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INFORMATIONAL MECHANISM OF THE EFFECTS OF LOW DOSES IONIZING RADIATION ON LIVING ORGANISMS

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Abstract: *A cybernetic approach was used for description the effects of low doses ionizing radiation on organisms. The signal-information perception of radiation explains the effects of its low dose, non-linear character of dependence of biologic response of irradiated dose, hormesis phenomenon, apoptosis, remote consequences of irradiation, bystander and other post radiation effects. The informational approach to the effects of low-intensity radiation on the organism can be the supplement to the existing radiobiological theories, allowing them to expand, introduce new concepts and approaches to the correction of post-radiation effects, radiation rankings based on their signal importance.*

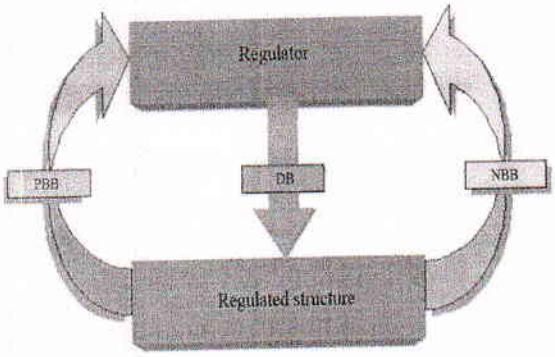
Keywords: ionizing radiation, low doses, information mechanism

Under the impact of weak ionizing radiation on the living organism there are a number of effects that can not be explained from the standpoint of the classical physics and chemistry laws. The literature E.B. Burlakova et al. (1996, 36, 4, 35-38] and the results personal research K.Ya. Bulanova, L.M. Labanok (2004, 2006) allow us to distinguish the following characteristic features of post-radiation effects of low-intensity ionizing radiation and low doses of radiation, which so far have not a clear explanation. The dependence of the biological effects on the radiation dose has a complex nonlinear character; there is objective evidence of distant post radial manifestations; the majority of post-radiation effects mediated by changes in various body systems; in the holistic organism post radial offset and changes are detected only at functional loads; the sensitivity of cells, organs and systems of the irradiated organism to the impact of other

damaging factors changes; radiogenic effects are nonspecific and may become the basis both for the development of pathological conditions and radioresistance (adaptive response) increase; the severity of post-radiation change is largely determined by the physiological state of the body, organs and tissues, as well as the exposure area. Postradiation changes in the organism are usually not related to the specific character of the impact: there are no radiation sickness symptoms, but existing diseases present themselves and start to progress, the level of spontaneous chromosomal damage increases, etc. However, during the post-radiation period many radiobiologists also noted activation of life processes in living organisms, in order to describe this phenomenon, in 1980 the term "radiation hormesis" was proposed S.P. Yarmolenko (1988). Screening of living organisms from the natural radiation background leads to a weakening of the metabolic processes and reduce the viability of the organisms. Therefore, radiation is the part of the environment necessary for the normal development of a living organism. This allows suggesting the presence of effects of ionizing radiation of both physiological and pathological levels Z. Bak, P. Aleksander (1963). But while acknowledging the presence of opposite effects of radiation on the organism, there is no possibility to explain the radiobiological paradox: mismatch between an insignificant quantity of absorbed energy and extremely high degree of the response of a biological object. In particular, the absorbed dose of 10 Gy is lethal for most mammals, expressed in thermal terms it corresponds to a glass of hot tea. The leading role of the atoms ionization in the post-radiation effects at this dose absorbed is also questioned S.P. Yarmolenko (1988). There is no full solution of the fundamental radiobiology problem - the definition of the laws of the biological response to ionizing effect, on the basis of which the radiation reactions of the organism can be controlled.

While recognizing and highly appreciating the radiobiology progress it's impossible to ignore the view on its crisis S.P. Yarmolenko (1997). The emergence of this situation to a certain extent contributed to the methodology, which has prevailed in radiobiology. It was considered, that in order to describe both radiobiological effects and the effects of radiation on physical objects the law of energy conservation may be equally applied, and the causes of the phenomena occurring on the macro level can be attributed to processes occurring at micro levels. Since it is assumed that the micro-level phenomena are spontaneous, therefore, the processes occurring at the macro level cannot be considered as appropriate. All these methodological principles of research lose the certainty of interpretation when applied to biological objects.

Living organisms, first of all, are complex systems, the most important feature of which is the essential relationship of their properties, resulting in the emergence of new properties unusual to the system forming parts. The elements combined into the system and isolated ones respond to the same effects in different ways. During the study of the organism's reactions to the irradiation, it is necessary to apply methodological approaches that are suitable for the description of complex systems. Also, when choosing methodological approaches it's necessary to take into account the special characteristics and origins of living organisms' system formation - DNA molecules, which are, in fact, the information matrixes. It is the copying of information and step-by-step reading of the genetic code, which create an algorithm of formation of all the structures of the living organism from the natural chemical elements. In the living organism information flows become primary in relation to the flow of matter and energy. Formed under the control of the matrix information, organs and systems are combined into a single unit not by covalent or ionic bonds, but informational ones, which form the basis of control of matter flow and energy in the whole body. Moreover, living organisms are self-regulating behavioural type systems. The simplest self-regulating system (Figure 1) consists of two elements: control and compelled ones, and the unity of functions in such systems is created through direct and backward bonds, the last ones divided into positive bonds (PBB) determining the increase in the control parameter, and negative bonds (NBB) contributing reduction in regulated quantities. Signal reception should initiate the turning on of the regulator, thus, the impact of any factor must be accompanied with the presence and realization of its signal importance for receiving structure of the organism.



DB- direct bond; PBB is a positive backward bond;
NBB - negative backward bond

Figure 1: scheme of a simple self-regulating system.

The increasing of complexity of the self-regulating systems structure is based on the fundamental principle of hierarchy: primary regulatory structures are the part of the

superstructure systems of higher order as subordinated ones. If we arrange the organism self-regulating systems according to the complication of the organization, increasing the hierarchical status of each super-system, they will gain the following sequence: a gene - cell - body - CNS. Therefore, the central nervous system becomes the hierarchically main regulator in higher animals and man organisms, and genome functioning is subject to central regulation, although there are mechanisms (PBB and NBB) to provide specific effects on the control center.

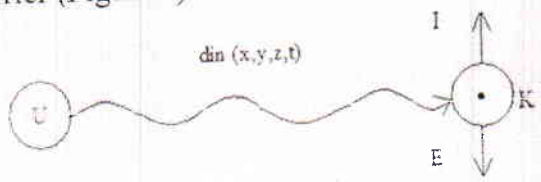
Concerted regulatory action of direct bonds, PBB and NBB are the basis of homeostasis, which the living organisms maintain through the hierarchical self-regulating system. That means that living systems are targeted, so the physiological, biochemical and energetic processes lose spontaneity. None of the parameters in substances or energy flows can change uncontrollably while maintaining the viability of the biological system and the central nervous system.

Promoting the idea of the informational importance of low-intensity radiation for the organism, it is necessary to take into account that the information does not apply to the categories of substances or energy N. Wiener (1968). Since the communication between control and subordinate units, combining them into a single hierarchical subordination system, based on information interaction and the signal has an initiating role in self-regulation, so neither the system nor the processes occurring in them have no physical or chemical interpretation. The study of complex systems of this type, as well as the principles of management can be carried out using a methodological approach, based on the provisions of cybernetics, information theory.

The founder of cybernetics, Norbert Wiener (1968) defined the signal information, as the content received by the organism from the outside world in the process of adaptation. The idea that the organism perceives different kinds of effects through the signal was presented and confirmed in the last century by I.P. Pavlov (1951, Vol. 3, Chap. 2, pp. 335-336). Modern scientists made these ideas more concrete, believing that "the outside world through a variety of impact parameters enters the organism in the form of information processes..". Inside system control also "is performed by the signals from all its systems, organs" K.V. Sudakov (2005, pp. 105-110.).

Does the ionizing radiation, like other natural factors, have the signal importance for living organisms, which allows to implement post radial effects due to the initiation of information processes, woven organically into the system of self-regulation? In the first place, classical radiobiology always pointed out to a systemic response of biological

object under the influence of ionizing radiation. In the second place, the energy itself can be an information carrier (Figure 2) E.I. Nefedov et al. (2005).



E - energy, that characterizes informational carrier. I – informational component (options of combination of energy and information during the effect on the body: $E >> I$, $E \approx I$ и $E << I$)

Figure 2: connection between dynamics of wave process with the information transfer and energy

The data presented in the picture shows that only in the case when the energy parameters are small ($E << I$), organism structures are able to perceive the information. Therefore, the zone of the low-level radiation creates real conditions for its signal perception by the organism. Currently, there is the proposed criteria on the basis of which it is possible to detect the presence of informational perception of radiation on the basis of organism reactions. Informational impact of radiation on the organism have the following features G.N. Ponomarenko (1999).

1. The energy of reaction that develops in a biological system after the factor impact multiply exceeds the energy that caused it, realizing by the free energy of the organism.
2. The direction of the reaction is determined by the impact area, depending on the field of stimulus application the organism reacts differently.
3. The reaction depends on the repeatability of factor actions (single or continuous).
4. The reaction begins to develop at the time of impact and continued in subsequent periods when an action has already been completed.

It is important to note that these signs of the informational impact of EMR on organism can be founded in a number of the mentioned above paradoxical effects of low-intensity ionizing radiation.

It was found that cyber systems are able to respond not only to the absolute values of the impact, but also at relatively small deviations from these values. Complex self-regulating living systems have the same properties, which is still one of the criteria for judging the informational radiation impact.

The assumption that the signal nature of the effect of ionizing radiation on living organisms also was expressed at the Plenary Meeting of the Scientific Council of RAS on radiobiology by AA Yarilin (1999).

It may therefore be concluded that the leading role in forming of the radiobiological response of the organism to low-intensity radiation and low-dose of peculiarities of the systemic organization of the living, the signal, rather than the energy importance of a particular energy range of radiation K.Ya. Bulanova, L.M. Lobanok (2004). In the zone of low-intensity radiation impact neither energy qualities, nor any other qualities of the material object (ionizing or non-ionizing) are not important for substantial information, extracted by a living organism K.G. Korotkov (2001).

The use by living organisms of low-intensity radiation of wide range as a signaling information carrier allows living organisms to implement successfully the development processes, systemic complication and evolutionary transformations, expand habitat. It should be recognized that the radiation background is essential, having a constructive effect on organisms, their separate systems, cell growth and differentiation.

The signal-information process management mechanism is used by living organisms also for intersystem communication through generating its own low-intensity radiation, with the signal importance for organism systems. These features of self-regulation mechanisms in living organisms were found during the study of mechanisms of therapeutic effects of technogenic EHF radiation N.D. Devyatkov et al. (1991), which energy consists only $1{,}17 \cdot 10^{-3}$ eV, which is smaller than the energy of thermal motion of the atoms, the hydrogen bond energy, therefore during its outside impact it cannot reach the sensitive structures of the organism, even the skin, However, therapeutic effects of mm-radiation on the organism were proved. Studies have revealed that under the influence of adverse factors on the organism, in its certain structures the generation of coherent radiation of thermal intensity is stimulated. The frequency characteristics of the exogenous acoustic waves are a signal for the formation of resonance systems substructures of cells that begin to generate themselves in the wave regime imposed corrective violations. Normalization of homeostasis is a signal for the collapse of these structures. In a practically healthy organism EMR radiation does not cause changes, but can perform other functions– raise (under repeated) non-specific resistance of the organism.

It is important to note that, in information systems in addition to perception, transmission, memorization, retrieving, and resetting the translation of information, there is also the possibility of displacement of previous information with subsequent information. This feature of information systems allows to implement the idea to put the EMR into practice, which signal and information perception by the organism is not

directed at the development of pathological processes, but can change the perception and the implementation of the ionizing radiation effects. For this purpose, after exposure of low intense ionizing radiation on experimental animals (1 Gy) they have been irradiated with EMR EHF (39.5 GHz) for one hour. The results showed (Figure 3) that EHF were able to inhibit the display of radiation-induced effects leading to disruption of thrombocyte aggregation ability in the nearest terms (day 3 days), and as well as in the long-term period (30 days).

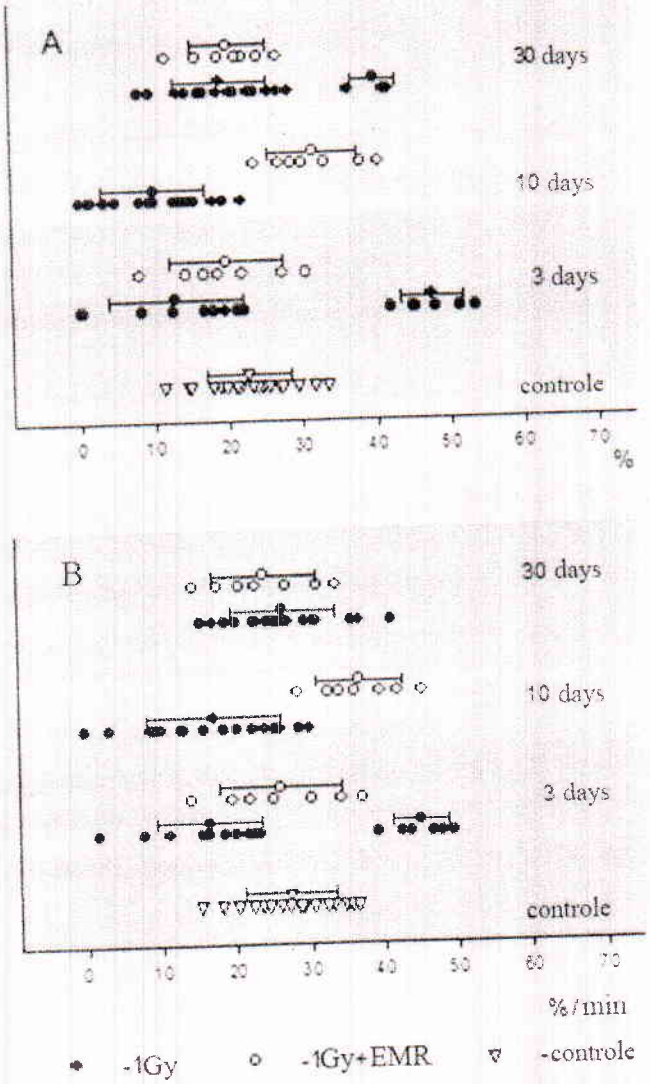


Figure 3: the effects of the recovery by EMR EHF of radiation-induced damages of level (A) and speed (B) of platelet aggregation in rats irradiated with a dose 1Gy

That EHF radiation, impacting sharply resonant, led to selective normalization of thrombolytic activity in the irradiated organism, but failed to prevent violations in other systems. In any system of the body is necessary to act in order to prevent damage and

loss of complex, self-organizing, self-healing system after exposure to ionizing radiation. Which systems of the organism should be influenced in order to prevent damage and loss of complex, self-organizing, self-healing system after exposure of ionizing radiation? V.I. Vernadsky (1970, Vol.3, p 14) believed that "life does not cease with the destruction of some substance, but with the destruction of the structure, the organization", i.e. interconnections. Information theory states that the main reason for their destruction is a decrease in the stability of hierarchically main steering mechanism. It is known that processing of the information received has a great influence on the formation of the organism's response to signal. Arrival and accumulation of some amount of information within the system allows, on the one hand, to expand the informational interaction with the environment. On the other hand, significant increase in information flow and excessive accumulation of information leads to the opposite effect, namely to the disorganization of the system. The excess of information does not allow to solve arising informational problems efficiently, the system gets into a tension state, which leads to the development of pathological processes. Being driven to the extreme state of tension it can get out of balance, lose its stability irreversibly. Perhaps, the exposure directed to the restoration of central control unit functions will allow self-regulation mechanisms to normalize the biochemical and physiological processes in the irradiated organism.

All the above-mentioned theoretical and experimental data was sent to confirm the idea of information perception of radiation. It is more difficult to establish how the organism recipes the radiation. In that light, of the interest is the resonance-field hypothesis by V.P. Kaznacheev et al. [1985], the idea of the existence of the wavelike information matrix in the organism structure P.P. Garyaev (1994, vol. 5). No less important studies by L.A.Chizhevsky (1978), through which were developed ideas about the role of diverse environmental rhythms in the formation of the set of systemic asynchronous activities in each organism structural unit. It is possible that a hierarchy of oscillators is able to create not only the basis of the stability and resistance of the organism to the impact of external vibrations sources, but also to ensure the reception of disturbing, resonance and other effects of those vibrations.

In general, the informational approach to study the radiation effects on the organism helps to explain many postradiational phenomena. Living organisms like the information systems, acquire and display new qualities: the ability to preserve logic and a chronicle of events, use previous experience and predict the consequences, distinguish the signals selectively. The presence of these qualities can explain the features of the

reactions of organisms on different doses of ionizing radiation, non-linearity of the relations of dose / biological response, of different various tissue and specific radio-sensitivity, hormesis, adaptive response, appearance of system-wide reactions in post-radiation effects (stressor component, apoptosis, immune response), ability to change a threshold of radiation perception, radiobiological paradox, sensitizing of irradiated organism to the effect of other factors and long-term consequences of radiation.

In conclusion, it should be noted that the radiobiological problems are handled by experts of different profiles, so the systematization of the results is based on the metrology inherent in each area of research and relevant to the particular problems of individual sciences. Since all the idea of the impact of the radiation on the organism and its systems is based on the experimental data, it makes the basis not to reject any of the scientific disciplines, not to apply the "either ... or" principle but to recognize the importance of each of them, as well as the possibility of using different ways to describe the same objects. Living organisms, on the one hand, are physical, material structures, which can be studied by a variety of instrumental methods, and on the other hand, are behavioural type systems, where management and informational exchange are the most important characteristics. In order to describe the processes occurring in the organism after exposure to low-level radiation, along with other research methods there also the cybernetic approach should be used, which allows to use a picture of information, the laws of its transmission in the behavioural type systems for the interpretation of post-radiation effects. Informational approach to the effects of low-intensity radiation on the organism can become a complement to the existing radiobiological theories, allowing to extend the idea of the mechanisms of the effect of radiation, as well as to offer new concepts to create and implement innovative approaches to correction of post-radiation effects, to rank radiation effects with regard to their signal importance for the organism.

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