CRITICAL VALUES OF THE EXTERNAL MAGNETIC FIELD LEADING BIOLOGICAL EFFECTS IN
THE HUMAN ORGANISM

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Abstract

In the framework of the simplified stochastic model the critical values of an induction of the external magnetic field leading to sharp increase of fluctuations of a casual current of biologically important ions in different blood vessels of a human body are calculated.

Interest to the magnetic-biology is caused, first of all, by the ecological reasons. Present time exist sets of the experimental facts, that natural and technogenic weak, low-frequency electric and magnetic fields (LFEMF) represent potential threat for health of people and they are not less essential ecological factor, than other meteorological ones. With development of a radio communication, TV, radionavigation, a radar-location and mobile telephones in front of mankind it arises a problem of the environment “electromagnetic pollution” which results from activity of people. Thus, biosphere of our planet feels on itself the regular influence of fields of the artificial origin besides the natural geomagnetic and space electromagnetic field. At interaction a weak electromagnetic radiation with biological objects the integrated heating does not exceed 0.1 degrees [1,2]. Therefore, earlier was considered, that LFEMF are safe for the person, biological action of such fields seemed to be impossible from the point of view of physics. The experimental researches, which were performed for the last decades, testify the high sensitivity of biological systems to the LFEMF of weak intensity [3-5]. However, the physical, biological and chemical mechanisms of influence of the given fields on biological systems in all spent researches were not established well. It should be stressed that the results of different experimental groups often have inconsistent character, that essentially complicates understanding of mechanisms of action of the weak LFEMF on the biological objects [5-7]. Thus, most actual questions in electromagnetobiology are:

• revealing of the basic laws of interaction of an electromagnetic field of a technogenic origin with biological systems and an environment;

• development of reliable means of protection against negative influence of LFEMF on ecological systems.

It is well-known, that biological objects are the complex open nonlinear dynamic systems and their states can be determining in their reaction and not just the influencing external fields. Their complexity is caused by that, being macroscopically, they consist of many objects accepted for elements of their structure. By consideration of mechanisms of interaction of the weak LFEMF with elements of complex biological system there is a necessity of search of the most fundamental principles determining such interaction. Apparently, these principles lay in the field of studying non-equilibrium and non-linear interactions of biological systems as a whole, or their separate elements. Prigozhin marked that open systems continuously fluctuate [8]. Fluctuation is casual deviation of the physical quantities describing system from their mean values. Sometimes a separate fluctuation or their combination can become so strong, that the organization existed before does not survive and collapses. Therefore, the huge interest represents not only research of interaction of an electromagnetic field with biological systems as a whole, but also its interaction with separate elements of system. It is possible to carry vessels, cells, lipids, fibers, and also their water solutions to the last.

In Refs [9,10] the simplified stochastic model to study influence of a weak external magnetic and electric field on fluctuation of an ionic casual current in blood has been offered. It is shown, that the external stationary magnetic field can cause sharp increase in fluctuation of an ionic electric casual current in biological cells, in particular in blood vessels owing to Brown movement of the free charged ions. Analytical expression for kinetic energy of a molecule of environment in the considered volume was obtained. The results of energy of molecules in the volume of a capillary and an aorta near to critical value of an external magnetic field were presented. It is shown, that as approaching critical values of a magnetic field, the averaged energy of the molecule localized in a capillary increases for some orders of magnitude in comparison with its thermal energy. As a result the pressure of blood can increase in the considered volume which may appears as a small red macula on the skin of man body. As well as the large value of energy may be enough for destruction of chemical communications. Even if the value of a magnetic field not so close to critical values, a significant effect can be reached with increase in
time of an exposition of a magnetic field. In Refs. [9,10] all numerical calculations have been performed only for ions of calcium-Ca\(^{2+}\). In the alive organisms, except for ions Ca\(^{2+}\) also ions of magnesium Mg\(^{2+}\), potassium K\(^{+}\), sodium Na\(^{+}\), iron Fe\(^{2+}\) are biologically important.

In this work we have calculated critical values \(B_{cr}\) of an induction of external magnetic field leading to sharp increase fluctuations of a casual current of biologically important ions in different blood vessels of a human body (Table 1). Thus we consider each blood vessel as a separate element of an organism and \(B_{cr}\) is calculated by the formula which easily it turns out from expression resulted in Ref.[9,10]

\[
B_{cr} = \frac{6\pi \eta r}{qn}
\]

where \(\eta = (1.1 \div 1.2) \cdot 10^{-3}\) kg/(m·s) is the viscosity coefficient of blood, \(r\) is the radius of an ion, \(q\) is the charge of an ion, \(n\) is a number of ions of the given element volume \(V = \frac{\pi d^2}{4} \cdot l\) of a vessel.

### Table 1. Geometrical sizes of the blood vessel of human body.

| Vessel             | Diameter, \(d\) (10\(^{-2}\)m) | Cross section, \(S\) \((10^{-4}\) m\(^2\)) | Length, \(l\) \((10^{-2}\) m) | Total number in the organism | Volume of vessel, \(V\) \((10^{-8}\) m\(^3\)) |
|--------------------|-------------------------------|---------------------------------|---------------------|-----------------------------|---------------------------------|
| Aorta              | 3.2-1.6                       | 8.0-2.00                        | 80                  | 1                           | 640-160                          |
| Hollow veins       | 2.0                           | 3.14                            | 50                  | 2                           | 157                             |
| Large veins        | 1.0-0.5                       | 0.80-0.20                       | 30-10               | 1000                        | 24-2                            |
| Large artery       | 0.6-0.1                       | 0.28-0.01                       | 40-20               | 1000                        | 11.2-0.2                        |
| Small artery       | 0.1-0.02                      | 0.01-0.003                      | 5-0.2               | \(10^8\)                    | \(5 \cdot 10^{-2} \cdot 6 \cdot 10^{-4}\) |
| Capillary          | \((10-5) \cdot 10^{-4}\)     | \((19.63 \div 78.5) \cdot 10^{-8}\) | 0.1                 | \(10^9\)                    | \((2.0 \div 7.9) \cdot 10^{-8}\) |

The number of ions in the considered volume was determined by the use of data presented in Table 2. Results of calculations are presented in Table 3.

### Table 2. Parameters of a mineral exchange in blood[11].

| Parameter                        | Mole /liter |
|----------------------------------|-------------|
| Calcium in whey of blood         | 2.25-3      |
| Magnesium in whey of blood       | 0.70-0.99   |
| Iron in whey of blood            | 12.5-30.4   |
| Potassium in plasmas of blood    | 3.48-5.3    |
| Sodium in plasmas of blood       | 130.5-156.6 |

### Table 3. Critical values of induction \(B_{cr}\) an external magnetic field (T).

| Element of vessel | Aorta \(10^{-12}\) | Hollow veins \(10^{-12}\) | Large veins \(10^{-12}\) | Large artery \(10^{-12}\) | Small artery \(10^{-10}\) | Capillary \(10^{-3}\) |
|-------------------|--------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| B(Ca\(^{2+}\))    | 0.50-0.88          | 5.0                      | 0.2-1.0                  | 0.7-23.5                 | 2.3-70.6                 | 0.26                     |
| B(K\(^{+}\))      | 0.15-0.26          | 0.26                     | 1.6-21                   | 7-184                    | 45-9500                  | 0.6                      |
| B(Na\(^{+}\))     | 0.32-0.54          | 0.6                      | 4.3-65                   | 21-650                   | 650-16250                | 1.4                      |
| B(Mg\(^{2+}\))    | 0.12-0.32          | 0.4                      | 2.6-50                   | 13-435                   | 435-12500                | 0.9                      |
| B(Fe\(^{2+}\))    | 2.3-3.5            | 3.6                      | 27-280                   | 140-4030                 | 450-9500                 | 9.4                      |

### Conclusions

In this work critical values of an induction of an external magnetic field of \(B_{cr}\), which influence on ions of the vital elements can cause change in a biological organism, for the first time have been calculated. Results of calculation show that the values of \(B_{cr}\) depending on the volume a vessel and number of ions in an important biological element in the given volume accepts values from \(10^{-12}\)T us to \(10^{-3}\)T. These results allow us to explain the inconsistency and discrepancy between different experimental data obtained by different experimental groups at various times: any biological organism represents itself as complex and individual system for each object. Therefore, the data corresponding to one person cannot be considered as the standard for another person. The everything depends on structure of blood, concentration of the vital elements and characteristics of vessels in an organism. The consent of ions of biological important elements in an organism is various depending on the nature of a structure of the person. In this connection, it will be unequivocally impossible to establish what the biological response to all organisms as a whole.

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