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The Dissemination of Magnitotactic Microorganisms in the Water Reservoirs of Georgia

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Abstract

A search for magnetotactic bacteria was conducted in several water reservoirs of Georgia. At least five species of magnitotactic microorganisms reacting to geomagnetic field have been found. The majority of the organisms move in northern direction.

Light and electron microscopic studies of the morphological features of these microorganisms have indicated that all magnetotactic cells contain magnetic domains, so-called magnetosomes. The shape, dimensions and intracellular guantity of these organeles are species – specific.

Keywords: magnitotactic microorganisms, magnetic domains, magnetosomes, magnetotaxis, eutrophic lakes, microaerophiles, obligate anaerobes, biogenic magnetitis, enriched culture.

1. Introduction

Microorganisms are one of the most interesting and at the same time rarely studied phenomena of the microbial world; they are oriented in the earth's magnetic field and are moving in the direction of magnetic lines of this field. These microbes i. e. Magnetotactic bacteria were discovered by Blakemore in 1975 (Lins de Barro, Eskuivel', 1989). During the last decade a number of researchers have identified some morpho-physiological and biochemical properties of such bacteria (Balkwill, Maratea, 1980; Bazylinski et al., 1988; Blakemore, 1975; Blakemore, 1932). In particular, it has been shown that magnetotactic microorganisms synthesize the magnetic particles within the cell that defines the direction of movement of these bacteria in the Earth's magnetic field (Blakemore, Frankel, 1989). It has been discovered that magnetotaxis is a very common phenomenon in the microbial world and that this feature is characteristic of various forms and sizes of microorganisms in all regions of the earth. Simultaneously, bacterial species found in the north hemisphere tend to move to the North Pole, while in the southern hemisphere – to the south (Bazylinski et al., 1988).

Despite the great efforts, so far the only type of magnetotactic bacteria, Aguaspirillum magnetotacticum MS – 1, was obtained in its pure culture type. This bacterium is spiral-shaped with bipolar flagella and contains a chain of 40-100 nm magnetic particles surrounded by membrane. The X-ray structural and Mössbauer spectroscopy analyses defined that these particles

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represent pure magnetite Fe3O4. The magnetic particles surrounded by the membrane were called "Magnitosome" (Balkwill, Maratea, 1980).

Concurrently, a number of important and interesting issues are completely unresolved. Particularly, what are the transport mechanisms of iron ions into the cells? What factors define the form, size, number and direction of magnetic domains? What is the biological essence of magnetotaxis? What are the peculiarities of the genetic apparatus of magnetotactic bacteria? Can Biogenic Magnetite be used in medical and industrial practice?

Aguaspirillum magnetotacticum is not a favorable object to get a large amount of biogenic magnetite. Its reproduction requires a complex number of components and the use of fine laboratory methods.

All of the above undoubtedly makes the identification and examination of new magnetotactic bacteria urgent. Therefore, we set a goal of our study to research the spread of magnetotactic bacteria in the natural or artificial reservoirs of different regions in Georgia.

2. Materials and methods

We examined magnetotactic bacteria in the following reservoirs: Turtle Lake, Lisi Lake, Tbilisi Water Reservoir, Bazaleti Lake, Nadarbazevi Lake, Jandari Lake, Sioni Reservoir, Zhinvali Reservoir, Sagamo Lake, Paravani, Paliastomi, Batumi Pioneer Park Lake and a large number of small water reservoirs and swampy areas in different regions of Georgia. In total, samples were taken from 47 water reservoirs, and 5-6 samples were taken from each reservoir. Special attention was paid to reservoirs with organic remains, silt and residual vegetation.

The samples were taken in sterile laboratory flasks, so that the ratio of silt and water in the vessel was 1: 3. The test samples were incubated for 1-2 months at a room temperature with poor lighting conditions. Periodically, distilled water was added into the flasks with samples to fill the evaporated water. In addition, the microscopic analyses were conducted to study the presence of magnetotactic bacteria. For this, a constant magnet was attached to the surface of the flask, and the filter device provided by Matsunaga and co-authors (Blakemore et al., 1979; Blakemore et al., 1985) was placed in the flasks.

Detection of magnetotactic bacteria and identification of the direction and speed of their motion were made by the microscope of Nikon TMD-2. A detailed morphological study of bacterial cells was made by electronic microscope JEOL, model JEM 1200 EX using standard methods.

3. Results and discussion

As it is known, in most cases small size of eutrophic lakes and reservoirs, as well as wetland areas with organic compounds provide favourable conditions for magnetotactic bacteria (Kalmijn, Blakemore, 1978). This condition was accepted as a main point for the selection of water reservoirs. In addition, samples were taken from the adjacent areas of northern shores as it is known that in the north hemisphere the magnetotactic bacteria tend to move to north.

The majority of magnetotactic bacteria, found so far, are microaerophiles (Kalmijn, Blakemore, 1978), and in some cases the obligate anaerobes (Matsunaga, Kamija, 1987). That is why the samples were taken from 10-15 cm depth, with appropriate precautions to avoid intense contact with atmospheric air.

As a result, it was identified that in the composition of microflora of six water reservoirs there are microorganisms that react with Earth's magnetic field and to the field that was generated by school magnet. Such microorganisms were found in Jandari, Sagamo and Paravani Lakes, Paliastomi and its adjacent small reservoirs and in the natural lakes on the territory of the Batumi Pioneer Park. All of these water reservoirs are rich in organic waste and silt.

Observations carried out by an optical microscope showed that these microorganisms moved mostly to the north, while their movement speed and trajectory differed significantly from each other. It should be noted that in the reservoir where magnetotactic microorganisms were found, one type of magnetosensitive microbes were prevalent.

The study of the morphology of discovered magnetotactic microorganisms has shown a significant difference in the forms of these bacteria. For example, the bacteria in Jandari Lake have a rod-shape form and contain a single chain of pyramidal magnetic domains, each of which contains 6 magnetosomes with the dimensions 150x50x50 nm.

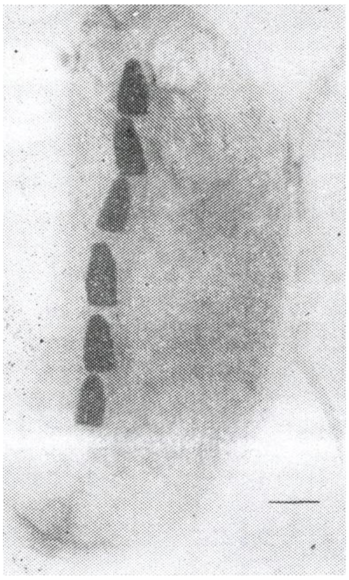

Fig. 1. Magnetotactic bacteria in Jandari Lake

The samples of the Batumi Pioneer Park Lake were particularly rich in magnetotactic bacteria. In certain conditions, these magnetic cocci constituted the absolute majority of microflora in the sample. Their cells contain two chains of cube-shaped magnetic domains. The sizes of magnetosomes were 80x80x100 nm. These bacteria are characterized by a strong flagellar apparatus that is peripherally located.

Long-shaped, single-celled microorganisms, containing a long line of cube-shaped magnetosomes, have been detected in the small reservoirs of Paliastomi Lake and nearby. In the same reservoirs a sphere-shaped magentotactic cells with a large diameter were found; they have high electronic density formations on the surface of the cell. The speed and trajectory of these "giant" cells differ significantly from other magnetotactic microorganisms, but the nature of their interaction with the magnetic field clearly indicates the magnetotactic "behavior".

In Sagamo and Paravana Lakes magnetic spirals were observed that are not fundamentally different from magnetotacticum MS-1 strain found by Blakemore.

Some types of magnetotactic microorganisms detected in Georgia's water reservoirs are described by various foreign researchers (Bazylinski et al., 1988; Paoletti, Blakemore, 1988), but the only type that has been studied in detail is Aguaspirillum magnetotacticum (Balkwill, Maratea, 1980). These bacteria have been obtained as a pure line (Towe, Moench, 1921), which enabled researchers not only to conduct microbiological and morphological studies, but also to examine a number of biophysical and genetic parameters. Execution of such research requires a pure culture of microorganism. At the same time, studying the morphological details of the cells, as well as studying the properties of biogenic magnetitis, it is enough to have enriched culture.

The method provided by Matsunaga, (Blakemore et al., 1979) that was applied in the study, allowed us to obtain such enriched culture. In such way, preparations that primarily contained magnetotactic bacteria were obtained. To study the structure of magnetosomes and organization of cell morphology, the magnetotactic bacteria from Batumi Pioneer Park Lake were selected to get such preparations.

As it was mentioned above, these microorganisms reproduce significantly faster in laboratory conditions and after the incubation period of 1-2 months, their concentration reaches 10^7-10^8 cells / ml. As it is obvious from the results, these cells contain two chains of magnetic domains, in each chain there are 6-10 magnetosomes. All magnetosomes, except for those that are at the ends of the chains, are of equal size. Such distribution of the sizes of magnetosomes indicates the unfinished biomineralization process. In the majority of the bacterial cells of this population, magnetic domains are located in parallel near the surface of the cell. Such deployment of magnetosomes should have some biological essence, as in this case the magnetic moment of bacterial cell is significantly increased. It should be noted here that the magnetic moments of magnetotactic cells never exceeded 1,3x 10^{12} erg/G (Bazylinski et al., 1988). This phenomenon also has its explanation, because the greater value of magnetic moment could cause the attachment of cells to one another.

In some cases the cells in which magnetosomes were not located in parallel were observed. Also, the cells with three chains of magnetosomes were found. It is not excluded that such changes were caused by cell damage during the preparation of electro microscopic preparations.

In some preparations, magnetotactic cells in the division process were observed. Initially, the number of magnetosomes is doubled and only after that the cell divides into two daughter cells. This process clearly indicates that the formation of magnetosomes and their organization in the cell are genetically determined.

The current research revealed that although studies on magnetotactic bacteria are at the initial stage, the research in this direction can be very interesting both in fundamental and practical terms. The fact that bacterial cells can synthesize magnetic particles with the size of nanometers, explains the prospect of its use in production. The development of new, cheap methods to produce magnetic particles of submicron sizes can have a great impact on many areas of high-tech industry. For example, biogenic magnetite can be used in the manufacture of magnetic tapes, machines with magnetic memory and magnetic circuits, as well as the creation and manufacture of biosensors and different mediators.

The use of biogenic magnetite for practical purposes is the primary task of research in this direction; furthermore, the study of the genetic and biochemical aspects of magnetactic bacteria is very interesting in terms of identification the mechanisms of interaction of living organisms with the magnetic field. It is also important to study magnetotactic bacteria to determine the ways of evolution of life on the Earth.

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