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RADIATION AND HYPOXIA STUDIES: EFFECTS OF HIGH-ENERGY ATMOSPHERIC PARTICLES ON BIOLOGICAL ORGANISMS AND POSSIBILITIES OF THEIR REHABILITATION

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The influences of cosmic radiation on atoms and molecules in the Earth's atmosphere were observed with subsequent transformation of atoms, molecules of gases, as well as development of states of oxygen deficiency (hypoxic) in biological organisms, some recommended ways of such disorders correction.

Purposes of this work were to study radiation effects in ionosphere with subsequent high-energy transformations of atoms, molecules of gases at different heights above the Earth surface; interaction of some high-energy atmospheric particles with biological objects at near Earth's heights up to 5.500 m above sea level, and oxygen roles in consequences of biological organisms' irradiation.

Methods. Analysis of results of satellite and rocket observations of the Earth atmosphere gases exploring at different altitudes above sea level. The investigations were done in mountain conditions at EMBS research station of the National Academy of Sciences of Ukraine. The comparative analysis of results of long-term observation of patients using standard laboratory methods, complex of methodological techniques such as clinical, physiological studies of respiratory, and cardiovascular systems. The research has been carried out concerning hematological, immunological states; functional state of higher nervous activity, mental and neurotic state; antihypoxants use, histochemical, biophysical methods, math modelling, others.

Results. The data obtained during the satellites atmosphere exploring were presented: studies of influences on the structure of atoms, molecules in atmosphere, concentrations of gases from ionosphere to the Earth surface, such phenomena as photochemical processes, photoionization. The notion "information" was discussed basing on the phenomena, described in the article. Described studies of gases particles modification, oxygen deficiency in organisms (hypoxic states) were supplemented with the results of irradiated Chernobyl patients' examinations, rehabilitation by Ukrainian doctors, scientists in mountain conditions.

Conclusions. Phenomena of solar radiation influence on atoms, molecules and molecular complexes in the Earth's atmosphere was observed. The main attention was concentrated on the studies of gases concentrations at different heights with linked effects of oxygen roles in consequences of organisms' irradiation and rehabilitation. Practical recommendations for patients' medical care and rehabilitation were done.

Key words: radiation damage of organisms; hypoxia; high altitudes; high-energy particles; free radicals.

Humanity solves a number of contemporary practical problems high above the Earth's surface. These are high-altitude aviation flights, as well as space flights, in which crewmembers and passengers are exposed to significant doses of radiation as well as molecules of oxygen or other gases deficiency in case of contact of organism with the surrounding atmosphere. Some publications in this item were prepared in Ukraine [1–4] and abroad [5–7]. Our predecessors in science suggested the concept of "environment conditionally suitable for life" (approximately above 3 thousand m above sea level (a.s.l.)) and "environment unsuitable for life" (approximately above 5 thousand m a.s.l.) of human and other higher living organisms in mountains [3]. In our previous works, we observed a number of physical factors in the Earth atmosphere, like ones, reveled during earthquakes studies that make environment unsuitable for life [8, 9]. In present publication, we consider briefly the impact of cosmic radiation factors on atoms, molecules and molecular complexes in the Earth's atmosphere [1, 10–15]. Consequently, the first group of methods that had given the data to present article included the results of satellite observations and rocket observations [1–4, 16–21]. Because of this influence, the stay of humans and higher living organisms above the indicated limits becomes impossible. Today's task is to diagnose the full range of gas and electrodynamic parameters that characterize the ionosphere. Such diagnostics is possible only *in situ*, on spacecraft launched into the ionosphere [1, 3, 22–28]. For this purpose, special low-orbit satellites and high-apogee sounding rockets are used. Satellites are good because they allow ones to place solid instrumentation systems on board and take measurements on a planetary scale [1–4, 29–35]. During the space age, about 20 ionospheric satellites were launched, the last of which, the Chinese Seismo-Electromagnetic Satellite Mission (CSES), was realized in 2018 [1, 3, 36, 37]. The heights of satellite orbits are strictly limited from below by the deceleration factor against the atmosphere — at least 250–300 km. Even then, if the orbit height is maintained with the help of corrective engines [38–41] this open the possibilities of novel equipment usage for discoveries [42–45], as well as new methods development [46]. In most cases, ionosphere satellites are launched to altitudes of 500–700 km, well developed for the needs of remote sensing, into the outer part of the ionosphere (Fig. 1) [47–53]. Thus, the D and E regions and the lower part of the F region, which are so important for understanding the ionosphere and space weather, are beyond the capabilities of satellite sensing [47–52]. Satellite and rocket experiments not only complement each other, they must be combined with each other [53–57]. This gives the possibility for mathematical and program modelling [58–61], as well as for theoretical studies and conclusions [60]. Finally, all such data basing today in science and technique are the results of satellite observations as well as obtained in process of rocket observations [1–5, 7–62]. The second group of methods we used for our studied was linked with investigations in high-mountain conditions at research station of the National Academy of Sciences of Ukraine (EMBS). There are the comparative analysis of the results of long-term observation of patients in hospital conditions using many standard laboratory methods of their states examinations. The conducted scientific research consisted of a complex of methodological techniques and approaches such as clinical and physiological studies of respiratory and cardiovascular systems, hematological and immunological states, and functional state of higher nervous activity, mental and neurotic state. Administration of antihypoxants, histochemical, biophysical and other methods were used to evaluate oxybiotic processes. Mathematical processing of the results, as well as methods of mathematical modeling were applied. In addition, the next question that we raised in the process of these studies was: what measures should be taken in order to secure the stay of people above such limits. Our well-grounded suggestions to use some specific pharmacological preparation for the prevention of some biological system damage were done previously [3, 62–65].

So, the sequence of material in present article is the following: 1) to observe briefly the impact of cosmic radiation on atoms and molecules in the Earth's atmosphere. Further, to examine subsequently a chain of interconnected natural phenomena: 2) transformation of atoms and molecules of gases in high-altitude atmospheric conditions, 3) as a result, damages of respiration effects in biological organisms and development of oxygen deficiency (hypoxic) states in them. Finally, 4) giving some recommendations of the ways of possible correction of developed hypoxic states and some other pathological states linked with cosmic radiation influences. In parallel, some information aspects of the organization of substances at different altitudes will be considered.

The purposes of this observation were to study deeply radiation effects in the ionosphere of the Earth with subsequent high-energy transformations of gases molecules at different altitude levels above the Earth surface, interaction of some high-energy atmospheric particles with biological objects at near Earth's altitudes (up to 5.500 m a.s.l.), and the impact on information processes in such complex systems. In addition, the manifestation of hypoxia phenomena was of our interest as well as its study in living systems by scientific groups of the National Academy of Sciences of Ukraine with possibility of organisms' further rehabilitation.

Atoms and molecules in the upper layers of the Earth's atmosphere: their transformation under the space radiation and satellite methods of their research. Research of the ionosphere with spacecrafts. In this chapter we observe briefly some main types of substances transformation in the Earth atmosphere under the influence of solar and galactic radiation [1, 3, 7–62]. Such results were obtained in process of many-years investigations of great groups of ionosphere researchers [1–5] and others. So, under the influence of the space factors (galactic and solar radiation, some others), first, a change in the chemical composition of the atmosphere happens. Adapted such materials from [1, 57] are on Fig. 1 (Chamberlain graph, 1981) and Fig. 2 (Kelley graph, 1989). The main means of ionosphere sounding have been and remain remote radio physical means — networks of ionosondes, incoherent scatter radars, systems for radio translucence of the ionosphere with GPS signals, etc. These tools make it possible to control the electron density distribution in the ionosphere with high accuracy. From the standpoint of the science today, this knowledge is not enough!

The ionosphere, as a material medium, is a weakly ionized gas located in the Earth's magnetic field, in which variations in the parameters of neutral and charged components and the electromagnetic field are closely related. In many cases, exactly these connections are interesting. Moreover, the study of a single ionosphere parameter (f. e. electron concentration), can disorient the researcher, for which the history of ionosphere research knows a number of examples.

Today's task is to diagnose the full range of gas and electrodynamic parameters that characterize the ionosphere. Such diagnostics is possible only *in situ*, on spacecraft launched into the ionosphere. For this purpose, special low-orbit satellites and high-apogee sounding rockets were used.

Satellites are good because they enable to place solid instrumentation systems on the board and do the measurements on a planetary scale. During the space age, about 20 ionospheres satellites were launched, the last of which, the Chinese Seismo-Electromagnetic Satellite Mission (CSES), was commissioned in 2018. Up to the last years, another similar satellite, Mikrosat-M, was being prepared for launching in Ukraine.

The ionosphere is formed because of solar radiation absorption by the atmosphere at altitudes of 100–200 km. In the region of wavelengths less than 1000 Å (extreme ultraviolet and X-rays), the energy of photons exceeds the

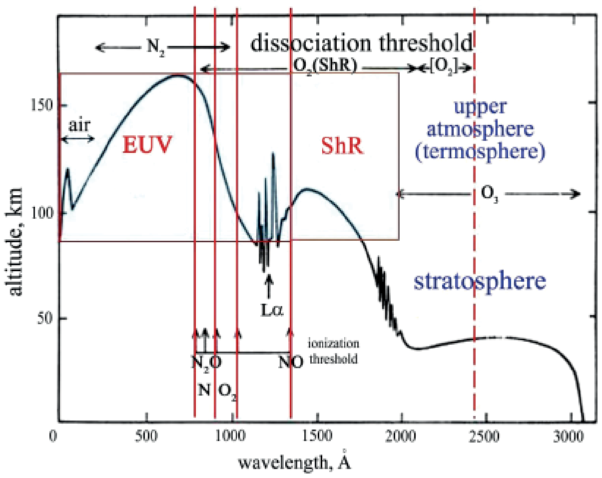

Fig. 1. **Some wave phenomena in the Earth atmosphere**
In the Schumann-Runge continuum (ShR), the flow of energy is: F ~ 15 erg/cm^{2}s. In extreme ultraviolet (EUF): F ~ 2 erg/cm^{2}s. For comparison: solar constant F* = 1.38 kW/m^2 = 1.38×10^6 erg/cm^{2}s. That is, F / F* ~ 0.001% (adapted from [25])

thresholds for dissociation and ionization of atmospheric gases, which causes the phenomenon of so-called "boiler of photochemical reactions" in the atmosphere, and this radically changes all properties of the atmosphere.

First, these processes cause a change in the chemical composition of the atmosphere (Fig. 2). If below 80 km the atmosphere consists of nitrogen molecules N_2 (78%), oxygen O_2 (21%), as well as small components — gases Ar, He, etc. (1%), then photodissociation of molecules occurs at high altitudes. Reactive atomic oxygen becomes the main one. The ionosphere being penetrated by solar radiation turns out to be an aggressive environment, a space factor that affects space-based systems.

Second, atmospheric gases are ionized, but at ionospheric heights, the degree of ionization is low. For example, in the region of ionospheric maximum at a height of ~300 km, the ratio of the concentrations of charged and neutral particles is less than 0.1%. Only in the magnetosphere does this ratio change in the opposite direction.

Thirdly, the ionosphere is colossally heated by the Sun up to temperatures of about 1000 °K. Since the brightness of the Sun in the short-wavelength part of the spectrum is a variable value, depending on the level of solar activity and under the influence of individual flares, the parameters of the ionosphere demonstrate significant variations (Figs. 2, 3).

We see that the ionosphere is not a static object, but a stationary process of circulation of neutral and charged particles. Arising under the action of solar ionizing radiation, charged particles can recombine partially with each other, returning to the mother's neutral atmosphere. Other charged particles partially flow along the lines of force of the Earth's magnetic field upwards into the magnetosphere. At night, the plasma stored in the magnetosphere descends to the heights of its birth and recombines. Thus, the ionosphere, like a candle flame, retains its shape, despite the fact that a new one continuously replaces the substance that forms it (Fig. 3).

Consequently, we can subdivide the groups of factors that influence on the content of atmosphere at different levels above the Earth. Being summarized, this information evidences about the changes in chemical composition of the air along the vertical line from the ionosphere to the surface of the Earth. Consequently,

1) Below 80 km: N_2 — 78%, O_2 — 21% (plus 1% — small components). Above 80 km: separation of components is according to individual barometric laws plus photo dissociation of O_2. At the heights of the F region, atomic oxygen O becomes the main gas component.

2) Plasma is formed, but it is a small chemical admixture to the neutral gas (in the maximum density of the ionosphere at an altitude of 250–300 km, the degree of ionization is < 0.1%).

3) The absorption of solar ultraviolet causes a colossal heating of the atmosphere (around 1000 K). Since the brightness of the Sun in this part of the spectrum is variable, the temperature and density of the upper atmosphere undergo enormous variations.

Photoionization. Photoionization phenomenon was described enough completely in [60]. Photoionization of the neutral

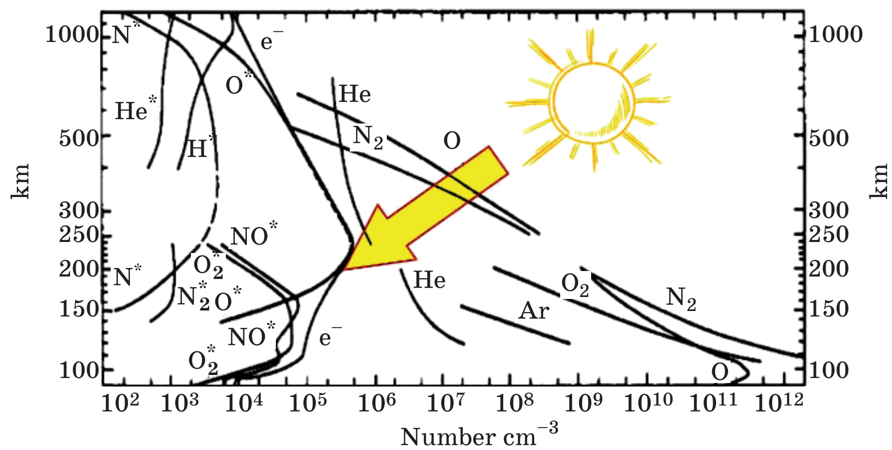

Fig. 2. **The concentration of neutral and charged components of the atmosphere (horizontal axis) as a function of height (vertical axis)**
The upper atmosphere is a chemically active environment under the aggressive influence of solar radiation. The upper atmosphere is a photochemical boiler. Plasma is born, drifts up and down and recombines. In this way, the ionosphere is formed (adapted from [1, 57])

components of the atmosphere by the extreme ultraviolet and X-ray radiation of the Sun is the primary reason for the ionosphere existence and it is the main factor that define gas content of it and atmosphere in general [60]. The data about the ionization potentials and the corresponding wavelengths for a number of atmospheric components are known for today. Respectively, it is known that for the Earth's atmosphere ionizing radiation is with , and for the main components with [60].

The most significant photoionization processes for the ionosphere are the following [60]:

$$N_2 + hv \rightarrow N_2^+ + e^-, \quad (1)$$

$$O_2 + hv \rightarrow O_2^+ + e^-, \quad (2)$$

$$O + hv \rightarrow O^+ + e^-, \quad (3)$$

In the D region:

$$NO + hv \rightarrow NO^+ + e^-, \quad (4)$$

$$O^2\,(^1D_a) + hv \rightarrow O_2^+ + e^-, \quad (5)$$

Dissociative ionization is also possible:

$$N + hv \rightarrow N^+ + N + e^-, \quad (6)$$

$$O_2 + hv \rightarrow O^+ + O + e^-, \quad (7)$$

whose contribution to the resulting photoopization rate is small (q(6) ≅ 0.02q(1); q(7) ≅ 0.15q(2), where q(6) — is the rate of photoopization in the process (6)).

Less important, but noticeable processes are [60]:

$$N + hv \rightarrow N^+ + e^-, \quad (8)$$

$$He + hv \rightarrow He^+ + e^-, \quad (9)$$

$$H + hv \rightarrow H^+ + e^- \quad (10)$$

The rate of photoionization of the $n^{\text{-th}}$ component of a neutral gas is q_n (z) i.e., the number of photoionization events per unit of volume is determined by the following expression:

$$q_n(z) = n_n(z) \sum_{\lambda \le \lambda_m} I_\lambda(z)\sigma_{n\lambda} = n_n j_n \;, \quad (11)$$

where n_n — is the concentration of gas component of sort n; $I_\lambda(z)$ — is a stream of photons with a wavelength X at a height z; $\sigma_{n\lambda}$— is the cross-section of photoionization of gas component of sort n. Photoionization coefficient is for radiation with wave length $\lambda \le \lambda_m$. For $I_x\{z)$ we have, as in the case of dissociating radiation:

$$I_x\{z) = I_2\infty exp(-\tau_\lambda) =$$
$$= I_2\infty exp\,|-sec\chi > \sigma_{n\lambda}{}^a\,|\,n_n dz|,$$

where τ_λ — is the optical depth for radiation n; wavelength X; $\sigma_{n\lambda}{}^a$ — is the cross section of a photon absorption with a wavelength X of a gas component of type n; x — is the zenith angle of the Sun. For $x > 80^e$, the function $sec\,\chi$ should be replaced by the Chapman function Ch(y).

So, these equations describe the effects of solar and galactic radiation on particles in atmosphere: atoms of the lightest elements and the simplest gas molecules. When particles in the atmosphere (especially in upper atmosphere – ionosphere) are exposed to solar or galactic radiation, energy excited them. Being in excited states, the simplest molecules and atoms of elements of atmospheric gases start their transformation. Such forms of the matter as free radicals, ions, another types of charged particles with high energies that are able to damage biological organisms are formed in these conditions. For example, at 600 km a.s.l., the concentration of particles is ~10^6 cm^{-3}, and in interplanetary space is ~10 cm^{-3}. In our previous publication [1–3] it was grounded, that for the processes

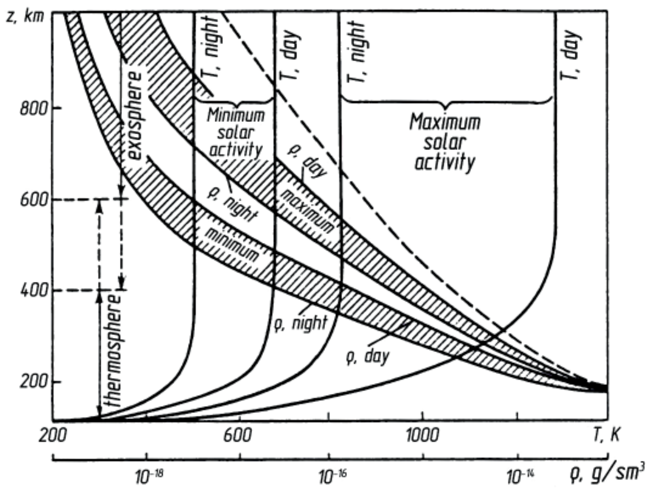

Fig. 3. **Variations in temperature and density of the upper atmosphere (adapted from [29])**

understanding in atmosphere and radiation influences on the matter not only such characteristic, as density of particles in atmosphere (or particles concentration) is important, but also the length (distance) of the free path between the particles. The closer to the Earth's surface, the shorter the free distances (paths) between the particles in atmosphere. On the other side, the higher above the Earth's surface — the greater the free path between these particles. These dependencies in characteristics changes we had demonstrated below in this chapter. It is necessary to mention too, that above we had described the state and processes in the upper atmosphere. But according to Figs. 1–3 we can see "tail effects" moving to the Earth's surface: some processes and particles characteristics became stronger revealed, other — weaker revealed. In addition, such regulations we had shown on Fig.4 with the further explanations.

We tried to summarize natural effects linked with two types of phenomena — 1) space radiation (solar, galactic, other) by itself, and 2) excited atmospheric particles which can be radioactive – can be the reasons of radioactive transformations of the matter close to the Earth's surface and damages of biological objects. The results of such theoretical generalization for space electromagnetic radiation (solar, galactic, others) we had already published in the first article on this item [62]. Doing this for our today continuation of investigations – excited atmospheric particles which can be radioactive — we had subdivided also four groups of effects, and they are listed below in similar manner. They are given on Fig. 4, compare them with [62].

Dependencies in molecular particles characteristics under the influences of space radiation at different altitudes above the Earth surface up to the ionosphere:

The vertical "ionosphere – Earth surface" (1, *a*, *b*).

1, *a*. Increasing the effects along the vertical

1) The densities of matter particles at different altitudes above the Earth surface are increased (gases, microscopic dust particles others — up to biomolecules and solid matters). 2) Number of neutral particles in atmosphere is increased. 3) Protective properties of the atmosphere are increased.

1, *b*. Decreasing the effects along the vertical

1) Various effects associated with high-energy, radiative effects on substances decrease. 2) The closer to the Earth's surface, the shorter the free distances (paths) between atmospheric particles. 3) Radiation doses, obtained by persons during the flight. 4) Radiation influences on the surfaces of the aircrafts. 5) Number of charged particles and free radicals in atmosphere decreases.

The vertical "Earth surface – ionosphere" (2, *a*, *b*)

2, *a*. Increasing the effects along the vertical

Numerous effects described in the point 1, *b* demonstrate increasing: 1) Various effects associated with high-energy, radiative effects on substances are increased; 2) The further from the Earth's surface, the longer the free distances (paths) between atmospheric particles; 3) Radiation doses, obtained by persons during the flight;

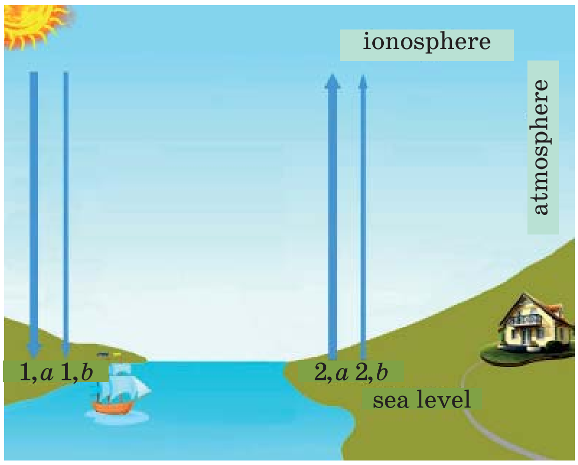

Fig. 4. **Changes in characteristics of matter particles (gases, microscopic dust particles, free radicals, ions, and other types of charged and neutral particles) at different levels above the Earth surface.**
Adapted from [62]

4) Radiation influences on the surfaces of the aircrafts. 5) Number of charged particles and free radicals in atmosphere is increased.

2, *b*. Decreasing the effects along the vertical

Various effects listed in the point 1, *a* demonstrate decreasing: 1) The densities of matter particles at different altitudes above the Earth surface are decreased (from biomolecules and solid matters — to gases, microscopic dust particles others); 2) Number of neutral particles in atmosphere is decreased; 3) Protective properties of the atmosphere is decreased.

Important general regularity was registered in process of these investigations. With shortening the free distances (paths) between atmospheric particles, the densities of matter particles are growing near the surface of the Earth and on its surface. Respectively at such distances, where the particles begin to "feel" each other (i.e., forces of attraction-repulsion arise between them), one can speak of the origination of the concept of information as a measure of the ordering of these particles.

So, we can see, that atmospheric gases particles in excited state (ions, free radicals, radioactive isotopes of H^+, O^-, N^+, NO^+, others) can be registered and more close to the Earth's surface — up to a few kilometers above and even at the a.s.l. In our previous publications [3, 62] we had examined electromagnetic radiation (solar, galactic), which also demonstrate its "tail effects" close to the Earth's surface. These two types of phenomena — 1) radiation (solar, galactic) by itself, and 2) excited atmospheric particles, which can be radioactive — can be the reasons of radioactive transformations of the matter close to the Earth's surface and damages of biological objects. These natural phenomena cause different effects associated with high-energy, radiative effects on substances in the atmosphere and at the surface of the Earth's, as well as on living organisms at different heights above the Earth's surface (Figs. 5, *a, b*; 6). The atoms of elements in atmosphere, which we see as the most damaged by radiation (C, O, N with their ions, free radicals etc.) are involved as well into the chains of biochemical reactions of organism. Oxygen plays the leading role among all other elements in subsequent scenarios. F.e. changes in oxygen transportation and/or utilization leads to hypoxic states development, and so on). Therefore, modification of these elements in atmosphere under the radiation influence with further involving them in such reactions causes notable effects on the organism state (Fig. 6). General image of Krebs cycle give us possibility to imagine great damages of it functions in case of attacks by atmospheric "hot particles" with high energies O, O^*, O_2, O_2^*, N^*, N_2^*, NO^*, others (compare with Figs. 1, 2). Such phenomena — radiation influence on atoms and molecules in living organisms will be explained and described in details further in this publication.

Effects of the particles with high energies that appeared in atmosphere as result of the space radiation on condensed matter close to the Earth's surface and biological objects. Condensed ordered matter and notion of "information". We have already described above the effect of production of particles with high energies in atmosphere as result of space radiation, and the most usual among them were H^+, O^-, N^+, NO^+, "hot particles" with high energies O, O^*, O_2, O_2^*, N^*, N_2^*, NO^* and some others. Being spread as the "tails" to the Earth's surface they interact with the matter there, where matter densities is increased more and more (sure, in such concentrated (condensed) media free distances (paths)

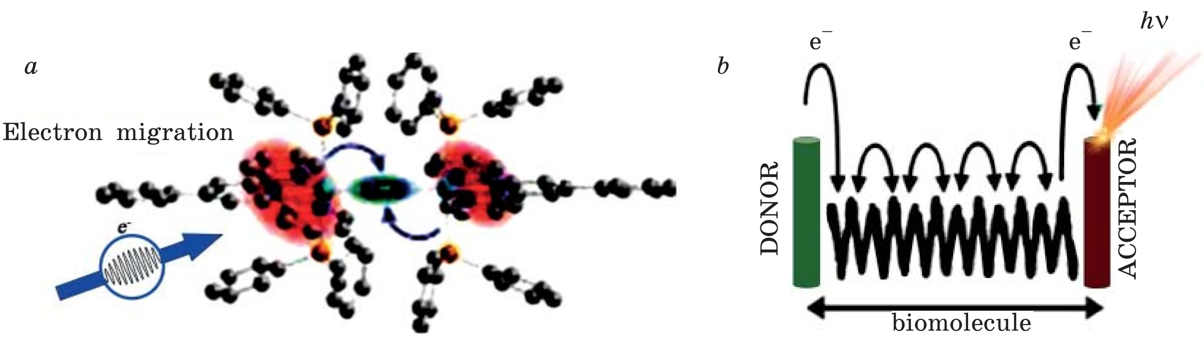

Fig. 5. **Action of electron with high energy on biological macromolecule with migration of its additional energy along the molecule:**
a — the initial moment of attack of biological macromolecule by a high-energy quantum; *b* — hypothetic scheme of capture of quantum of radiation energy by acceptor part of biomolecule and schematic representation of transfer of this energy along a helix of this biomolecule

between “close–to–surface” matters particles are shortening). In such conditions, the crystals were formed — inorganic as well as organic nature. Consequently, such condensed forms of matter demonstrate an order in their structures — the notion “information” appears: “information is a property of the orderliness of condensed systems (including living systems)”. Such “crystals in organic Nature” we usually call “biological objects” — biological macromolecules, their complexes, DNA, viruses, membranes... and further more highly organized structures — living systems.

Well known, that listed above H^+, O^-, N^+, NO^+, and some other elements and simple fragments of molecules with high energies from the atmosphere [60] can be captured easily and incorporated into the structures of such condensed media and more highly organized structures. But they are “not normal” — their inner energies are higher than in structures in normal conditions. Such great energies cause different effects in such “inorganic” and “organic” crystals. Below we observe some effects of such “high energy particles” on biological objects, which captured such particles. Main information below was presented in [65] — excellent review, a book with results and their analysis. So, phenomena of interaction of simple fragments of molecules with high energies from the atmosphere with biological objects and linked problems [66–85] will be observed below.

Effects of oxygen on the matter at the Earth’s surface and biological objects. In the experimental studies, it was registered that oxygen influences greatly on the effect of irradiation of dry enzymes, nucleic acids, dry seeds, spores, etc. This demonstrated convincingly that the oxygen effect extends to the direct action of radiation and, therefore, is realized in other ways than in aqueous solutions [65, 79, 84]. Further, it was shown that oxygen can enhance the effect of radiation even being added to biological object after irradiation, i.e. in period, when the primary products of irradiation, due to short time of their lives, have already disappeared [60, 65, 78, 84].

General image of Krebs cycle give us possibility to imagine great complex damages of its functions in case of attacks by electrons with high energies and atmospheric “hot particles” with high energies O, O^*, O_2, O_2^*, N^*, N_2^*, NO^* others, see formulas (1)–(10) and Fig. 6. Numerous links and elements of the Krebs cycle can be changed due to such influences. The arrows at the figure indicate only some possible points of attack of elements of the Krebs cycle and some involved substances by such electrons or/and high-energy particles, the possibility of some

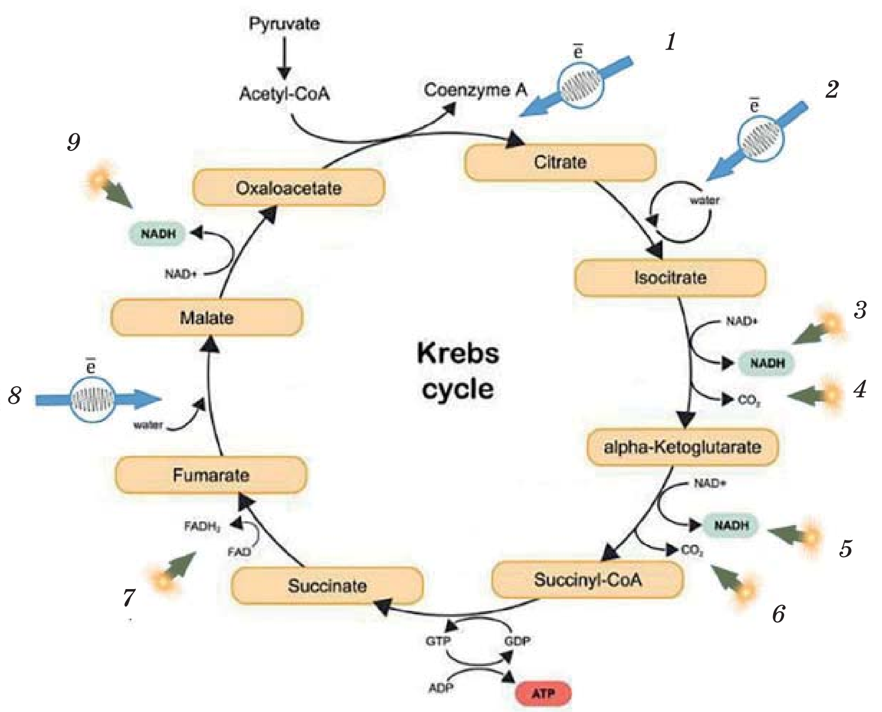

Fig. 6. **One of the various natural phenomena that cause numerous effects associated with high-energy, radiative effects on substances in the atmosphere and at the surface of the Earth**

atoms in compounds replacement (H, O, C, N, others) with subsequent damage of the nearest bonds, etc. Naturally, there are much more such vulnerable points in the cycle, taking into account equations (1–10, 13–16); atoms, compounds of almost the entire cycle are vulnerable. The numbers near the arrows are linked with the numbers of photoionization reactions above:

Reactions with high energy electrons participation (3, 8, 10) — arrows 1, 2, 8.

Reaction with hydrogen with high energy participation (10) — arrows 3, 5, 7, 9.

Reaction with oxygen with high energy participation (3, 7) — arrows 4, 6.

Since tissues of human organism consist on 65–70% of water, the primary radiation chemical reactions develop primarily in the aqueous phases. These reactions we had described already in [62]; so, arrows 2, 8 point also to locations in a cycle that can be damaged due to the water radiolysis effects. Reactions of free radical oxidation will be observed below in the next sub-chapter.

Due to the basic investigations, there was formed an idea about sub lethal and potentially lethal radiation damages of the cells. Such damages were possible to eliminate more or less successfully by the work of enzymatic systems of intracellular repair. With the development of these ideas, it became clear that oxygen also participates in the processes of realization and repair of radiation damage. It was found that these last processes are not only energy-dependent, but they are also oxygen-dependent. Thus, the main effect associated with the presence of oxygen in the irradiated biological environment. Due to its involvement in the reactions of radiation the consequences was the fixation of potentially lethal radiation damages in cells, and these damages were transformed into irreversible damages [65, 79, 83, 84].

Numerous studies have shown that a decrease in the oxygen concentration in the irradiated tissue volume reduces the radiosensitivity of this tissue and reduces the severity of its damage. Tissue hypoxia can be achieved by reducing the oxygen concentration in the inhaled air to 10–7–5% immediately before and during the irradiation [65], limiting oxygen transport by blood, and other methods discussed below.

The role of free radical oxidation in the pathogenesis of radiation damages. It was shown above that free radicals were chemical structures with specific properties formed under the influence of high energies in the Earth's ionosphere in great quantities. Their number decreased noticeably with approaching to the Earth's surface. These rare remained radicals from atmosphere can be captured by biological structures with fatal consequences for them (biostructures damages, destroying, etc.)

At the same time, free radicals can be formed in living systems by themselves [65, 83, 84]. Free radicals in biological systems, first of all, act as initiators of peroxidation process. When free radical interacts with a molecule of organic compound — a new molecule and new radical are formed, and the latter continue the chain of interactions. Thus, peroxide oxidation proceeds as a chain process. B.N.Tarusov and M.N. Emanuel demonstrated that the kinetics of peroxidation of organic compounds corresponded to the mechanism of branched and degenerate-branched radical reactions [60, 65].

Radicals–initiators of reactions of peroxidation (PO) can appear under the influence of radiation quanta — ionizing, ultraviolet and even visible [84]. These quanta, falling from outside or being produced inside of organic substrate (due to the content of natural radionuclides in it) predetermine PO. The role of PO initiators can play radicals formed during the electron transport chains functioning during the interaction of iron ions with oxygen and so on. Practically in the cells of any organism at every moment of its life, there are radicals of different structures that can play the role of PO initiators [84–103].

The next stage of the process – continuation of the chain — is a sequence of radical-molecule reactions [65]:

$$RH + {}^\bullet OH \rightarrow R^\bullet + H_2O$$

$$\text{or} \quad RH + HO^\bullet \rightarrow R^\bullet + H_2O \qquad (13)$$

$$R^\bullet + O_2 \rightarrow ROO^\bullet \qquad (14)$$

$$ROO^\bullet + RH \rightarrow ROOH + R^\bullet \qquad (15)$$

$$R^\bullet + O_2 \rightarrow ROO^\bullet \text{ and so on} \qquad (16)$$

At this stage, a gradual increase in numbers of active radicals continue to form chain. Finally, in reality, the events of opposite direction inevitably take place – chain termination as a result of interaction (recombination) of radicals with each other [65, 84]:

$$R^\bullet + R^\bullet \rightarrow R - R^* \rightarrow R \rightarrow R + h\nu \qquad (17)$$

$$ROO^\bullet + ROO^\bullet \rightarrow ROOR^* + O_2 \rightarrow \rightarrow ROOR + O_2 + h\nu \qquad (18)$$

The excited products formed during such reactions give off excess of energy of electronic excitation in the form of radiated quanta. This phenomenon initiates the effect of chemiluminescence.

Another variant of chain termination occurs when the radical interacts with the molecule of inhibitor substance [65, 83, 84]:

$$R\bullet + Hin \rightarrow RH + In\bullet \quad (19)$$

Outwardly, this reaction does not differ from usual reactions of chain propagation [65]. However, the fundamental difference is that the radical formed in result of reaction is relatively stable and does not continue the chain.

If the frequency of circuits' breaks prevails over the frequency of branching, PO process is terminated. With the reverse ratio of these reactions, the rate of PO gradually increases with the increasing of amount of active products and increasing the substrate molecules number involved in this process. Hence, one of the most important features of PO is the process develops even in the absence of specific catalysts (enzymes), self-accelerating, autocatalytically under favorable conditions: temperature, free access of molecular oxygen and sufficient amount of radical initiators [65, 85–103].

The honor of free radical reactions of PO discovering in tissues and liquid media of organism belongs to B.N. Tarusov [65]. He had discovered that PO reactions develop most effectively in lipid-containing structures, primarily in biological membranes, when these objects were exposed to ionizing radiation.

Reactive oxygen species were found in great variety of cellular organelles, although in very low concentrations they were approximately in 10^{-11} mol/L.

The superoxide anion radical has been found in membranes (nuclear, plasma, microsomal, and mitochondrial). Ability of anion radical to penetrate easily through biological membranes anion channels without specific carriers in chloroplasts was registered [65].

Experimental evidences of superoxide anion radical ability to activate directly the processes of lipid peroxidation were obtained in 1982. The process of formation of lipid peroxides is chain free radical process. Peroxidation is initiated under the condition when free radicals appear in lipid phase, and they can interact with easily oxidized lipid molecule (LH). For example, LH can be unsaturated fatty acids of phospholipids in biological membranes. In this case, a free radical of lipid L• is formed. In presence of oxygen, reaction between the L• radical and O_2 molecule is going [65].

$$L\bullet + O_2 \rightarrow LOO\bullet \quad (20)$$

Lipid peroxide radicals appear in result of this reaction. The rate constant of this reaction is 10^7–10^8 mol/L/s, activation energy is close to zero. This means that at oxygen concentrations above 10^{-6} M, all L radicals are converted into $LOO^{\bullet}$ radicals.

The peroxide radical can interact with new molecules of unsaturated fatty acids with the formation of hydroperoxide LOOH and the new radical L• [65].

$$LOO\bullet + LH \rightarrow LOOH + L\bullet \quad (21)$$

This reaction also has low activation energy and high rate constant, which value depends on the type of compound being oxidized.

More and more new LH lipid molecules and molecules of oxygen are involved in the process. As a result, LOOH hydroperoxides are accumulated, but the number of L• and LOO• radicals does not change (the principle of indestructibility of free valence). Although structurally radicals L•, L_1•, L_2•, etc., as well as LO•, LO_1•, LO_2• etc. can differ from each other.

In the presence of metals with variable valence, the process described above acquires a branched type due to the reaction [65]:

$$LOOH + Fe^{2+} \rightarrow LO\bullet + \bullet OH + Fe^{3+} \quad (22)$$

So, new free radicals and ions were produced, and hence new products of peroxidation appeared too. Further course of branched chain processes leads to the formation of new products of lipid oxidation: peroxides, epoxides, acidic compounds, aldehydes and ketones, unsaturated fatty acids, which in excess concentrations cause toxic effect. Oxygenase systems, including cytochrome P-450 play an important role in the inactivation of lipid toxic substances in animals.

According to E.B. Burlakova and co-authors [65], the intensity of free radical lipid peroxidation processes (LPO) is linked with the composition and physical state of phospholipids (their fluidity), with the structure and functions of biological membranes, with their sensitivity to signals and extreme influences. So, POL is extremely important for the regulatory and informational role of membranes in cellular metabolism (in case if it is normal).

The participants of LPO reaction are following [65]. Lipids (unsaturated fatty acids) of biomembranes, biological fluids and molecular oxygen, the resulting lipid peroxidation products (primary, secondary, final). LPO catalysts (stimulators) are active forms of oxygen (free radicals, peroxides) that are formed in living systems as intermediates in number of enzymatic reactions, products of photo- and radiochemical reactions, and free metal ions with variable valence and their molecular complexes. Finally, there are variety of antioxidant mechanisms that provide structural-spatial and biochemical obstacles on the way of lipid peroxidation and breakage of chains of free radical oxidation.

The main indicators of the intensity and dynamics of lipid peroxidation in living systems are the products of lipid peroxidation by themselves. They act also (at least, their primary products) as catalysts for the process, ensuring its self-accelerating autocatalytic process. The second source of information is the state of antioxidant systems — the amount of antioxidants (AO) of different types, the activity of antioxidant enzyme systems [65, 83–103].

LPO products. The primary products of LPO are free oxidative radicals: superoxide, hydroperoxide, and hydroxyl •OH, hydroperoxides, lipid peroxides, epoxides, and diene conjugates. The secondary products of lipid peroxidation are aldehydes, in particular, malondialdehyde (MDA), determined in the reaction with 2-thiobarbituric acid (TBA), as well as gaseous products of oxidative degradation of fatty acids (ethane, pentane); they are formed when double bonds in the carbon chain are broken. The final products of lipid peroxidation are fluorescent products of oxidative co-polymerization of lipids and proteins — Schiff bases (lipofluorescent, lipofuscin pigments), determined by the methods of fluorescence analysis [65].

As a result of observation of complex of all problems associated with the development of LPO in living systems, following provisions were stated [65]:

a) Objective prerequisites for the development of non-enzymatic reactions of free radical oxidation (LPO) exist in all living systems, without exception. They are due to the presence of easily oxidizable organic compounds in their structure (primarily in biomembranes). These compounds can accumulate potential energy in their molecules. Among organic molecules, the most vulnerable to peroxidation reactions are polyene molecules of fatty acids (linoleic, linolenic, and especially arachidonic), which are part of the phospholipids of biological membranes and blood lipoproteins.

b) The presence of free oxygen in the biosphere, its use in the life of plant and especially animal organisms, its presence in biological fluids and extracellular space makes constant contact of oxygen with membrane lipids unpreventable. Therefore, the spheres of LPO reactions are the areas of these contacts.

c) The use of oxygen in such important intracellular processes as biological oxidation and oxidative phosphorylation (the inner membrane of mitochondria), oxidative macrosomal destruction of xenobiotics, presence and functioning of specialized electron transport chains in these organelles, formation of free radical intermediates in process of enzymatic catalysis and due to the existence of natural radiation background are accompanied by the appearance of reactive oxygen species such as radicals and peroxides, which play the role of catalysts and products of non-enzymatic lipid peroxidation. Their presence even in the most negligible quantities ensures that the activation barrier is overcome. This creates conditions for processes of free radical lipid peroxidation reactions, for realizing potential possibilities listed above (a, b).

d) Ions of metals with variable valence (Fe, Cu, Co, Mo, Mn, etc.) can act as branching factors for free radical oxidation chains and, consequently, for general increase of lipid peroxidation.

e) The combination of listed prooxidant factors determines the universal nature, the ubiquitous distribution of LPO processes in all living and actively metabolizing systems. Moreover, the dual role of LPO intermediates, their ability to act also as autooxidation catalysts cause real danger of progress of free radical chain reactions and, as a result, complete destruction of membrane structures, cells and organisms with oxygen access. Only the presence of factors with opposite action, antioxidant systems, keeps the lipid peroxidation process at a stationary basal level, which does not change normal life activity. The resulting prooxidant-antioxidant balance is the most important mechanism of homeostasis.

f) Any significant stress in living system functioning, caused by unusual external agents (in their strength, duration, quality) is accompanied by the increase of oxidative metabolism, an increase of production of reactive oxygen species and activation of lipid peroxidation process, which is able to overcome the AO-protection barrier. Thus, external stress impacts, together with internal prerequisites, act as components of causal complex that determines the development of a wave of LPO activation ("explosion") in living systems.

Exposure to ionizing radiation is the most impressive example of stress effect that causes the activation of free radical lipid peroxidation in the tissues of irradiated organism [65, 103].

Physiological antioxidant system of biological organism under the influence of radiation. All currently existing living organisms have a number of inherited, genetically determined adaptive means of protection against toxic destructive action of free molecular oxygen — this the most universal poison. Means that help to overcome the danger of oxidative destruction of complex organic compounds and biological structures [65, 79, 83–105].

From one side, the oxidative capacity of oxygen is used in animal and human organisms to provide energy and use it for new biosynthesis, to maintain organism temperature, muscle work, oxidative destruction of xenobiotics, harmful microorganisms, etc. The material expression of this way of solution of oxygen problem was the creation of complex membrane-bound enzyme ensembles — the systems of electron transport of mitochondria, the endoplasmic reticulum, the enzyme system of "oxidative explosion" in the membranes of phagocytes, etc.

On the other hand, protection of biological structures from oxygen excess, and, especially, the most vulnerable membrane formations, was solved in Nature, at least partially, by creating specialized enzyme systems — antioxidant enzymes (AO-enzymes), capable of maintaining prooxidant-antioxidant balance in intracellular and intercellular fluids and in lipid structures of membranes. In such a way appear the "order" in organization of molecular consequences and biochemical pathways in living Nature; further it was logically linked with the notion of "information".

It should be emphasized that both problems — biologically necessary utilization of free oxygen and AO–protection from it – are solved in the most closely interconnected way. The first line of cell defense from O_2 toxic effects is to prevent the producing of its active forms. The cytochrome C-oxidase enzyme carries out a four-electron reduction of O_2 to H_2O without formation of active intermediates. The second line of defense is formed by AO-enzyme systems, localized in the cell primarily in the most vulnerable loci — mitochondria and microsomes — organelles that implement the function of electron transport systems. The stationary level of O_2 and H_2O_2 in intact mitochondria changes from 10^{-11} to 10^{-9} mol/L, respectively. AO–enzymes prevent the "leakage" of reactive oxygen species (radicals, HO_2•, and hydrogen peroxide) from actively functioning systems of biological oxidation, preventing the danger of uncontrolled oxidative destruction of biological structures of cells.

AO-enzymes include superoxide dismutase (SOD), which inactivates superoxide radical anion; catalase, which decomposes hydrogen peroxide H_2O_2, as well as enzymes of glutathione system (GSH); glutathione peroxidase (GPO), which decomposes organic (lipid) peroxides (along with H_2O_2); glutathione reductase (GR), which reduces glutathione oxidized during enzymatic (GPO) and non-enzymatic reactions, as well as family of glutathione transferases (GT), which alkylate by glutathione various toxic metabolites and xenobiotics. Finally, to AO-enzymes the ceruloplasmin belongs (main AO-enzyme of the blood), as well as transferrin (with some restrictions).

Superoxide dismutase (SOD) catalyzes the reaction:

$$O_{2^-} + O_{2^-} + 2H^+ \rightarrow O_2 + H_2O_2 \quad (23)$$

As result of the reaction, hydrogen peroxide is formed, which is capable to inactivate SOD. Therefore, SOD is localized and usually functions in collaboration with catalase, which quickly and efficiently decomposes H_2O_2. The rate of superoxide dismutase reaction is very high; the second-order rate constant reaches $2{\times}10^9$ $mol^{-1}s^{-1}$ [65]. The active center of the enzyme contains metal atoms with variable valence.

Mn-SOD of mitochondria and Cu, Zn-SOD of the cytosol are the most important AO-enzymes that inactivate the superoxide radical and, accordingly, reduce the overall toxic effect of oxygen and its active forms.

Catalase is a hemeprotein that catalyzes the reaction:

$$H_2O_2 + H_2O_2 \rightarrow O_2 + 2H_2O \quad (24)$$

AO-enzymes SOD and catalase, functioning together, in the most cases timely inactivate reactive oxygen species (ROS), O_{2^-}, H_2O_2, which are formed both during normal cell activity and under conditions of significant LPO activation, including pathologically conditioned. However, LPO activation develops most effectively in the lipid (phospholipid) structures of biomembranes and is accompanied by the formation of lipid peroxides, which only slightly can be eliminated by SOD-catalase system.

Glutathione peroxidase (GPO) — is a selenoprotein. It is possible that, at least in human serum, GPO is present as selenoglycoprotein. The GPO molecule has a molecular weight of about 74 kDa and consists of four identical subunits. GPO neutralizes not only H_2O_2, but also organic peroxides (including lipid peroxides), formed in organism during the activation of lipid peroxidation [65].

Glutathione transferase (GT) is a whole family of enzymes with polyfunctional activity that mainly detoxifies various xenobiotics, including peroxides. E- and S-GT destroy organic (lipid) peroxides. GT unites at least 11 isoforms (A, B, C, etc.) [65].

The origin of antioxidant enzymes was probably the oldest protective system. The archaic origin of this mechanism can be confirmed due to the discovery of AO-enzymes or their simpler analogues in all living organisms in contemporary World. Each of them is aimed specifically at eliminating one of the dangerous initiators of LPO or its products [65].

Methods of medical treatment and rehabilitation of patients irradiated in Chernobyl zone basing on the results of hypoxia studies at EMBS NASU. The pathological states we observed in this article, associated with the action of various types of radiation effects on organism and the role of oxygen in these phenomena, just were within the competence of scientists and doctors who worked at the Elbrus Medical And Biological Station (EMBS NASU) [3, 63–65]. A great contribution to these works was made by Prof. Komisarenko S.V. [104, 105].

These groups of professionals specialized in the development of new methods of treatment and rehabilitation of persons who received various doses of radiation during the accident at the Chernobyl nuclear power station in 1986. Among them, there were representatives of the civil population “chernobyltsy”, as well as people who worked for the liquidation of the accident consequences “liquidators”.

At EMBS the concept of gradual adaptation to hypoxybaria, oxygen regimes of organism and their regulation, and functional respiratory system were proposed and substantiated; consequently, a number of mathematical models were elaborated. This made it possible to characterize different types of hypoxic states not only qualitatively, but also quantitatively, to estimate their degrees, to predict changes in the state of organism under the influence of extreme factors, to analyze the role of certain physiological reactions in compensation of oxygen deficiency, and to transform the science of hypoxia from experimental-descriptive sphere to an exact one. Research conducted at EMBS revealed the destructive (pathogenic) and constructive (cyanogenic) mechanisms of development of hypoxic conditions in organism, allowed for the first time in world practice to justify and develop new highly effective methods of treatment, prevention, rehabilitation, increasing the organism’s stability and performance — hypoxytherapy. Hypoxytherapy can be implemented in mountain conditions, pressure chambers or using various hypoxicators. Hypoxytherapy methods are widely used today in spa medicine, cardiology, pulmonology, neurology, psychiatry, pediatrics, gynecology, aviation and space medicine, and training of athletes.

On the basis of many years of research, the “Elbrus” classification of hypoxic conditions was created [65], the terminology in this field is formulated, which is widely used by contemporary researchers.

New highly effective methods for medical treatment and rehabilitation of patients irradiated during nuclear accident in Chernobyl. If to speak about the new highly effective methods for medical treatment and rehabilitation of patients irradiated during nuclear accident in Chernobyl (1986), that were developed at scientific base EMBS in Caucasus it is necessary to remember following data. Among such methods there were the following: gradual adaptation to high-altitude conditions, training in pressure chambers, inhalation of gas mixtures with low oxygen content, and the effect of intermittent hypoxia. These methods are successfully used in numerous medical institutions, hospitals, and sports centers in different countries.

For the first time, the method of gradual adaptation to low pO_2 in inhaled air was used in a pressure chamber for the treatment of patients with bronchial asthma, and later – children with whooping cough. In mountain conditions, the method of gradual adaptation was initially used to treat patients with some mental illnesses (catatonic form of schizophrenia), bronchial asthma, and chronic non-specific lung diseases [65]. Subsequently, for the treatment of patients by methods of adaptation to hypoxybaria at EMBS at altitude of 2100 m a.s.l. special inpatient department was organized for the recovery of patients from areas with ecologically unfavorable conditions — town Shevchenko (Kazakhstan) and town Chornobyl (Ukraine).

The methods of medical treatment using adaptation to hypoxic environment in Elbrus were successful for many patients with various diseases. There are: respiratory allergies, anemia, hypertension, diabetes, coronary heart disease, arrhythmias, neurodystonic and "post-Chernobyl" syndromes, for girls with juvenile dysfunctional disorders etc. [65]. In the process of medical treatment, doctors deeply studied the peculiarities of the genesis of hypoxic conditions, the mechanisms of sanogenesis. Important work for the treatment of people injured during the Chernobyl accident and the liquidators of the consequences of this accident began immediately after the accident in May 1986. As a result, the symptoms of the liquidators' diseases were determined, as well as the characteristics of radiation-induced diseases of children from Chernobyl zone.

At EMBS, it was shown that in the genesis of the "Chernobyl syndrome" polyfunctional disorders in the systems of oxygen transport and utilization, which led to the development of hypoxic conditions, are of primary importance. The clinical picture of vegetative-vascular dystonias, anemias, respiratory allergies, dyscirculatory encephalopathies etc manifested these conditions.

In the process of adaptation to the mountain conditions, in process of usage of developed methods of medical treatment, people irradiated in Chernobyl nuclear accident demonstrated following positive results [65]:

– the psycho-emotional state and regulation of vegetative functions, indicators of functional mobility and dynamism of nervous processes were improved;

– indicators of breathing, hemodynamics, immune status of blood, heart rate and its electrical activity were normalized;

– degenerative changes in blood cells decreased;

– regeneration processes were activated;

– aerobic and anaerobic enzymes in tissues;

– oxygen content in arterial blood increased;

– activities of succinate dehydrogenase and creatine phosphatase were changed in positive for organism directions;

– increased lysosomal activity of white blood cells;

– increased DNA synthesis;

– the economization of oxygen transport systems took place.

So, in patients with listed disorders, "mountain-treatment" or "mountain-therapy" caused general condition and well-being improvements, increase in the adaptation reserve, transition to a new level of regulation, so on.

Conclusions

In present article the impacts of cosmic radiation on atoms and molecules in the Earth's atmosphere were analyzed.

1. The results of exploring of various characteristics of the Earth atmosphere gases content at different altitudes above the Earth were suggested. The data obtained during the atmosphere exploring by satellite were presented. Concentrations of the gases starting from the ionosphere to the Earth surface were revealed and described.

2. Further, the chains of interconnected natural phenomena were examined subsequently. Phenomena of solar radiation influence on atoms, molecules and molecular complexes in the Earth's atmosphere were observed (including photochemical processes, photoionization). Transformation of atoms and molecules of gases in high-altitude atmospheric conditions were described. Some other natural phenomena that effect on the structure of atoms, molecules and molecular complexes in the Earth atmosphere were observed.

3. Along with this, some information aspects of the organization of substances at the height of the ionosphere and near the Earth's surface were considered.

4. The most attention was concentrated on the studies of oxygen concentrations at different altitudes, transformations of oxygen molecules in ionosphere, lower levels of atmosphere and linked with these effects developments of hypoxic states in human organisms.

5. As a result, some damages of respiration effects in biological organisms and development of oxygen deficiency (hypoxic) states in them were examined.

6. Some recommendations of the ways of possible correction of developed hypoxic states and some other pathological states linked with cosmic radiation influences were suggested. Described studies of oxygen deficiency in

organisms (hypoxic states) were demonstrated on the results of the groups of Ukrainian scientists who worked in high mountain conditions at EMBS — scientific base of the National Academy of Sciences of Ukraine.

Some data of hypoxic pathological states studies were presented as well as some ways of their corrections. On the base of these studies practical recommendations for patients' medical treatment and rehabilitation were done. Some conclusions made on the basis of works on the rehabilitation of the people that were exposed to the consequences of the Chernobyl accident "chernobyltsy" as well as ones who liquidated consequences of accident "liquidators" since 1986. The obtained results can be spread on the treatment and rehabilitation of the people from other contingents of radiation risk.

General complete conclusions of such studies with recommendations were published. There are only a few in brief list below.

1. The symptoms of liquidators disorders were studied and described at EMBS. Radiation-caused morbidity of the children from the "4th radiation zone" was determined concerning different disorders: gastrointestinal — 78.6%, respiratory — 58.9%, thyroid gland — 57.1%, vegetative-vascular dystonia — 19%.

2. Disorders in oxygen transport system and oxygen utilization system caused hypoxic states development in irradiated people; and these disorders were primary for further development of "Chernobyl syndrome". Consequently, hypoxic states were developed in irradiated people in the result of anemias, vegetative-vascular dystonias, dyscirculatory encephalopathies, respiratory allergies etc.

3. Ten criteria of organism state were defined at EMBS: efficiency of processes of oxygen transport and utilization, organism's oxygen balance, degree of progressive action of hypoxia, physical and mental capacity, adaptability and level of adaptation, and etc. These criteria were defined as the most informative criteria for the estimation of "mountain-therapy" or "mountain-treatment" [62].

4. At EMBS there were registered that persons, which chronically obtained small doses of radiation, the organism's reserve capacities were reduced. There are: indicators of oxygen consumption, efficiency of oxygen transport systems, and activity of respiratory enzymes responsible for urgent adaptation.

The methods that were called at EMBS "mountain-therapy" or "mountain-treatment" of rehabilitation/treatment of the persons from radiation risk contingents were found as very effective. Their effectiveness was based on the adaptation to the mountains natural conditions (in Ukraine they can be Carpathians now, or mountains in other countries). Treatments, rehabilitation using hypoxia simulation were also effective; there were methods of hypoxytherapy (normobaric, hypobaric, hypercapnic, pulsed, periodic hypoxia, interval), as well as hypoxic states, simulated in the conditions of hypoxicator, barochamber, inhalation of hypoxic mixtures, and etc.). These methods, as well as hypobaric or normobaric interval hypoxia were effective in the replacement of the stepwise mountain adaptation. The Ukrainian sciantists suggested the most effective rehabilitation complex in which, together with "mountaintherapy", were united diet, phytotherapy, thermobarotherapy, developed complexes of breathing and physical exercises, intake of silicon waters, bromine-iodine waters, sulfate and dolomite natural waters, and etc.

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ДОСЛІДЖЕННЯ РАДІАЦІЇ ТА ГІПОКСІЇ: ВПЛИВ ВИСОКОЕНЕРГЕТИЧНИХ ЧАСТИНОК АТМОСФЕРИ НА БІОЛОГІЧНІ ОРГАНІЗМИ ТА МОЖЛИВОСТІ ЇХ РЕАБІЛІТАЦІЇ

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Розглянуто вплив космічного випромінювання на атоми та молекули газів земної атмосфери з подальшим ланцюгами їхніх перетворень, а також розвиток відповідних станів дефіциту кисню (гіпоксії) у біологічних організмах, рекомендовано шляхи корекції таких порушень.

Метою роботи було дослідити радіаційні ефекти в іоносфері з подальшим перетворенням атомів, молекул газів на різних висотах над поверхнею Землі; взаємодії деяких високоенергетичних частинок атмосфери з біологічними об᾽єктами на висотах від поверхні Землі до 5500 м над рівнем моря (н.р.м.), а також роль кисню в наслідок опромінення біологічних організмів.

Методи. Аналіз результатів супутникових і ракетних спостережень газів земної атмосфери на різних висотах над рівнем моря. Дослідження в гірських умовах на науково-дослідницькій станції ЕМБС НАН України: порівняльний аналіз результатів багаторічного спостереження за хворими з використанням стандартних лабораторних методів, комплекс методичних прийомів: клінічні, фізіологічні дослідження дихальної, серцево-судинної систем; гематологічних, імунологічних станів; функціональний стан вищої нервової діяльності, психічний і невротичний стан; застосування антигіпоксантів, гістохімічні, біофізичні методи, математичне моделювання та інші.

Результати. Представлено дані, отримані під час дослідження атмосфери супутниками: вплив на структуру атомів, молекул в атмосфері, концентрації газів від іоносфери до поверхні Землі, описані такі явища, як фотохімічні процеси, фотоіонізація. Обговорюється поняття «інформація» на основі феноменів, описаних у статті. Описано вплив модифікації частинок газів та виникнення у зв'язку з цим кисневої недостатності в організмах (гіпоксичний стан). Проаналізовано результати реабілітації осіб, опромінених унаслідок Чорнобильської аварії (із отриманням низьких доз радіації) українськими лікарями та науковцями в гірських умовах і подано відповідні рекомендації.

Висновки. Розглянуто вплив сонячної радіації на атоми, молекули та молекулярні комплекси в атмосфері Землі. Досліджено вплив концентрації газів на різних висотах та роль кисню при опроміненні організмів. Надано практичні рекомендації щодо лікування та реабілітації опромінених пацієнтів.

Ключові слова: радіаційне ураження організмів; гіпоксія; великі висоти; високо-енергетичні частинки.