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RADIATION BIOECOLOGY AND THERAPY TAKING INTO ACCAUNT THE AUGER EFFECT

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Abstract

A characteristic feature of the living organism's environment is the presence of virtually 100% chemical elements with a nuclear charge z of less than 10. This means that when exposed to radiation from an external source with any high-energy particles, this irradiation, in up to 99.9% of cases, causes the Auger effect in the near-surface zone of the target. This necessitates the introduction of a new class of particles in the living organism—internally generated multiply charged ions with a positive charge of two or more. Previously, this class of particles was not considered or accounted for as a biomedical factor. The radiation therapy protocol must apparently also take into account that the average actual time for tumor volume to double is 90-100 days, which means that the main part of the preclinical phase of its growth is formed over the course of seven to ten years. The physicist is forced to further restrict his subject matter, contenting himself with depicting the simplest phenomena accessible to our experience, whereas all complex phenomena cannot be recreated by the human mind with the precision and consistency required by the theoretical physicist. Higher accuracy, clarity, and certainty come at the expense of completeness (A. Einstein).

Keywords: *double- and third-charged ions, near-surface phenomena in the body, Physics and Reality of A. Einstein, radiation therapy Protocol, composite materials in protective coatings*

Introduction

A distinctive feature of the biomedical environment is the presence of virtually 100% chemical elements with a nuclear charge z of less than 10. This means that the main atomic and molecular components contain C, N, and O atoms. Therefore, when exposed to radiation from an external source with any high-energy particles—X-ray quanta, neutral atoms and molecules, and their ions of any charge—in over 99% of cases, this radiation is transformed in the near-surface zone of the target into a special nonradiative process, widely known to physicists and chemists: the Auger effect. "The physicist is forced to further restrict his subject matter, contenting himself with depicting the simplest phenomena accessible to our experience, whereas all complex phenomena

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cannot be recreated by the human mind with the precision and consistency required by the theoretical physicist. Higher accuracy, clarity, and certainty come at the expense of completeness" [1] and [2].

1. The Role of the Auger Effect in the Problem of "Physics for Life Sciences"

The Auger effect, observed since 1924, is the appearance, after ionization of an internal electron in the above-mentioned chemical elements, of a free Auger electron instead of a quantum of characteristic X-ray radiation. The energy of such electrons for carbon, nitrogen, and oxygen, including those in molecules such as water, varies little with phase composition and is completely independent of the type of incident particle. This is the basis for Auger spectroscopy for determining the chemical composition of a target substance (ESCA). In addition to the appearance of free electrons in the near-surface zone, positive ions of the taget substance are formed. In the body, these are primarily not atoms or radicals, but molecules with a charge multiplicity of two, and up to 30% are three or more. The mechanism for the appearance of multiply charged ions is associated with two processes associated with the Auger effect: the shake-off phenomenon and the existence of double Auger transitions with the simultaneous emission of two electrons. All these aspects were first considered in applications to aeronomy in [3, 4], including in assessing the degree of disturbance to the Earth's ionosphere during high-altitude nuclear tests (including the Starfish nuclear test in the Indian Ocean at an altitude of 400 km.). Given the importance of the Auger process in toxicology, it was considered twice in the early 1970s under the auspices of the IAEA. The range of experimental effects discussed was extremely broad: from the Auger effect during the isotropic radioactive decay of iodine I^{125} during the capture of an internal electron (from the K-shell) in biological elements (Biological toxicity associated with the Auger effect, 1971), to low-energy electron microdosimetry (Biophysical aspects of radiation quality, 1971), which is particularly important in the "Physics for Life Sciences" problem due to its detailed description of the radiolysis of various biological products. The physicist is forced to further restrict his subject matter, contenting himself with depicting the simplest phenomena accessible to our experience, whereas all complex phenomena cannot be recreated by the human mind with the precision and consistency required by the theoretical physicist. Higher accuracy, clarity, and certainty come at the expense of completeness.

In [**5**], the role of the Auger effect in the capture of an internal electron during isotopic decay is considered using the example of radioactive iodine "with the formation of a large electric charge (~ 18+) through the Auger process, which has even been called a 'molecular explosion' of chemical nature, which can increase the biological effect predicted on the basis of the absorbed dose by many times (10-20 times)." Incidentally, this is also a near-surface phenomenon, since the Auger electron formed in the aqueous medium of the body (with an energy of 0.5 keV) has a range of 25 nm. All this confirms the need to pay attention to a number of points when studying the contribution of the Auger effect specifically to processes in a living organism. The pioneering work here is, apparently, the information on the discussion of the report of A.E.S. Green in connection with the publication: [6] p. 483, while to the question (B.B. Singh): "will these results be valid not only for a water molecule in the gas phase, but what will happen for a solution of interest in biology?" followed the following answer from A.E.S. Green [6]: "Probably, in the process of excitation of a water molecule, which requires 7.5 eV, the phase state will not play a role since intermolecular interactions involve much lower energies."

We believe this is correct, at least for Rydberg electron excitation in molecules with closely spaced levels, the transitions between which occur in the microwave range, which is important in our considerations, including given the increasing anthropogenic impact of cellular communications. In [6], the dissipation of secondary electrons formed under the influence of various primary particles: X-rays, electrons, protons, etc., was considered. The local spatial and energy distribution of these electrons plays an important role in the action of the initial radiation. Data on various processes for water were considered (using the Born approximation of cross sections). These initial cross sections were then used to estimate the fraction of initial particles that determine the role of both primary and secondary and tertiary electrons in excitation, ionization, and dissociation. The results were used to estimate the contribution of various radiolysis products in biology and chemistry. Water has two known ionization potentials: 12.62 and 16.64 eV, and four discrete excitation levels: 7.4; 10.1; 11.0, and 13.3 eV. The 10.1 eV peak also includes vibrational levels of two low-lying Rydberg series, as does the 11.0 eV peak, with an estimated contribution from the high vibrational levels of Rydberg states. The Auger effect for chemical elements with z less than ~20 also dominates in solids, which is important to keep in mind in aeronautics, including studies of the degradation of structural composite materials. In our analysis, for the benefit of living systems, the possible contribution of this same effect to the formation of phenomena in protective coatings necessary for living things is important. Thus, our research suggests paying attention to the specific features of radiology, including therapy, associated with the need to take into account a process widely known in physics and chemistry: the Auger effect. This will enable the identification of real patterns under external influences in all practical situations, including experimental modeling, and will also serve the interests of the life sciences by enabling:

- determining the actual paths of irradiating fluxes in the biological environment, which effectively transfers the entire process of primary radiation exposure to the near-surface zone;

- introducing a new class of particles in living organisms – internally generated multiply charged ions with a positive charge of two or more, which had previously been simply not considered or accounted for as a biomedical factor.

2. Microwave Radiation in the Environment: Analysis of Sources.

2.1. Modern trends in the life sciences, with advances in mobile communications, taking into account the phenomenon of stochastic resonance.

The microwave range includes radiation with wavelengths from 1 mm (300 GHz – Extremely High Frequency (EHF)) to 1 m (0.3 GHz – Ultra High Frequency (UHF)), with an intermediate microwave range: frequencies from 3 to 30 GHz with a wavelength of (10 - 1 cm) – Super High Frequency (SHF). It should be noted that our report [7] already took into account the potential for microwave radiation generation by all the main components of the upper atmosphere: atomic oxygen, molecular nitrogen, and oxygen.

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It has been determined that microwave radio emissions of the oxygen atom, taking into account the selection rules for forbidden quantum electric dipole transitions (including Rydberg ones), are realized: in dm radio emissions: $\Delta n = 0$ at $n = 20$-40; in cm radio emissions:: $\Delta n = 1$ for $n= 10$-20, or for $l = -1$ and $n = 10$-20; and in mm radio emissions: $n > 1$ for $\Delta n > 1$, and at $\Delta n > 1$ at $n > 10$. For N_2 and O_2, all microwave emissions are realized for $n \geq 3$. It should be noted that as early as [8] an analysis of the causes of the experimentally discovered heating biological effect of microwaves was carried out, and the trigger effect with the subsequent excitation of collective chemical processes was also discussed. However, this approach was not continued, which is understandable in light of the development of supramolecular physics of Rydberg excited polyatomic molecules with high proton affinity: [9], p. 457. In this article, which is programmatic for our consideration, the entire mechanism of formation of "polyatomic Rydberg molecules" [10], which forms the basis of supramolecular physics, is briefly presented: "The reason why the Rydberg states of H_3 are stable obviously lies in the high stability of H_3^+ (or, in other words, in the high proton affinity of the H_2 molecule), which ensures that all Rydberg states of H_3 lie well below the energies of all excited states of the dissociation products of $H+H_2$ (p. 1248). It seems reasonable to expect that other molecules, say X, with high proton affinity will also give stable Rydberg states of the corresponding neutral species XH. Examples include H_2O, NH_3, and CH_4, all of which yield very stable ions when a proton is added. Thus, it seems possible that Rydberg spectra of H_3O, NH_4, and CH_5 will eventually be observed". Equally important is the work of [11], which examines the mechanism for signal amplification at the carrier frequency in the presence of a background flux over a wide frequency range. In our case, this could be an anthropogenic mobile phone signal superimposed on the ionospheric microwave spectrum. Here are the conclusions from [11]:

1) Stochastic resonance is a phenomenon in which, under certain conditions (in multistable or bistable systems), an increase in operating noise leads to more orderly behavior of the system.

2) This is a cooperative effect in which noise energy, distributed over a wide spectrum, is converted into output energy at the signal frequency, including anthropogenic ones.

3) The existence of stochastic resonance represents, at the very least, a general philosophical objection to skepticism regarding the possibility of the influence of weak electromagnetic waves on living systems. It should be noted that, in connection with the ever-increasing anthropogenic flux of microwaves (for several decades now, tenfold every 15 years ([12], p. 270)) the contribution of the stochastic resonance effect to microwave pollution of the environment is becoming increasingly significant! In Russian environmental science, the unity of model interpretation in various scientific fields is recognized, including from the point of view of the similarity theory developed by G.S. Golitsyn [13]. This makes it possible to achieve convincing results in the field of analysis of the statistical laws of nature. In accordance with them, "on a large scale, the universe tends to arrange itself according to general laws" [14], in Russian environmental science.

2.2. *Consideration of the "Biophysical Aspects of Radiation Quality" problem in the approaches of the IAEA (Vienna, 1971).*

Given the importance of the Auger process in toxicology, it was considered twice in the early 1970s under the auspices of the IAEA. The range of experimental effects discussed was extremely broad: from the Auger effect during the isotropic radioactive decay of iodine I^{125} during the capture of an internal electron (from the K-shell) in biological elements (Biological toxicity associated with the Auger effect, 1971), to low-energy electron microdosimetry (Biophysical aspects of radiation quality, 1971), which is particularly important in the "Physics for Life Sciences" problem due to its detailed description of the radiolysis of various biological products.

We believe this is correct, at least for Rydberg electron excitation in molecules with closely spaced levels, the transitions between which occur in the microwave range, which is important in our considerations, including given the increasing anthropogenic impact of cellular communications. In [6], the dissipation of secondary electrons formed under the influence of various primary particles: X-rays, electrons, protons, etc., was considered. The local spatial and energy distribution of these electrons plays an important role in the action of the initial radiation. Data on various processes for water were considered (using the Born approximation of cross sections). These initial cross sections were then used to estimate the fraction of initial particles that determine the role of both primary and secondary and tertiary electrons in excitation, ionization, and dissociation. The results were used to estimate the contribution of various radiolysis products in biology and chemistry. Water has two known ionization potentials: 12.62 and 16.64 eV, and four discrete excitation levels: 7.4; 10.1; 11.0, and 13.3 eV. The 10.1 eV peak also includes vibrational levels of two low-lying Rydberg series, as does the 11.0 eV peak, with an estimated contribution from the high vibrational levels of Rydberg states.

2.3. *Specific features in Radiation Therapy Protocols considering the Auger effect.*

The Auger effect for chemical elements with z less than ~20 also dominates in solids, which is important to keep in mind in aeronautics, including studies of the degradation of structural composite materials. In our analysis, for the benefit of living systems, the possible contribution of this same effect to the formation of phenomena in protective coatings necessary for living things is important. Thus, our research suggests paying attention to the specific features of radiology, including therapy, associated with the need to take into account a process widely known in physics and chemistry: the Auger effect. This will enable the identification of real patterns under external influences in all practical situations, including experimental modeling, and will also serve the interests of the life sciences by enabling:

- determining the actual paths of irradiating fluxes in the biological environment, which effectively transfers the entire process of primary radiation exposure to the near-surface zone; - introducing a new class of particles in living organisms – internally generated multiply charged ions with a positive charge of two or more, which had previously been simply not considered or accounted for as a biomedical factor.

3. Microwave Radiation in the Environment: Analysis of the Flow Parameters

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3.1. *Pioneering studies of the role of Auger effect in the Earth's ionosphere*

Fifteen years before our publications (which presented pioneering results on the truly decisive role of Auger processes in radiation, including microwave radiation, in the Earth's ionosphere), scientific team from India made the first attempt to estimate the possible contribution of the Auger effect to the total ion formation rate at altitudes of 100-125 km [15]. This was the FIRST ATTEMPT to formulate the problem correctly, but at that time the necessary information about the parameters of Auger processes in upper-atmospheric gases was ABSENT. In addition, the values used were overestimated, compared to those generally accepted today, for the density of ionospheric atomic oxygen with the cross-sections of absorption of solar X-ray radiation of about 3 nm taken in this model, which mainly determine the contribution of the Auger effect at the altitudes of the E-region of the ionosphere. Fifteen years before our publications (which included pioneering results on the truly decisive role of Auger processes in radiation, including microwave radiation, in the Earth's ionosphere), scientists from India made the first attempt to estimate the possible contribution of the Auger effect to the total ion formation rate at altitudes of 100-125 km In this article [15] on page 522, Table III, in the last line, total it is directly stated that "Ionization by Auger effect" is greatly underestimated – in the ratio: 10^7 to 2.4×10^8.

The first measurements of such cross-sections were carried out in [16] and we used them to interpret the first high-altitude nuclear test at an altitude of 400 km, Starfish, in the Indian Ocean. This is the subject of our publication [3].

Issues of importance for radiation ecology following the 2005 Chernobyl disaster were discussed at a Joint Meeting of the Presidiums of the Russian Academy of Sciences and the National Academy of Science of Ukraine within the Ukrainian Education and Science Days in the Russian Federation [17], p. 1129, based on the scientific report of Academician of the National Academy of Sciences of Ukraine D.M. Grodzinsky on the radiobiological and radioecological consequences of the Chernobyl disaster: the main results over 25 years. Studies on model objects—molecular biological or cytological systems not exposed to factors other than radiation—have yielded surprising results: 1. The effects of external and internal irradiation are characterized by relatively different biological effectiveness. Specifically, internal irradiation, which is caused by the accumulation of radionuclides in the tissues of various organs in humans and animals, is more powerful than external irradiation from gamma radiation sources. This phenomenon, confirmed by numerous experiments, can be entirely linked to our proposed role in radiation ecology of the Auger effect, where the entire process is transferred to a narrow near-surface zone (the depth of which is determined by the short range of the Auger electron), and the actual impact of gamma radiation simply no longer exists! 2. The difference between chronic external irradiation with increased activity should also be linked to the contribution of the Auger effect, since all this irradiation exerts its effects within a very narrow zone due to the short range of Auger electrons in a living organism! In the same publication [17], pp. 1129-1132, Corresponding Member of the Russian Academy of Sciences L.A. Bolshov presented a report based on a study of the consequences of the accident at the Fukushima-1 Nuclear Power Plant in Japan. Here we must recall that the radioactivity of water should be associated only with the characteristic X-ray (0.2 nm) radiation of tritium, accompanied by an Auger electron with an energy of about 500 eV. Thus, the initially identified consequences of radioactive contamination turned out to be quite limited, given such (in the theory) an energetically insignificant influence on living things. Thus, an analysis of the role of the Auger effect in radiation ecology showed that its contribution in most cases facilitates the existence of a living system, although it also introduces very insufficiently studied effects into its near-surface zone.

For the first time, within the framework of the specialized Symposium on Solar-Terrestrial Physics in Sao Paulo, held under the auspices of the International Session of COSPAR (Brasili'a), we published a report on the role of the Auger effect in the Physics of Solar-Terrestrial Relations as applied to the Earth's ionosphere [18]. It should be emphasized that Pierre Auger himself understood, very correctly and broadly, the full importance of what he had discovered experimentally in 1924 in the laboratory, in a Wilson chamber, having extended his research on the contribution of the Auger shower phenomenon to the "upper layers of the Earth's atmosphere" [19]. Taking into account P. Auger's possible interest in the higher layers of the atmosphere, including the Earth's ionosphere, at the end of 1992 we addressed an information letter to him, who was then serving as Chairman of the French Atomic Energy Commission. The letter was prepared with the support of the Club of St. Petersburg Scientists at the French Consulate at the S.I. Vavilov State Optical Institute (GOI) by research associate M.S. Kartasheva and presented in P. Auger's Paris apartment to Doctor of Physics and Mathematics T.A. Vartanyan, also an employee of the All-Russian Sci. Center GOI at that time.

Thus, our research [20] calls attention to the specific features of radiology, including therapy, associated with the need to take into account a process widely known in physics and chemistry—the Auger effect. This will allow us to identify real patterns under external influences in all practical situations, including experimental modeling, and will also serve the interests of the life sciences, enabling us to: - determine the actual paths of irradiating fluxes in the biological environment, which effectively transfers the entire process of primary radiation exposure to the near-surface zone; - introduce a new class of particles in living organisms—internally generated multiply charged ions with a positive charge of two or more, which had previously been simply not considered or accounted for as a biomedical factor.

The authors' publication [21] in Acta Astronautica, allows us to conclude that there are no safety issues in either orbital or future interplanetary manned flights!

3.2. *Supramolecular mechanisms in chemistry and physics and microwave radiation of the environment in electron transitions between Rydberg states.*

In [22], and in the Japanese Journal in December 2025 [23], our pioneering proposals for incorporating Rydberg excitation and associated microwave transitions into modern supramolecular physics were published. This was presented in a report at the specialized International Symposium on the Physics of Solar-Terrestrial Relations in Alma-Ata, Kazakhstan, in October 1994 [24]. It is important to note that we based our work on the unique approach within supramolecular chemistry, previously developed by Nobel laureate J.-M. Lehn. In his monograph [25], he emphasized that the influence of space on living systems can be taken into account through the use of Rydberg states, as well as proton transfer: "Proton transfer is of fundamental importance in

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the bioenergetics of a living organism, directing the processes of transport and the synthesis of ATP – adenosine triphosphate acid – the supplier of chemical energy for biochemical and physiological processes in the body."

It should also be emphasized that progressive scientific views have now noted the following positive dynamics in their understanding of the unique phenomena observed at the sites of the Chernobyl disaster, as well as in the zone of the destroyed wall between East and West Germany: - in the Chernobyl exclusion zone, there is a clear absence of visible factors of initial contamination; - in the former strip near the Wall, there is no noticeable ecological disturbance to vegetation.

In [26], Nobel Laureate A. Szent-Gyorgyi actually foresaw our approach through supramolecular physics: "The concept of charge transfer brings into play excited levels previously thought inaccessible, since the usual energy required to raise an electron to a high Rydberg excited level of the molecule to which it belongs is too high." At the same time, the possibility of a contribution from the "massiveness of the reacting molecules, which favors charge transfer," was discussed. So, our supramolecular physics, which allows the Rydberg electron to immediately appear at an energy level of ~ 10 eV, both in the Rydberg molecule – water associate, and in biomaterials, turns out to be important, *including oncology*., possibly manifesting neoplasms in the skin.

In [27], page 96: "The need for metastatic disease prevention at the earliest stages of treatment has been substantiated.", and also page 15: From the mathematical model of carcinogenesis, it follows: "...the average actual tumor volume doubling time is 90-100 days. Thus, for a tumor to reach a size of 1 cm^3 and a mass of 10^9 cells (which is the tumor volume diagnosed by an oncologist in most cases), its constituent cells must undergo more than 30 doublings. This means that the majority of the "natural growth history" of epithelial malignancy... (when the tumor size is less than 1 mm^3) is asymptomatic and hidden from both the host and the physician, and takes an average of 7-10 years to develop."

Conclusion

Thus, our research suggests paying attention to the specific aspects of radiology, including therapy, associated with the need to take the Auger effect into account. This will allow us to identify real patterns of external exposure in all practical situations, including experimental modeling, primarily for the life sciences:

- determine the actual paths of irradiating fluxes in the biological environment, which effectively transfers the entire process of primary radiation exposure to the near-surface zone;

- introduce a new class of particles into living organisms: internally generated multiply charged ions with two or more positive charges, which previously had simply not been considered or accounted for as a biomedical factor.

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APPENDIX

Table. Lists virtually all the parameters for the main composition of products and fragments of metabolism and fermentation in the human gastrointestinal tract [**28**].

Gas	Gas En, nm [**29, 30**]	ω, percent [**31**]	ΔE_0, eV	References
O	2,3	0,69	474-509	[**32**]
O_2	2,3	0,69	456-507	[**33**]
N_2	3,1	0,43	315-367	[**33**]
CO	4,4 (C)	0,26 (C)	221-256	[**33**]
	2,3 (O)	0,69 (O)	437-502	
CO_2	4,4 (C)	0,26 (C)	223-260	[**33**]
	2,3 (O)	0,69 (O)	467-508	
H_2O	2,3	0,69	448-501	[**33**]
HCl	6,15 (L-edge)	0,12 (L)	162-174	[**34**]
	0,44 (K-edge)	9,89 (K)	2249-2391	
CH_4	4,4	0,26	229-250	[**35**, **36**]
NH_3	3,1	0,43	325-373	[**35**]

The following notations are introduced here: K- and L-absorption edges (En), fluorescence yields per atom (ω) and Auger electron energies (ΔE_0) in atmospheric gases.

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