ABSTRACT

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NOISE MONITORING FOR IMPROVEMENT OF OPERATIONAL PERFORMANCES OF THE AIRCRAFT IN VICINITY OF AIRPORTS

Air transportation is very beneficial for national and international economy, but it produces an aircraft noise – some kinds of damages, particularly for population and environmental systems in airport vicinity. Aircraft noise levels are subject of aircraft certification, the aircraft with incorrect levels of noise are illegal to be produced and operated. Permanent or/and temporary noise monitoring to be undertaken usually in local community on assumption that aircraft noise will exceed what is considered 'acceptable' or legally permissible level of noise, and in this connection it is necessary to refer to the legislative control on aircraft noise. The number and location of the terminals in noise monitoring system is important depending upon the specific role they are to play inside this system.

Key words: aircraft noise, noise monitoring, terminals in noise monitoring system.

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3.6 ESTIMATION OF RADIOCAPACITY AND RELIABILITY OF WATER ECOSYSTEMS

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After the accident at the Chernobyl Nuclear Power Plant large territories of Belarus, Ukraine and Russia were polluted [1, 2]. Almost all of the contaminated land lies on the water catchment area of the Dnipro, so as a result of the surface runoff, radionuclide falls in waters of the Dnipro reservoirs cascade.

For assessment of radioactive contamination the following main concepts have been used.

Reliability − the fundamental property of biological objects that determines their existence and effective functioning in a randomly varying environmental conditions and time. The measure of reliability − the probability of fail-save existence of the system, which can vary from 0 to 1.

Reliability for sequential and parallel systems is calculated according to the following formulas (Table 1).

Table 1

Formulas for reliability for different type of systems

Reliability of the sequential system of n- elements is given by multiplying the probabilities	$P_{sequential} = \prod_{i=1}^{n} P_i$ (1)
Reliability of the parallel system consisting of n-elements is given by multiplying the probabilities	$P_{parallel} = 1 - \prod_{i=1}^{n} (1 - P_i)$ (2)

Radiocapacity factor (by V.I. Korogodin) is defined as the part of radionuclide (tracer – ^{137}Cs) received by separate components of an ecosystem.

In general radiocapacity – a fundamental property of ecosystems, which defines the critical amount of radionuclide that can be stably hold by the biota of the ecosystem without changes of its basic functions (biomass growthand habitat conditioning).

To assess the status and well-being of ecosystems more than 30 different indicators and parameters are used – variety of species, biomass growth, resources abundance etc. An important feature of these indicators is that almost all of them are beginning to change significantly only when the biota is undergoing significant changes. Practically it is very important to have indicators and parameters that allow to assess distribution and redistribution of pollutants in real ecosystems and landscapes. On the basis of theoretical analysis and experimental studies, we proposed to use such a measure – as radiocapacity and radiocapacity factor of ecosystems and their components.

According to general assessments about 40 % of the waastewateris formedin a 30-kilometer ChNPP zone, 40 % isformed in the territory of the polluted regions of Belarus, and the remaining 20 % – from the contaminated territories of Ukraine which are not closed for economic activity. The Dnipro, as is known, as a result of regulation, represents a cascade of six large reservoirs, which flow into the Dnipro-Bug estuary. Analyzing the magnitude and speed of water exchange between the reservoirs, one can see that the exchange between them is not more than 1/30 volume per year. This characterizes the cascade as a system of reservoirs, which are very slowly exchanging water. Methods of radiocapacity estimation can be applied to such system. Main parameters and characteristics of the Dnipro reservoirs are given in Table 2.

Table 2

Characteristics and parameters assessments for Dnipro water reservoirs for ^{137}Cs

Water reservoir	Square, km^2	Volume, km^3	Average depth, m	Silt thickness, sm	$K_{\text{н}}$(water–bottom sediments)	Radiocapacity factor
Kyivske	920	3,7	4	10	100	0,7
Kanivske	680	2,4	4	10	50	0,6
Kremenchutske	2250	13,5	6	10	800	0,8
Zaporizke	570	2,4	4	10	100	0,7
Dniprovske	410	3,3	8	10	230	0,7
Kakhovske	2150	18,2	8	10	280	0,7

It can be seen that each of the reservoirs has low values of the radiocapacity factor with respect to ^{137}Cs. Since the Dnipro reservoirs cascade is a system of reservoirs that slowly exchange water, the following formula can be applied for calculating the general radio volume:

$$F = \frac{Kh}{H + Kh}, \qquad (3)$$

where $K$is the coefficient of accumulation in the system “water–bottom sediments”; h is the thickness of the silt sorbing layer; H is the average depth of the reservoir. F indicates the part of radionuclide in bottom sediments and ($1–F$) corresponds to the part of radionuclide in water.

It follows from this formula that the radiocapacity factor of cascade (F_k) of reservoirs is equal to F_k = 0,9994. This value shows an extremely high degree of radiocapacity factor of a cascade, which is much higher than the radiocapacity factor of Kremenchug reservoir which is the best with respect to radiocapacity.

The formula and estimate of the radiocapacity of the Dnipro reservoirs cascade allowed for the first time in the post-accident period to predict with high accuracy the distribution of ^{137}Cs in the cascade in its sediments and water and predict that the part of ^{137}Cs will be firmly «buried» in the silt of the Kiev reservoir.

The proposed model and the corresponding assessment are made for the case of a single entry of radionuclide into a cascade. For the long-term radionuclide inputs, the model must to be modified by using differential equations. But even 25 years after the accident, the difference in the radioactivity of the water of the Kyiv and Kakhovka reservoirs remains sufficient andits degree is the same as in the first years after the accident.

In the case of other important radionuclide ^{90}Sr, the situation is different. The matter is that for ^{90}Sr the radiocapacity factor of the Dnipro reservoirs cascade does not exceed the values of 0.2–0.3. In this case, the factor of the total radiocapacity of the cascade for ^{90}Sr does not exceed 0,5–0,6, and there is no significant deposit of strontium in the bottom sediments. The content of ^{90}Sr in water is not more than 10 times different from the Kiev and Kakhovka reservoirs. This is well confirmed by the real data of observations in 1987–1993. Thus, the given example demonstrated the heuristic character of analysis of real large and small ecosystems by means of their radiocapacity.

The theoretical analysis of the problem of biosystems radioecological reliability has shown that the dynamics of the radioacapacity factor of the ecosystem biota under the influence of gamma irradiation and the introduction of heavy metals (Cd) almost coincides with the dynamics of such biological index as the growth rate. It is possible to state that the ^{137}Cs tracer behavior in the ecosystem, as an analogue of the potassium mineral nutrition, reflects the degree of well-being of the state of the ecosystem biota. Thus, we get the conclusion: the higher biota’s ability to accumulate and hold the tracer, the better the state, and therefore, the reliability of the ecosystem biota.

As a result of the Chernobyl accident, the ^{137}Cs tracer was "widely scattered" around the world. Therefore, it is possible to use this circumstance to establish the rules for the redistribution of tracer by different types of ecosystems. If in the dynamics of the radiocapacity factor with respect to the tracer shows a sharp change in its content in the ecosystem biota, that may indicate a noticeable reaction of the biota to the received effect [3, 4].

Behavior of the tracer can serve as an "ecological indicator" for assessing the state and reliability of biota. It is known that a decrease in the pH of the water in the lake ecosystem results in the desorption of radionuclides from the bottom sediments and biota into water, which in turn leads to a decrease in the radioactivity of the bottom biota and an increase in tracer content in water. This results in additional dose loads on the biota of the lake water and for people who use water for drinking and irrigation.

Tests of ecosystems biota allowed to establish limits for permissible doses to biota [5, 6]. In particular it has been established that the dose of 4 Gy/year for plants and hydrobionts and the dose of 0.4 Gy/year for animals can serve as a limit for which biota can still be reliably [6, 7].

To assess the content of radionuclides corresponding to these doses, B. Amiro's dose factors [8] were used, which showed that the ^{137}Cs content in biota is capable of producing exactly such a critical dose of 4 Gy / year. That is, an estimate of the radioactive content of the ecosystem biotic component, when the reliability of the ecosystem biota is close to zero, has been obtained. It is shown that in the range of doses for a biota from 0 to 4 Gy, the reliability can vary linearly from 1 to 0. Thus, the radiocapacity parameter can serve as a measure of the reliability of a biota in any ecosystem.

Let's consider some examples. Using theoretical results received by the consistent reliability model, two versions of the reliability measure of the Dnipro cascade were calculated for the process of containing radionuclides in it: without taking into account the participation of the biota of reservoirs and under the conditions of a real adaptive biota response at relatively small radiation dose (about 0.1–0.5 Gy / year, Tables 3−6).

Table 3

Estimation of radioactive factors by ^{137}Cs on the example of the Dnipro reservoirs cascade in conditions of adaptive biota response and without it (assessment of the cascade of reservoirs reliability the with the participation of biota)

Reservoir	*F* (bottom sediments)	*F* (biota)	F_i (summarized)
Kyivske	0,7	0,1	0,8
Kanivske	0,6	0,08	0,68
Kremenchutske	0,9	0,04	0,94
Zaporizke	0,7	0,16	0,86
Dniprovske	0,7	0,1	0,8
Kakhovske	0,8	0,14	0,94

General reliability and radiocapacity of Dnipro cascade is calculated by the formula:

$$F_{\text{cascade}} = 1 - \Pi\,(1 - F_i). \qquad (4)$$

Assessments gave the following results:
F_{cascade} (without biota) = 0,9998;
F_{cascade} (with biota and adaptation) = 0,999993.

Table 4

Estimation of radioactive factors by ^{137}Cs on the example of the Dnipro reservoirs cascade in conditions of adaptive biota response and without it, with taking into account the radiation synergy effect and cadmium (assessment of the cascade reliability with the participation of biota)

Reservoir	*F* (bottom sediments)	*F* (biota)	F_i (summarized)
Kyivske	0,7	0,09	0,79
Kanivske	0,6	0,07	0,67
Kremenchutske	0,9	0,036	0,936
Zaporizke	0,7	0,14	0,84
Dniprovske	0,7	0,09	0,79
Kakhovske	0,8	0,13	0,93

General reliability and radiocapacity of Dnipro cascade is calculated by the formula:

$$F_{\text{cascade}} = 1 - \Pi\,(1 - F_{\text{i}}).$$

Assessments gave the following results:
F_{cascade} (without biota) = 0,9998;
F_{cascade} (with biota and adaptation) = 0,9999.

Table 5

Estimation of radiocapacity factors for ^{90}Sr on the example of Dnipro cascade in conditions of adaptive biota response and without it (estimation of cascade reliability with participation of biota)

Reservoir	F (bottom sediments)	F (biota)	F_i (summarized)
Kyivske	0,3	0,15	0,45
Kanivske	0,2	0,1	0,3
Kremenchutske	0,5	0,2	0,7
Zaporizke	0,4	0,2	0,6
Dniprovske	0,4	0,18	0,48
Kakhovske	0,5	0,16	0,66

General reliability and radiocapacity is calculated as:

$$F_{\text{cascade}} = 1 - \Pi\,(1 - F_i);$$

F_{cascade} (without biota) = 0,95;
F_{cascade} (with biota and adaptation) = 0,992.

Table 6

Estimation of radiocapacity factors for ^{90}Sr on the example of Dnipro reservoir cascade in conditions of adaptive biota response and without it, taking into account the synergies effect of radiation and cadmium interaction (assessment of the cascade reliability with the participation of biota)

Reservoir	F (bottom sediments)	F (biota)	F_i (summarized)
Kyivske	0,3	0,14	0,44
Kanivske	0,2	0,09	0,29
Kremenchutske	0,5	0,18	0,68
Zaporizke	0,4	0,18	0,58
Dniprovske	0,4	0,16	0,56
Kakhovske	0,5	0,15	0,65

General reliability and radiocapacity of the cascade are:

$$F_{\text{cascade}} = 1 - \Pi\,(1 - F_i);$$

F_{cascade} (with biota) = 0,95;
F_{cascade} (with biota and adaptation) = 0,992.

Radiocapacity assessment also includes radionuclides transfer between various components of affected ecosystems. When process of radionuclide transfer into bottom sediments, which are the main depot of radionuclides accumulation in water bodies is studied, two principal mechanisms are distinguished: biogenic and chemogenic [10]. Biogenic migration means absorption of radionuclides by hydrobionts conducive to transfer of the radionuclides into the bottom sediments as a result of their physiological processes. Chemogenic migration is divided into three directions: first direction means sorption of radionuclides in suspensions of organic origin followed by sedimentation onto the water body bottom where the radionuclides shall be sorbed directly by the bottom sediments. Second direction means simultaneous precipitation with crystalizing calcium carbonate (the most frequent phenomenon with ^{90}Sr). The third direction means sorption capture of radionuclides with coagulating gels of iron, manganese or aluminium hydroxides [10].

Change in the specific activity of the radionuclides in water in the event of its one-time ingress into a water body may be described with the following equation [10]:

$$\frac{\partial C_1(t)}{\partial t} = \frac{D}{L}\frac{\partial C_2(z,t)}{\partial z} - \frac{V_0 K_p C_1(t)}{L} - \lambda C_1(t), \tag{5}$$

$$z = -V_0 t,\ t > 0,$$

where: C_1 – stands for the specific activity of the radionuclides in water, Bqcm^{-3}; $C_2(z,t)$ stands for their specific activity in the bottom sediments at depth z and time t; D – stands for efficient diffusion coefficient of radionuclides in the bottom sediments, cm^2 year^{-1}; L – stands for average depth of the water body, dm; V_0 – stands for the in crementrate of the bottom sediment layer (as a result of detrital matter formation), cm year^{-1}; K_p – stands for the coefficient characterising distribution of radionuclides between the solid and liquid phases in a water body; λ – stands for a radioactive decay constant, year^{-1}.

Box models are often used to describe the transfer (transition) and migration of radionuclides in any ecosystems. The entire transfer chain of radionuclides in such models is divided into "boxes". Interaction between boxes in mathematical models is determined by coefficients describing the transfer speed [12].

The box model method adequately describes the transfer of radionuclides in hillside ecosystems exemplified with a system including eight boxes: "Forest", "Outskirts", "Meadow", "Terrace", "Flood Plain", "Water", "Biota", "Bottom Sediments". Impact of the contamination upon the people is considered in the form of a separate ninth box, where collective dose for human population is accumulated [15].

To model the transfer of radionuclides in typical ecosystems of villages in Ukraine, the box model method is applicable as well. Such method allows us to appraise adequately and prognosticate certain radioecological processes between basic links of the trophic chain "soil – hay – cows – milk – forest products – people" in such systems [9, 11, 14].

The box models for migration processes of radionuclides were constructed for Glyboke and Daleke lakes, which are the most radionuclide-contaminated water bodies within the Chernobyl Exclusion Zone. Behaviour of ^{137}Cs and ^{90}Sr was analysed, since they are the main dose-forming isotopes in contaminated water bodies and in their biotic components.The constructed models (Fig. 1) included such boxes as "Land Runoff", "Water", "Biota (common reed)", "Bottom sediments".

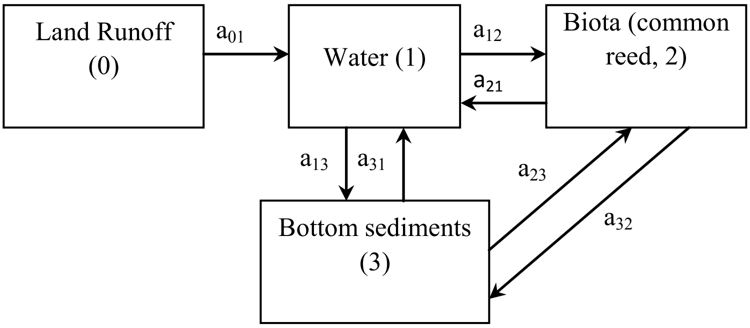


Fig. 1. Schematic diagram of the box model for transfer of ^{137}Cs and ^{90}Sr radionuclides in water bodies of the Chernobyl Exclusion Zone

In the course of modelling, the decay factor of radionuclides was taken into account. Initial data (see Table) for solution of the systems of differential equations were taken from a collective monography [13] (Table 7).

Table 7

Content of the main dose-contributing radionuclides ^{137}Cs and ^{90}Sr in the components of Glyboke and Daleke lakes, MBq [13]

Component of ecosystem	Glyboke Lake		Daleke Lake	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
Bottom sediments	962000	444000	51800	37000
Water	6200	50900	236	1650
Seston	2471	800	73	58
Biota	4598	3035	155	96
Communitiesofhigherwaterplants (commonreed, sedge, reedmace, *Sparganium*)	1458.6	260.4	41.90	4.1

Systems of differential equations describing the transfer of radionuclides between biotican dabiotic componentsin Glyboke and Dalekelakeswere solved by virtue of Maple VI software:

$$\begin{cases} \dfrac{dC_0}{dt} = -a_{01}C_0 - \lambda C_0, \\ \dfrac{dC_1}{dt} = a_{01}C_0 - a_{12}C_1 + a_{21}C_2 + a_{31}C_3 - \mathrm{a}_{13}C_1 - \lambda C_1, \\ \dfrac{dC_2}{dt} = a_{12}C_1 - a_{21}C_2 - a_{23}C_2 + a_{32}C_3 - \lambda C_2, \\ \dfrac{dC_4}{dt} = a_{13}C_1 - a_{31}C_3 + a_{23}C_2 - a_{32}C_3 - \lambda C_3, \end{cases} \tag{6}$$

where a_{01}, a_{12}, a_{21}, a_{23}, a_{32}, a_{13}, a_{31}stand for rates of radionuclides transfer between boxes; C_0–C_3stand for activity of radionuclides as % of their total stock in the ecosystem.

Results of the research with the model are shown on Fig. 2.

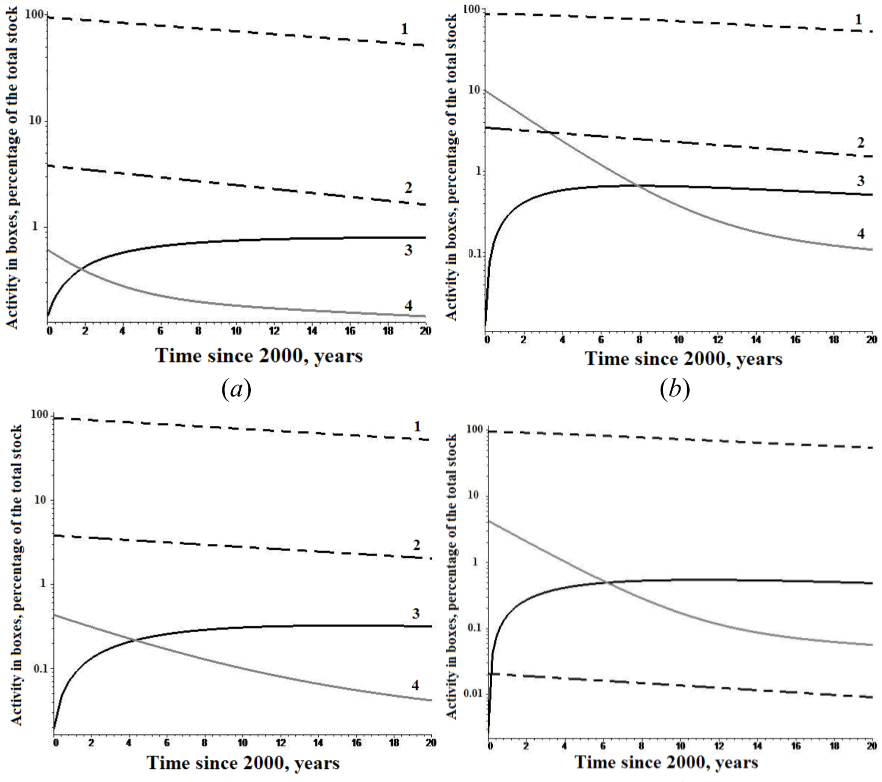
It was found that communities of common reed accumulated less than 1 % at most of ^{137}Cs and ^{90}Sr in Glyboke and Daleke lakes during 20 years following the sampling time in 2000–2004 years. This, most likely, may be explained with that some equilibrium in distribution of radionuclides between components of lake ecosystems has been established after the accident in 1986. Activity in other boxes (land runoff, water, bottom sediments) is reducing gradually.

Reduction of radionuclides activity in water and bottom sediments can be related to the transfer of the radionuclides into other components such as suspensions, detrital products, as well as higher aquatic plants.

Thus, the higher aquatic plants, being an integral component of ecosystems in fresh water, influence on redistribution and migration processes of radionuclides in water bodies.

Although percentage of radionuclides content in common reed communities is slight as compared with the total stock, the transfer of radionuclides to biotic components shall be nevertheless taken into account for elaboration of a set of measures aimed at prevention and minimisation of consequences of ionising radiation impact on the biota in water ecosystems.

Radiocapacity assessment in reservoirs of Dnipro river, plays crucial role in ecosystem stability investigation. By the example of Dnipro reservoirs, radiocapacity factor for ^{137}Cs and ^{90}Sr was determined.



(*a*) (*b*)

(*c*) (*d*)

Fig. 2. Calculations of ^{137}Cs and ^{90}Sr activity change in boxes of Glyboke (*a*, *b*) and Daleke (*c*, *d*) lakes:
1 ▬ ▬ ▬ ▬ ▬ Bottom sediments, 2 ▬ ▬ ▬ ▬ Land runoff, 3 ▬▬▬▬▬ Biota (Common reed),
4 ▬▬▬▬▬ Water

Box models of radionuclide-contaminated Glyboke and Daleke lakes in the Chernobyl Exclusion Zone have been designed and analysed.

Slight increase of the radionuclides content (< 1 %) in «Biota (common reed)» box of Glyboke and Dalekelakes in the Chernobyl Exclusion Zone has been obtained.

Generalreductionof^{137}Cs and^{90}Sr radionuclides contentinabiotic components of the water bodies (inparticular, in “LandRunoff”, ”Water” and ”BottomSediments” boxes) as some percentage of their total stockineco systems has been prognosticated.

Research results maybe used to calculate the radio-capacity of radionuclide-contaminated water bodies, to elaborate measures aimed at minimisation of adversecons equences of ionisin gradiation for the biota.

РЕФЕРАТ

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ОЦІНКА РАДІОЄМНОСТІ ТА НАДІЙНОСТІ ВОДНИХ ЕКОСИСТЕМ

Статтю присвячено дослідженню радіонуклідного забруднення водних об'єктів. Дослідження спрямовано на оцінку надійності та радіоємності екосостем Дніпровських водосховищ, а також переходу радіонуклідів між компонентами водних екосистем Чорнобильської зони відчуження.

Визначено фактор радіоємності для ^{137}Cs та ^{90}Sr для різних водосховищ Дніпра. Побудовано камерні моделі переходу радіонуклідів між біотичними та абіотичними компонентами найбільш забруднених озерних екосистем Чорнобильської зони відчуження.

Ключові слова: радіонуклідне забруднення, радіоємність, фактор радіоємності, камерна модель, Чорнобильська зона відчуження, каскад Дніпровських водосховищ.

РЕФЕРАТ

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ОЦЕНКА РАДИОЕМКОСТИ И НАДЕЖНОСТИ ВОДНЫХ ЭКОСИСТЕМ

Статья посвящена исследованию радионуклидного загрязнения водных объектов. Исследования направлены на оценку надежности и радиоемкости екосостем Днепровских водохранилищ, а также перехода радионуклидов между компонентами водных экосистем Чернобыльской зоны отчуждения. Определены фактор радиоемкости для ^{137}Cs и ^{90}Sr для различных водохранилищ Днепра. Построено камерные модели перехода радионуклидов между биотическими и абиотическими компонентами наиболее загрязненных озерных экосистем Чернобыльской зоны отчуждения.

Ключевые слова: радионуклидное загрязнение, радиоемкость, фактор радиоемкости, камерная модель, Чернобыльская зона отчуждения, каскад Днепровских водохранилищ.

ABSTRACT

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ESTIMATION OF RADIOCAPACITY AND RELIABILITY OF WATER ECOSYSTEMS

Paper deals with the investigation of the water bodies radionuclides contamination. The research is focused on the Dnipro water reservoir ecosystems reliability and radiation capacity assessment, as well as radionuclides transfer between the components of aquatic ecosystems within Chernobyl Exclusion Zone. Radiocapacity factor for ^{137}Cs and ^{90}Sr was determined for various reservoirs of Dnipro river. Box models of radionuclides transfer between biotic and abiotic components of the most contaminated lake ecosystems within Chernobyl Exclusion Zone, were built.

Key words: radionuclide contamination, radiocapacity, radiocapacity factor, box model, Chernobyl Exclusion Zone, cascade of Dnipro reservoirs.

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3.7 MODELS FOR ASSESSMENT OF NO$_x$ EMISSIONS FROM TURBOFAN ENGINE OF AIRCRAFT

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Aircraft emissions are of concern due to the expansion of air traffic over the years (a mean annual rate of 5 to 7 %) and their potential impact on air quality in local, regional and global environments [1,2]. Even if in some the European hubs their capacity is close to the limit (never mind operational or environmental), the transfer of the air traffic to other airports, with less intensive traffic, but usually closer to habitation areas, once again making a rise to concerns about their LAQ tasks.

The analysis of emission inventories at major European (Frankfurt am Main, Heathrow, Zurich and etc.) and Ukrainian airports highlighted that aircraft are the dominant source of air pollution in most cases under consideration, with contribution to inventory higher than 50 % of their total values in most of the airports [3, 4]. The aircraft emission inventory is usually calculated on the basis of certificated engine emission (EE) indices, which are provided by the engine manufacturers and reported in ICAO EE database [5]. It is necessary to mention that ICAO EE database has gained from a very limited number of newly manufactured engines during the certification process [6], even someone may conclude that the best practice is included first of all.

The emission indices rely on well-defined measurement procedure and conditions during aircraft engine certification. Under real circumstances, however, these conditions may vary and deviations from the certificated emission indices may occur due to impact such factors, as:

- the life expectancy (age) of an aircraft – emission of an aircraft engine might vary significantly over the years (the average period – 30 years), usually aging aircraft/engine provides higher emission indices in comparison with same type but new ones;
- the type of an engine (or its specific modification, for example with different combustion chambers) installed on an aircraft, which can be different from an engine operated in an engine test bed (during certification);
- meteorological conditions – temperature, humidity and pressure of ambient air, which can be different for certification conditions.