Study of magnetic and gamma radiation influence on bacterial cultures' vital activity

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ABSTRACT. The vital activity of various bacteria was investigated under exposure to magnetic radiation and influence of the latter on their activity. The magnetic radiation magnitude determined by a degree of radiation accumulation in the studied biological media was evaluated by the magnetic susceptibility method. A correlation was obtained between the relative change of magnetic susceptibility of exposed nutrient media and the bacteria fissiparity rate in those media. In addition to magnetic radiation, the paper studies the action on microorganisms of small doses of ionizing radiation.

Keywords: magnetic radiation, nutrient medium, magnetic susceptibility, bacteria, gamma-rays, radiation dose, hormesis.

Introduction

The contemporaneous mankind lives in the era of computers, electronic devices, mobile communication and other radio equipment. These devices are emitting electromagnetic radiation. The interaction of this radiation with the substances are the target of very long-lasting and multilateral studies. The urgency of the study of electromagnetic radiation influence onto living organisms cannot be overemphasized due to its importance for all mankind on a global scale.

A new form of radiation was recently discovered; it was observed in experiments of small metal wires electric blasting in a liquid [1]. Initially authors called this phenomenon a "strange radiation". This radiation was observed on nuclear emulsions and both the form and length of macrotracks (track length greater than 1 mm) made it possible to speak about a new form of high-energy radiation.

Further experiments demonstrated that the nature of this radiation has a pure magnetic character and consists of two components (the term “strange” was later replaced by “magnetic”) which can be described as light magnetic monopoles whose quantum equations have been given by G. Lochak [2] as will be further explained in section 2.

In discovering any new phenomenon (which in our case is a form of radiation) the influence of such a radiation onto biological objects represents a specific interest. Experimental investigation of the magnetic radiation’s effect onto biological systems like mice were carried out by Ye.A. Pryakhin (Ural Scientific-practical Center if Radiation Medicine) in collaboration with L.I. Urutskoev on the base of the Atomic Energy Institute named after I.V. Kurchatov (Moscow) [2]. The main results of the work are that, after acting on them with magnetic radiation the following effects were observed: an increase of efficiency of DNA reparation, increase of stem cells resistance against genotoxic factors, acceleration of cell cycle and also an increase of functional activity of the hematopoietic, immune, and nervous systems.

The results obtained in [3] testify an influence for good on biological objects.

In Pryakhin’s works mice were used as the target of research. These biological systems are rather complex by their organization. In order to understand the nature of radiation influence onto live objects it seems to be necessary to carry out experiments with simplest organisms. In our opinion, microorganisms (in particular, bacteria) can serve as objects of that kind.

In the present paper, we investigated the influence of a magnetic radiation on the vital activity of various bacteria in exposed nutrient media. As a means to assess the magnetic radiation’s influence on nutrient media the value of magnetic susceptibility χ of nutrient medium was taken. The choice of the method and methodology of estimation of the magnitude of the effective radiation was determined by the fact that the magnetic susceptibility is a straight indicator of the value of accumulated magnetic radiation in an object exposed.

Along with the research of magnetic radiation influence on biological objects, in this paper the problem of investigation of influence of small dose ionizing radiation on the vital activity of microorganisms was stated. A Cs ^{137}source with gamma-quanta energy 0.66 Mev was used as ionizing radiation emitter.

It is widely thought that any doses of ionizing radiation produce a harmful action with biological effect being proportional to the value of the dose of ionizing radiation interacting with an object. However, in the middle of 20th century it was found that the action of a low intensity radiation is not only harmless but often works positively on organisms (the hormesis effect) [8]. An opinion exists stating that a small power radiation is an integral part of the vital power [11].

1 The technique of low-energy generation of magnetic radiation

To generate the magnetic radiation we used a low-energy electric discharge realized between two carbon electrodes in a liquid [4].

The discharge was carried out in a working liquid in a plastic container placed into a small separating magnetic field (100-500 Oe) created by Helmholz coils. The liquid used was a mixture of water and glycerol with the latter component content being about 30 to 40%. The sketch of the experimental installation is presented in Fig.1.

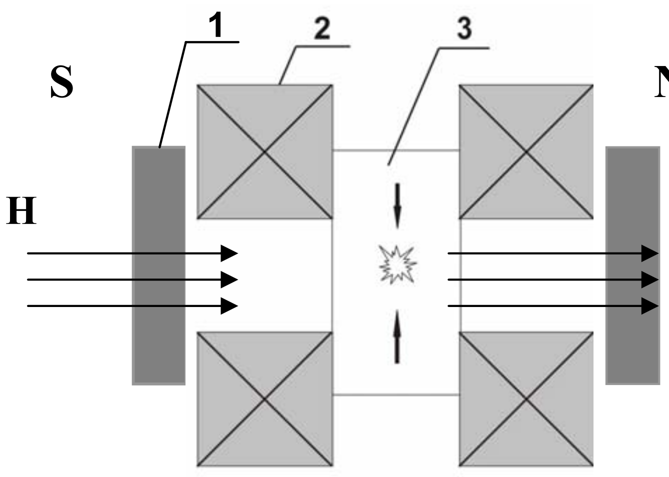

Fig.1. Schematic representation of the experiment with electric discharge in liquid. 1. Vials with water solutions to be exposed. 2. Helmholtz coils. 3. The domain of electric discharge realization.

Fig.1 depicts the lines of magnetic flux (**H**) as well as radiation poles: the north (N) and south (S) ones. The samples' exposure was carried out on both poles.

To investigate biological objects in solutions a specially elaborated technique to deliver radiation and carry out posterior study of magnetic susceptibility was applied. Preliminary research helped to eliminate all possible errors in sample preparation and uncontrolled influence of outside medium.

2 Investigation of magnetic radiation influence on vital activity of bacterial cultures.

In the present paper bacteria of various types were used as biological objects of study of the magnetic action on living systems. In what follows, a brief information can be found concerning microorganisms investigated in the paper:

Staphylococcus aureus (Gram-positive cocci) – the main causative agents of pyoinflammatory disorders in human beings. In particular, those cause 70–80% of septic arthritis of adolescent patients, more rarely in adult ones (especially in those suffering from rheumatisms or having prosthetic joints).

Escherichia coli are motile straight rod-shaped bacteria belonging to the family *Enterobacteriaceae* (intestinal bacteria). Enterobacteria lives on plants and in soil, they enter in microbe associations in intestinal tracts of animals and human body. During last 20–30 years their meaning in human pathology has had an essential growth. They are part of large guts microflora of homeothermals, reptilia, fishes, and insects.

Aeromonas hydrophila form motile coccobacilli and belong to the family *Vibrionaceae*. Infection diseases originated by bacteria of the *Aeromonas* species:1) cellulitises and wound infections caused by a contact with contaminated water, soil, and food products; 2) diarrheas registered also in warm weather and manifested by acute short-time and self-limited affects; 3) septicaemia observed more frequently in patients with liver disorders and immunodeficiency.

The development of the research methods was carried out in several stages with variation in nutrient media types and bacteria species. On the initial stage of experiment, a suspension of *Aeromonas hydrophila* microorganisms in a physiological salt solution was investigated. It was found experimentally that the physiological salt solution possesses very weak magnetic susceptibility, i.e., the magnetic radiation cannot produce an effect on the magnetic properties of a given sample. The physiological solution with bacteria was subject to magnetic radiation on north and south poles. Afterwards the bacterial cultures were re-plated into a nutrient medium, which is meat-peptone broth. As the result of experiment, it was obtained that the rate of exposed bacteria reproduction does not differ from the rate of bacteria reproduction in the control group.

On the next stage an experiment consisting of exposing the meat-peptone broth (i.e. a nutrient medium possessing a measurable magnetic susceptibility) to radiation with posterior plating of bacteria into it. As the result, an essential increase of bacteria reproduction rate was obtained at the north direction of radiation.

Hence, the conclusion follows that the magnetic radiation acts on the nutrient medium and not on the bacteria themselves.

Posterior experiments were carried out solely with nutrient media possessing a noticeable magnetic susceptibility.

The next stage of the study consisted of the analysis of sensibility of different types of bacteria to the orientation of radiation. The liquid magnetic medium was subject to magnetic radiation of the north (N) and south (S) poles. Afterwards into the medium studied microorganisms cultures were plated and incubated during 24 hours at 37C. The microorganisms were plated afterwards on dense nutrient media (meat-and-peptone agar) and incubated under the same conditions. The count of grown colonies was carried out by the calibrated loop technique [5]. Investigations were carried out for three types of bacteria.

Experimental results are presented in Table 1 (error $\pm$ 10 %).

The experimentally obtained data show that in plating bacteria into a nutrient medium exposed to radiation on north direction their quantity increase by two exponents of ten in comparison with the control group. The quantity of bacteria in the sample with radiation applied in south direction differs insignificantly from that in the control group. As a consequence, posterior experiments with exposition of nutrient medium to radiation were carried out only on the pole N.

The volume of accumulated magnetic radiation in nutrient medium can be evaluated via the quantitative change of its magnetic susceptibility.

In the present paper, the change of magnetic susceptibility was measured by the inductive frequency domain method described in [6]. The

Table 1. Count of bacteria quantity on different poles

Bacteria species	Quantity of bacteria in nutrient medium, radiation exposed on south direction (in 1 ml)	Quantity of bacteria in control sample (in 1 ml)	Quantity of bacteria in nutrient medium, radiation exposed on north direction (in 1 ml)
Escherichia coli	$(3 \pm 0.3).\ 10^8$	$(1 \pm 0.1).10^8$	$(1 \pm 0.1).10^{10}$
Aeromonas hydrophila	$(1 \pm 0.1).10^8$	$(1 \pm 0.1).10^8$	$(1 \pm 0.1).10^{10}$
Staphylococcus aureus	$(1 \pm 0.1).10^4$	$(1 \pm 0.1).10^4$	$(2 \pm 0.2).10^6$

relative error of magnetic susceptibility measurement under temperature stabilization is known to be 10^{-6} of the measured value.

In the experiments with exposure of samples of nutrient media to radiation four probes of the solution studied were used from the beginning. All probes underwent identical non-controlled influence under transportation and in their allocation in the same laboratory room. Two probes were control ones and two probes were working ones. Control and working probes after exposition to radiation were placed into containers nontransparent for magnetic radiation.

The working probes were exposed to radiation at the same time and in the same conditions. Into one of them bacteria were plated, while the other one was measured for magnetic susceptibility. This method was used on purpose, because it was found that in placing the solution into an alternating radio-frequency magnetic field a loss of properties accumulated during the process of exposing to radiation takes place. 48 hours after plating, the bacteria were counted in both the control and exposed samples. The measurement of the physical parameter, i.e., magnetic susceptibility, was carried out on the second pair of control and exposed samples.

The results of experiments are given in Fig.2 and Fig. 3 for different species of bacteria.

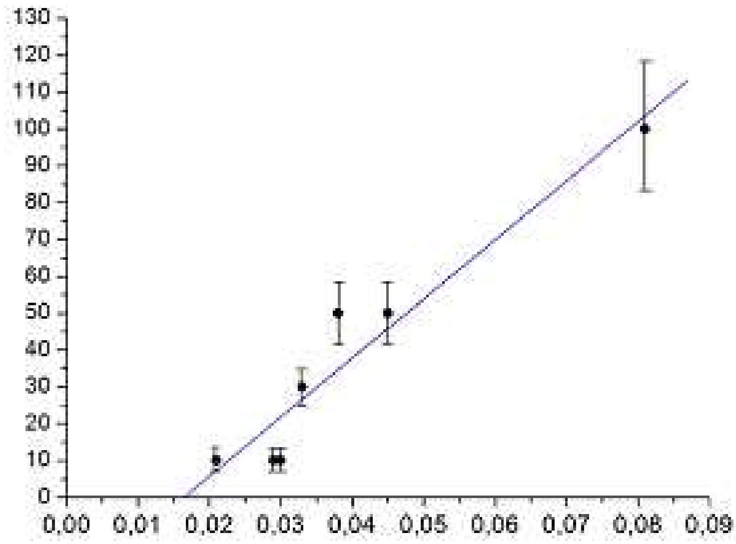

Fig.2. Dependence of quantitative variation of *Escherichia coli* with respect to nutrient medium's magnetic susceptibility. Notation used: $N$and$N*$ are the quantities of bacteria in 1 ml prior and after the exposure respectively;
$\Delta\chi = \chi^*$ - χ is the change of magnetic susceptibility of nutrient solution, χ and χ^* are the values of magnetic susceptibility prior and after the exposition respectively

The magnetic susceptibility characterizes a degree of accumulation of the radiation in a substance. The nature of magnetic radiation is explained by a theoretical assumption by G. Lochak assuming that a magnetic radiation is composed of magnetic monopoles which are being the magnetically excited-states of neutrino and antineutrino coming up with beta decays in magnetic fields [7].

In the present paper, a possible source of magnetic radiation is the beta decay of components of cosmic radiation in the magnetic field of electric discharge in liquid. The variation of radiation dose is stipulated by electric discharge duration.

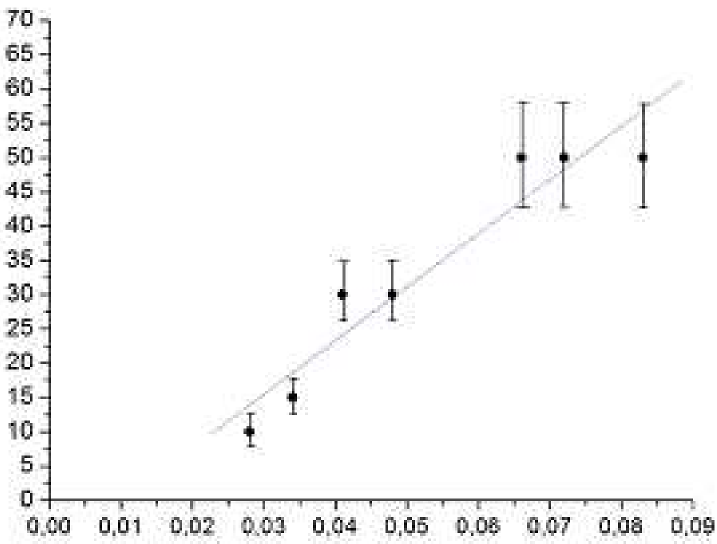

Fig.3. Dependence of *Staphylococcus aureus* quantity change on the change of nutrient medium's magnetic susceptibility. Notation used: $N$and$N*$ are the quantities of bacteria in 1 ml prior and after the exposition respectively;
$\Delta\chi = \chi^*$ - χ is the change of magnetic susceptibility of nutrient solution, χ and χ^* are the values of magnetic susceptibility prior and afterwards the exposition respectively

The observed effect of magnetic monopoles sorption can be explained by an interaction between magnetic monopoles and magnetic moments of electron shells or atoms. It is known that in inserting an atom or a molecule into the strong magnetic field of monopole a structuring of atom and molecule electron configuration happens in such a way that the electron structure is ordered which leads to a growth of the molecule's magnetic moment [8]. Indeed a similar phenomenon is observed in cited experiments. Following the experimental data obtained, a proportional dependence between the degree of magnetic radiation accumulation and the bacteria reproduction rate is observed.

3 Biological action of small dose ionizing radiation.

Since the influence of high-intensive radiation on a living object is a deeply investigated domain of knowledge, the issue of the action of small doses of ionizing radiation on living objects is of great interest. It could be noted that a linear extrapolation from large doses to small ones might solve the question about the consequences of weak actions whose mechanisms might thus be reduced only to a quantitative decrease of the expressiveness of radiobiological effects. However, with small doses of radiation some phenomena are not in accord with radiation damages initiated by a large dose radiation [9].

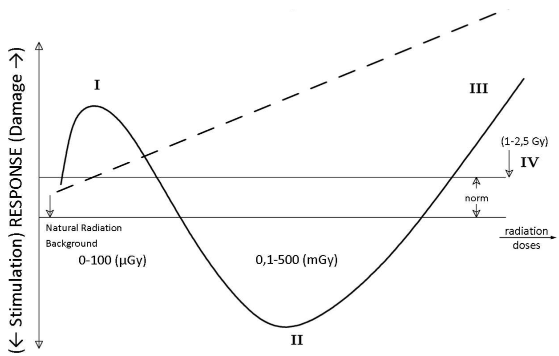

Fig.4. Biological effects' dependence on dose

An indicative graphic reflecting a relation between general biological effect and radiation dose is presented on Figure 4 :

In Fig. 4 three domains are marked: I stands for ultra-small doses (natural radiation background) – a phenomenon of hyper-radiosensitivity; II means effects of exposure to small doses of radiation that induces a stimulation of biological processes or the hormesis; III reflects the development of structural-functional under radiation of "average sub-lethal" doses. IV denotes doses corresponding to different stages of radiation disorders/diseases.

It seems to be evident that experimental data shown on this graphic do not agree with postulates about a linear dose–effect dependence and this manifests an inconsistency of the probabilistic theory for small range of ionizing radiation doses.

The Figure depicts also an interpolating linear function obtained by means of the probabilistic model.

4 Experimental study of the influence of small dose of ionizing radiation on the vital activity of bacteria.

In the represented experiments, the action of low-intensive radiation on the vital activity of various bacterial cultures is studied. The radiation was applied by means of Cs^{137} as a radiation source with gamma-quanta energy 0.661 Mev. By means of a laboratory dosimeter, the radiation power of the source was measured. It is equal to 0.8 mSv/hour (1Sv = 1Gy for gamma-radiation).

On the initial stage of experiments a physiological salt solution was used as a nutrient medium, i.e., a medium not contributing to bacteria reproduction. Such an experiment was carried out with the aim to determine whether a low-intensity ionizing radiation is interacting with bacteria or influences solely the properties of the nutrient medium. Two types of probes were used: a clean physiological solution and a physiological solution with microorganisms (*Escherichia coli)* plated into it.Every pair of probes was exposed to the action of gamma-rays in different doses: 0, 0.8, 1.5, 5 mSv. After exposition, bacteria were plated into the clean physiological solution. Two days later, bacteria were counted in each pair of samples. The result can be found in Table 2:

Table 2. The result of *Escherichia coli* bacteria count for two types of probes.

	Type \ Probe Dose (mSv)	0	0.8	1.5	5
Quantity of bacteria per 1(ml)	Physiol. solution	10^7	10^7	$5 \cdot 10^7$	$5 \cdot 10^6$
	Physiol. solution with bacteria	10^7	10^9	10^8	$5 \cdot 10^6$

Thus, on the basis of experimental results, one can conclude that a low-intensity ionizing radiation interacts with microorganisms. In the posterior experiments, nutrient solutions with bacteria plated in them will undergo gamma-radiation.

One of the tasks of this work is to determine a range of doses in which a radiation stimulation or the hormesis effect are observed. On further stages of our study we used the following species of microorganisms: *Escherichia coli, Staphylococcus aureus, Aeromonas hydrophila.*

$\sqrt{10^2 + 10^2} = 14\%$A statistical treatment of the data obtained was made: the relative error of the calibrated loop technique (the method for bacteria counting) is 10%. Since on the graph we show the ratio of bacteria quantities prior and afterwards exposition to radiation respectively, we have the error of the counting method:

The following values of radiation doses were selected: 0, 0.8, 1.5, 2.4, 3.2, 5, 15 mSv. The dependence of microorganisms' reproduction rate on doses of radiation received by nutrient media is studied. The experimentally obtained results are shown in Tables 3, 4, 5 and in Fig. 5, 6, 7 for several species of bacteria (N*/N is calculated with the error 14%).

Table 3. The dependence of *Escherichia coli* bacteria quantity on the dose of ionizing radiation, where $N$and$N*$ stand for the quantity of bacteria per 1 ml prior and afterwards exposure to radiation respectively.

Experiment #	Dose (mSv)	Quantity of bacteria (in 1 ml)	$Log(\frac{N*}{N})$
1	0	$(1\pm0.1).10^6$	0.000±0.05
2	0.8	$(5\pm0.5).10^6$	0.699±0.06
3	1.5	$(1\pm0.1).10^7$	1.000±0.04
4	2.4	$(1\pm0.1).10^8$	2.000±0.06
5	3.2	$(1\pm0.1).10^7$	1.000±0.04
6	5	$(5\pm0.5).10^5$	– 0.301±0.06
7	15	$(1\pm0.1).10^4$	–2.000±0.06

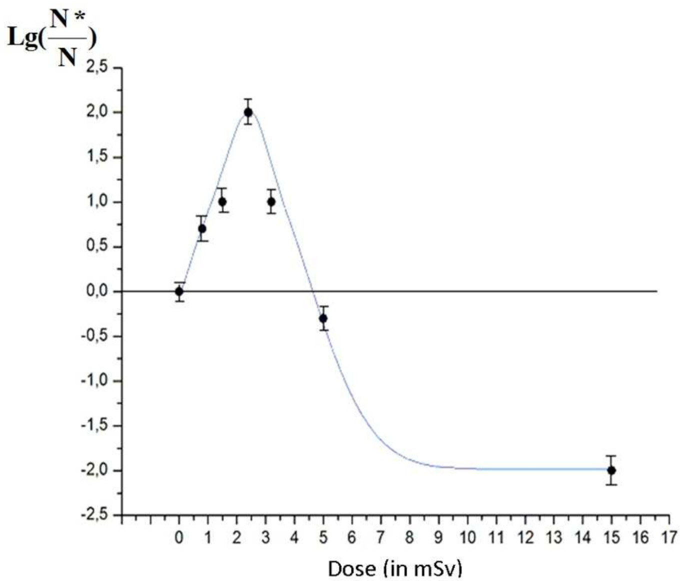

Fig.5. Dependence of *Escherichia coli* bacteria quantity on the dose of ionizing radiation.

Table 4. Dependence of *Staphylococcus aureus* bacteria quantity on the dose of ionizing radiation, where $N$and $N*$ are the bacteria quantities in 1 ml prior and afterwards exposing to radiation respectively.

Experiment #	Dose (mSv)	Quantity of bacteria (in 1 ml)	$Log(\frac{N*}{N})$
1	0	$(1\pm0.1).10^5$	0.000±0.05
2	0.8	$(1\pm0.1).10^7$	2.000±0.06
3	1.5	$(5\pm0.5).10^6$	1.699±0.06
4	2.4	$(1\pm0.1).10^7$	2.000±0.06
5	3.2	$(1\pm0.1).10^7$	2.000±0.06
6	5	$(5\pm0.5).10^5$	0.699±0.05
7	15	$(1\pm0.1).10^3$	-2.000±0.06

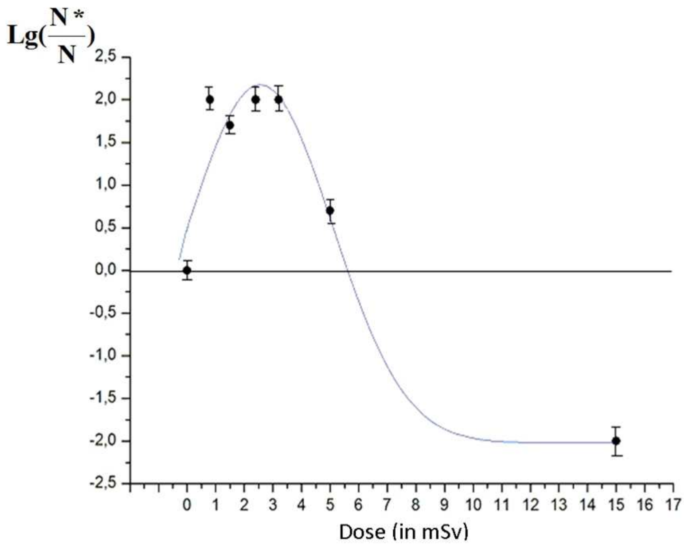

Fig.6. Dependence of *Staphylococcus aureus* bacteria quantity on the dose of ionizing radiation.

Table 5. Dependence of *Aeromonas hydrophila* bacteria quantity on the dose of ionizing radiation, where $N$and $N*$ stand for the bacteria quantities per 1 ml prior and afterwards exposing to radiation respectively.

Experiment #	Dose (mSv)	Quantity of bacteria (in 1 ml)	$Log(\frac{N*}{N})$
1	0	$(5\pm0.5).10^6$	0.000±0.05
2	0.8	$(1\pm0.1).10^8$	1.699±0.06
3	1.5	$(5\pm0.5).10^7$	1.000±0.04
4	2.4	$(1\pm0.1).10^7$	0.699±0.06
5	3.2	$(1\pm0.1).10^8$	1.699±0.06
6	5	$(1\pm0.1).10^5$	-0.301± 0.06
7	15	$(5\pm0.5).10^4$	-2.000±0.06

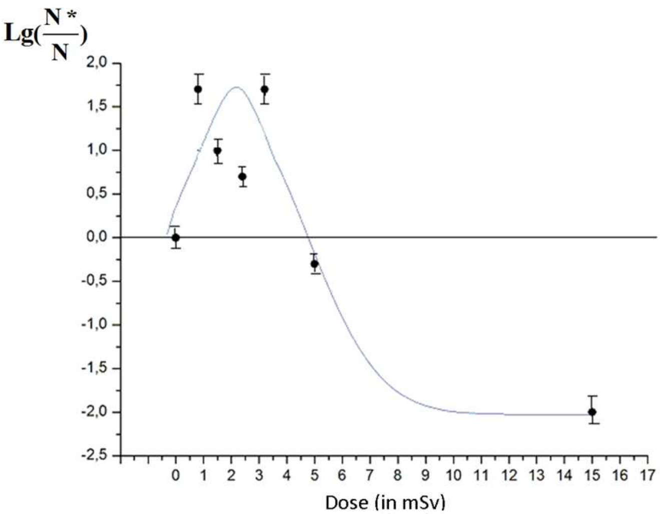

Fig.7. Dependence of *Aeromonas hydrophila* bacteria quantities on the dose of ionizing radiation.

The paradoxical character of the hormesis phenomenon is in the fact that the probability of the event when gamma-quanta under such low levels of radiation will hit every separated bacterium is negligibly small. Nevertheless, cells "are feeling" the event and react to it. For the hormesis effect, not the substance ionization is responsible but an excitation in the form of collective electron excitations: excitons, polarons. According to this hypothesis, the assumption of the hormesis effect is related to the Vavilov-Cherenkov radiation, most part of which is radiated in the volume of exposed medium in UV range. Depending on the radiation wavelength and the properties of exposed substance, the wavelength of photons can reach several centimeters that is immeasurably less than the migration distance of other forms with I.R. energy in the exposed volume. Consequently, hence follows the probability of various bacteria's stimulation by quanta radiating from Vavilov-Cherenkov radiation [10]. In comparison with ionization, the energy created by ionizing radiation in the substance of exposed organisms must be higher.

The results obtained in this paper confirm the assumption about a relation between the effect of Vavilov-Cherenkov radiation and consequences of influence of a low-intensity I.R. on the increased activity of bacteria division. From the depicted graphs of results several conclusions can be made. Firstly, the used source of radiation, which power of dose constitutes 0.8 mSv/hour, satisfies the goals stated in this paper . In other words, the hormesis effect can be observed at doses of order 1 mSv. Secondly, for three different bacteria species one can distinguish the dose range with negative and positive biological effect: the positive one for [0.8 – 3.2] mSv; for doses exceeding 4 mSv an inhibition of the division processes takes place.

It seems to be important to note that the presented experimental results can be applied only to living systems like bacteria. For other biological objects the dose ranges may be absolutely different.

5 A complex action of gamma- and magnetic radiation on vital activity of bacteria

The main aim of this series of experiments is the study of the joint action of gamma- and magnetic radiation on microorganisms. By the experiment's technique one sample underwent solely ionizing radiation. The second sample first underwent gamma- and then magnetic radiation on the pole N. As in the previous experiments, the dose of ionizing radiation was varied. The results of the experiments carried out are shown in the following table (γ stands for gamma-radiation while M denotes magnetic radiation):

Table 6. Estimation of bacteria quantity under a complex action of gamma- and magnetic radiations

Radiation dose (mSv)	0	1.5		15	
Radiation form	– // –	γ	γ+“Ã”	γ	γ+“Ã”
Bacteria quantity per ml (N)	$(1\pm0.1)\cdot10^8$	$(1\pm0.1)\cdot10^9$	$(5\pm0.5)\cdot10^9$	$(5\pm1)\cdot10^6$	$(1\pm0.1)\cdot10^8$

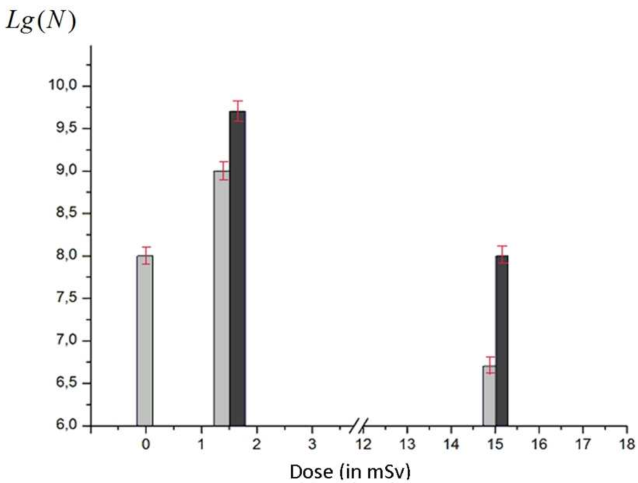

Fig.8. Dependence of *Aeromonas hydrophila* bacteria quantity on a complex action of gamma- and magnetic radiations.

In the analysis of the study carried out one should employ the results of E.A. Pryakhin's work [3], where two groups of mice underwent a high-intensity ionizing radiation. The doses were reaching the order 1 – 3 Sv. One of the groups was afterwards subject to magnetic radiation and compared with the other group (control). The group of animals subject to magnetic radiation when compared with the control group demonstrated significant improvements of biological parameters.

A similar effect was observed in experiments with microorganisms. At doses of order 15 mSv without action of magnetic radiation the process of cell division's inhibition takes place. Under the action of magnetic radiation on bacteria which previously underwent a dose of ionizing radiation of 15 mSv, the bacteria division rate restores and (in agreement with the data presented in the table) achieves the initial value.

A cooperative action of small doses of ionizing radiation and magnetic radiation represents a certain interest. In that case, a synergy of effects invoking an increased rate of bacteria division of both gamma- and magnetic radiations is observed.

6 Results and discussion

The present paper is the first work where the action of magnetic radiation on bacterial cultures is studied.

The investigations carried out reveal a correlation between the degree of accumulation of magnetic radiation by substances and the rate of bacteria division.

It is demonstrated experimentally that the action of magnetic radiation on biological objects on the north pole N is positive, while the effect is either weakly expressed or completely absent on the south pole S.

It is shown in this paper that the magnetic radiation compensates a negative impact of ionized radiation applied.

It is demonstrated that the positive influence of magnetic radiation in biological systems is revealed only through the water solutions of nutrient substances. The latter has its natural confirmation: electrical storm rains always has a good influence on crops and plants.

The fact of a positive influence of small doses of ionizing radiation on living organisms (such as bacteria) is proven experimentally. On the basis of the data obtained it turned out to be possible to determine ranges of positive and negative biological effects; a qualitative interpretation of the positive action of small doses is given.

Summary

In the paper a correlation between the levels of magnetic radiation's accumulation in nutrient media and the bacteria reproduction rate was determined. The substance was exposed to radiation in two poles: north N and south S. It can be resumed that biological effects of exposing to

radiation on the pole N is positive while on the pole S these are either weakly expressed or absent.

In addition, a positive influence of gamma-radiation on bacteria reproduction rate is discovered.

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