevtsovanl@km.ru

Abstract
Increasing radioactive and chemical contamination of the water environment focus attention on estimation of ecosystems balance. Radiobiological effects have modified different biotic and abiotic factors. In conditions of intricate influenced factors, the current investigations show evidence of numeric changes: from slight compensations to breathing to deep and irreversible breaches in vital functions of the most resistant populations. Such changes in water ecosystem 's quality as habitat always outstrip the change of ecological. This become apparent only with some delay and depends on the force and duration of influenced factors and metabolic plasticity of the organisms' adaptability to unstable environmental conditions. We offer the estimation system of breaches and their significance to the function of water biosystems. The maximum possible spectrum of changes in biosystems is estimated by a 10-point scale from compensated changes in the organism of most sensitive individuals (breach level with 1-point estimation to death of photosynthetic organisms and loss of biological value of water ecosystem (10-point estimation). Based on this estimation system, the level of breaches in a cool-pond of the Chernobyl NPP was estimated. Morphological changes and anomalies of reproduction system of fish, chromosomal mutagenesis of chironomides etc. were ranked at the 4 -5th levels.

Introduction
Among all countries of the world, Ukraine stands out because of the availability of urgent and complicated unresolved vitally important radioecological problems. The accident at the Chemobyl Nuclear Power Plant (NPP) on 26 April 1986 caused large-scale radionuclide contamination of the environment. The active zone of the reactor RBMK-1000 was destroyed, and about 1.95 IO^{18}Bq of radioactive substances was discharged into the environment as a result of the accident (1). An unprecedented technogenic radioecological anomaly resulted from the accident. A 30 km zone around the Chemobyl NPP was declared unfit for permanent habitation, including the lower reaches of the Pripyat' river and the upper section of the Kiev reservoir. Most of the radioactive material was discharged into the Dnieper river one of the largest rivers of Europe, its tributaries and reservoirs.

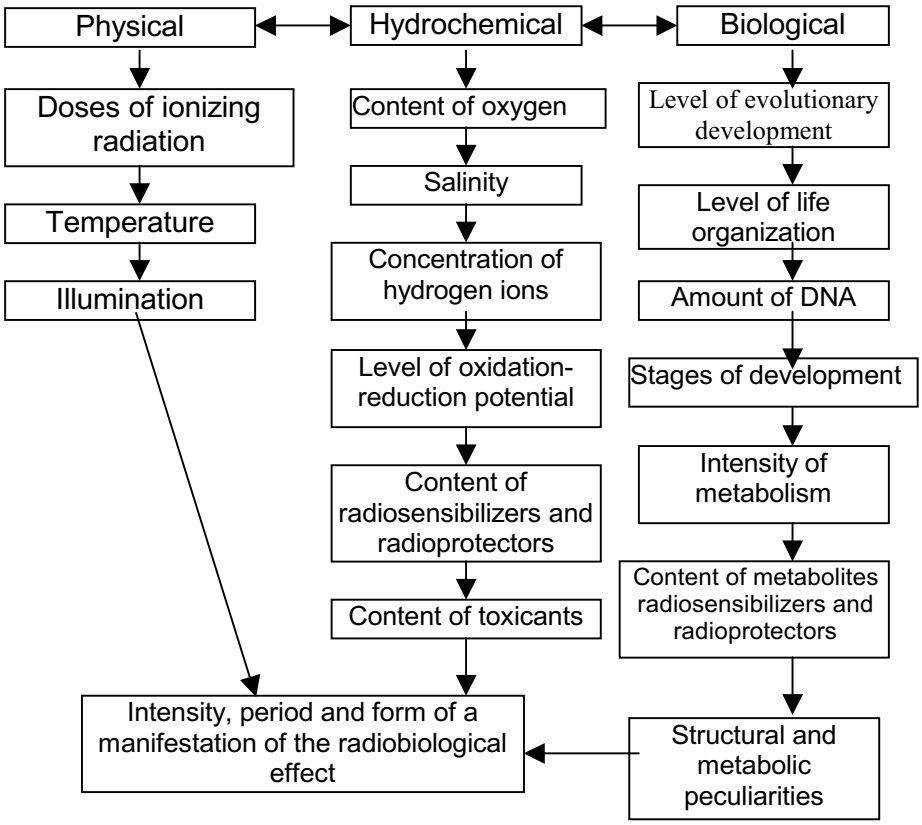
Methodology
There are following factors (Figure 1) that play a crucial role in the development of aquatic ecosystems, in their successions and functioning of trophic chains.

Figure 1: The main factors influencing the viability of aquatic biosystems



The evolutionary development of the biosystems of different levels of organization occurred under conditions of the influence of natural factors. This is reflected in ecological and metabolic peculiarities of organisms, in their morphological differentiation and role in the functioning of ecosystems. The anthropic factor includes a wide spectrum of the impact of humans upon the environment. In some cases the anthropic load not only attained, but also exceeded the intensity and extent of geochemical natural phenomena. Abundant evidence shows that the adverse effects of the anthropic factor upon aquatic ecosystems have attained ecologically significant levels, which exceed the influence of natural factors (2,3). The list of some of the main physical, hydrochemical, and biological factors modifying radiobiological effects in aquatic biosystems is presented in Fig. 2.

Figure 2: The main factors modifying radiobiological effects in aquatic biosystems



A wide species diversity of organisms, in its turn, is characterized by a wide spectrum of sensitivity and tolerance for the influence of different factors. The complexity of the problem of quantitative assessment of the extent of the influence of individual factors is conditioned by the above-mentioned facts. In the practice of investigations, the problem of determination of the extent of influence of individual factors upon the vital activity of organisms is rather successfully solved on the basis of the results of laboratory experiments. A special mathematical approach allowing to assess an extent of the influence of individual factors based on the coefficients of regression, the significance of which is determined in terms of the confidence limits of significance, was worked out for the clearly controlled two or three factors in different combinations.

Use of universally accepted IS units are not always possible for the quantitative determination of the intensity of the processes occurring at the ecosystem level. Thus, such processes or phenomena are not infrequently assessed with the use of conventional units. For example, O.P, Oksiyuk and her colleagues (4) have proposed the ecological classification of the quality of surface waters of land based on the use of conventional classes and ranks. According to this classification, the actual and potential values of saline composition, ecological, sanitary, toxicological, and radioecological indices of the quality of surface waters of land are subdivided into five classes, which, in their turn, are classified into nine ranks. There are many examples of the use of conventional units in science and practice. Our attempts to analyze the phenomena occurring in biosystems, as well as their quantitative assessment with the use of commonly accepted linear units, have been unsuccessful.

The quantitative scale of disruptions and their significance for the functioning of aquatic biosystems is proposed based on the analysis of possible disruptions in biosystems of different levels of organization caused by the influence of natural and anthropic factors.

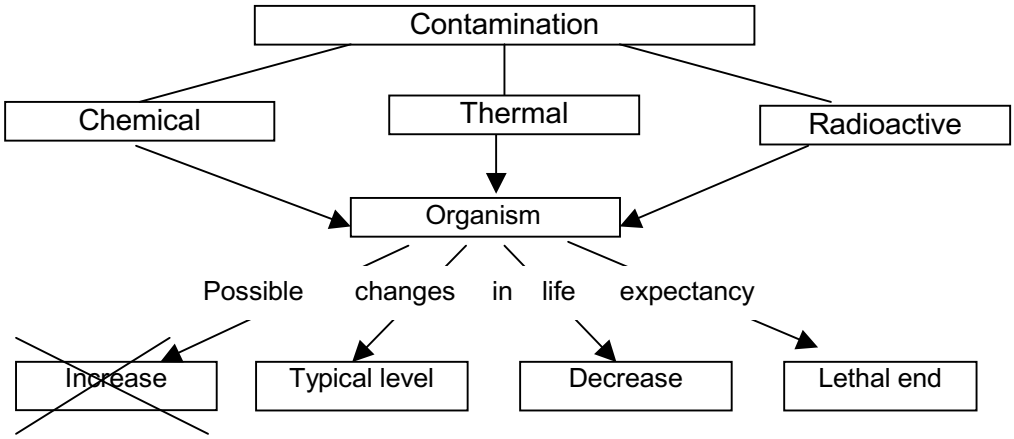
Table 1: Scale of disruptions in aquatic biosystems

Phenomena	Extent of disruptions, conventional scale-points
Compensated changes in the metabolism of the most sensitive individuals	1
Stable disruption of the metabolism of the most sensitive individuals	2
Compensated changes in the metabolism of the most resistant individuals. Stable disruption of the metabolism of the most resistant individuals	3
Disruption of typical structures in the most sensitive populations as a result of the disturbance of the balance between the survival-rate and death-rate	4
Disruption of typical structures in the most resistant populations as a result of the disturbance of the balance between the survival-rate and death-rate	5
Changes typical of the regress of biocenoses: the decrease in species diversity, increase in entropy, decrease in spatial heterogeneity, simplicity of trophic chain	6
Death of the most sensitive individuals and elimination of the most sensitive populations	7
Death of the most resistant individuals and elimination of the most resistant populations	8
Elimination of consumers, including fishes and invertebrates, from the composition of trophic chain	9
Death of photosynthesizing organisms, complete loss of biological value of aquatic ecosystems	10

From our viewpoint, the most significant disruptions of the functioning of aquatic biosystems are given in this scale. Although this scale is inconsistent with the accepted concepts on the sensitivity or tolerance of biosystems of different level of organization for the influence of specified physical and chemical factors, it encompasses a wide spectrum of possible changes in biosystems. Let us consider an example. The short-term changes in the photosynthesis or respiration occurring under the influence of chemical contamination or temperature in the most sensitive individuals (Table 2) correspond to the phenomenon of the first level - compensated changes in the metabolism of the most sensitive individuals. Some toxicants, in particular, inhibitors of photosynthesis may cause the death of photosynthesizing organisms. Obviously all aerobic organisms, beginning with oxyphilic fishes and ending with aerobic microorganisms, will also die, along with these organisms. The death of photo-synthesizing organisms and loss of biological value of aquatic ecosystems correspond to the phenomenon of the tenth level in the scale concerned and reflect the most significant disruptions.

Wide experience of hydroecological investigations of continental water bodies, as well as of the World Ocean, gained over the last 100 years suggests that anthropic impact may cause irreversible disruptions of the functioning of aquatic biosystems. A possible character of the changes in the life expectancy of the organisms subjected to the combined action of chemical, thermal, and radioactive contamination is given in Figure 3.

Figure 3: The scheme of possible changes in the life expectancy of organisms on exposure to the combined effects of chemical, thermal and radioactive contamination



Thus, biosystems formed during the process of long-standing evolution are subjected to the influence of extremely diverse anthropic factors, including the increasing chemical, thermal and radioactive contamination of hydrosphere.

Breaches in a cooling pond of the Chernobyl NPP

Abundant evidence on the hydroecological consequences of the accident at the Chernobyl NPP is dealt mainly with the problems of radioactive contamination of ecosystems. To a lesser extent these data reflect the response of biosystems to the action of technogenic radionuclides, which are a factor of chronic ionizing radiation in the biotopes of the exclusion zone and adjacent regions. Besides, radioecology, in particular aquatic radioecology, proved to be not ready to solve the problems derived from the accident with regard to methodology and methods. The absence of the purposeful programs aimed at the study of the manifestation and mechanisms of radiobiological effects and processes of reparation in biosystems of different levels of organization (not only in the first year after the accident, but also in succeeding years) is largely accounted for, namely, by the above-mentioned fact. Because of this, the information on the responses of biosystems, especially in the first weeks and months after the accident, is so scanty. When analyzing the impact of the Chernobyl discharge upon biosystems, account must be taken of the action not only of radionuclides, but also of the accompanying substances capable of influencing organisms, in particular, of the heavy metals accumulated in abundance in the exclusion zone. The data occurred after Chernobyl accident show the disruptions of the structure and functioning of representatives of the biota under conditions of intensive radioactive contamination of the cooling pond of Chernobyl NPP and other water bodies by the radionuclides discharged into the environment furnish convincing proof that the ecosystems lose their stability (Table.2).

Table 2: Disruption in biosystems under conditions of intensive radioactive contamination of water bodies

Water bodies	Disruption	Time of manifestation of disruption	Radiation dose or content of radionuclides in tissues	References
Water bodies in the 30-km zone of the Chernobyl NPP	A high level of chromosomal mutagenesis caused by the combined action of ionizing radiation and chemical contamination was observed in *Stylaria lacustris* (Oligochaeta)	1991	0.01 mGy/year	5
Cooling pond of the Chernobyl NPP	The processes of depression were registered in *Dreissena polymorpha*	1986-1987	$4 \bullet 10^5$ Bq/kg, 10-20 car from bottom sediments, 2-3 day/day from water	6
Cooling	The processes of fibrous osteo-	1991-1993	$^{90}Sr - 4.07 \bullet 10^4$,	7

pond of the Chernobyl NPP, water body in Kopachi village	dystrophy in the bones of *Rana ridibunda* and *Rana esculenta*, a relative increase in the number of osteogenous cells, a decrease in the synthesis of the main substance of bones; a decrease in the content of ashes by a factor of 0.5-2.0		^{134}Cs– $25.16 \bullet 10^2$, ^{137}Cs – $4.44 \bullet 10^3$ Bq/kg	
Cooling pond of the Chernobyl NPP	8% of males of *Hypophthalmichthys molitrix* kept in the fish-ponds before the accident, which attained sexual maturity in 1988, were sterile (hermaphrodites, individuals with undeveloped gonades	1989-1990	7-8 Gy	6
Cooling pond of the Chernobyl NPP	Cytogenetic analysis showed that the frequency of deterioration in the cells of thymus of fry of *Hypophthalmichthys molitrix* accounted for 22.7% (in control, it was 5-7%	1989	15 cGy	6

Based on the above-mentioned scale, the level of disruptions in the most radiosensitive hydrobionts, namely, in fishes (LD_{50} - 6-55 Gy), as well as in rather radioresistant Chironomidae (LD_{50} - 500-1600 Gy) occurring in the cooling pond of the Chernobyl NPP was assessed. The increase in the degree of asymmetry of rays in the thoracic fins of fry of *Lucioperca lucioperca* observed in 1986 and anomalies in the reproductive system of *Hypophthalmichthys molitrix* registered in 1989-1992 correspond to the fourth level of disruptions. The increase in chromosomal mutagenesis in Chironomidae registered in 1991 points to the fifth level of disruptions.

Conclusions

Wide experience of hydroecological investigations of continental water bodies suggests that anthropic impact may cause irreversible disruptions of the functioning of aquatic biosystems. A possible character of the changes in the life expectancy of the organisms subjected to the combined action of chemical, thermal, and radioactive contamination. The quantitative scale of assessment of disruptions in aquatic biosystems suggested by us can be used for the quantitative determination of the extent of influence of different factors, as well as for elaborating a powerful mechanism of control, prediction and management of the anthropic influence upon the ecosystems of continental water bodies

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