INDUSTRIAL BIOTECHNOLOGY AND BIOPOLITICAL PROBLEMS

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Birth of biotechnological industry is a new factor in ecological problems

The second half of the 20th century is characterized by the growth of the production of biotechnological products as an important ecological factor. This process is being carried out all over the world, particularly in the U.S.S.R. Microbial synthesis of bio-active compounds primarily antibiotics called for the creation of large plants equipped with devices where enormous microbial populations function. Industrial application of bacteria as a bioproducer of aminoacids and vitamins became very popular. The cultivation of yeasts for the purpose of obtaining single-cell protein is also widely used in the Soviet Union and several Eastern European countries.

Obtaining natural biosynthetic products such as human, animal and plant cells, as well as biomass, primary and secondary metabolic products is a specific peculiarity of biotechnolocal plants. It causes the increase of the natural concentrations of these products, breaking the correlation of its normal distribution in nature. Thus, the development of biotechnological industries is connected with the appearance of two biosocial issues.

The positive one is the possibility to provide humanity with bioproducts of which there is a shortage in nature. The creations of the biotechnology industry allow us to utilize agricultural and industrial wastes and, for all that, to use natural sources more rationally. At the same time one must take into account the possibility of the negative influence of certain factors of biotechnology on human beings and the environment.

It is estimated that the end of cultivation comes at a cell concentration equal to 10 per ml; it is obvious that a common industrial fermentator with a volume of 100-500 m contains an amount of bacteria or yeast cells numbering to 10. Though one can be sure that the producing strain is non-pathogenic in all cases, its presence within the small territory of a plant in the quantity of 10 living cells influences the environment and living beings in the working zone.

The experience of single-cell protein-plant exploitation in the U.S.S.R. showed that the unfavorable effect of biotechnology plants does not exist in principle. It spreads to the staff of the plant and the population of the nearest towns in case of the combination of the influence of the plant with other harmful ecological influences. Unfortunately, negative effects were found to persist in the absence of the living cells of the producer because of the ability of protein to be sensitized.

These facts cause people to harbor a negative attitude towards the development of industrial biotechnology, which can create a real barrier to the progress of science and technology. The task is to introduce the ecological appraisal of biotechnological industries and to create methods of control. First of all, there should be methods of biotesting of the environment in the area of large plants especially in cases of huge industrial centers with highly developed, populated areas.

Ecological analysis of a technological scheme of a biotechnology plant

Let's take the largest plants for obtaining single-cell protein and amino acids such as lysine, glutamic acid. Typical plants of this kind consist of five main technological steps: preparation of nutritious media, maintenance of pure culture, fermentation, isolation of the product, and the product's purification (Figure 1.)

Preparation of nutritious media includes dissolution of all the ingredients in one or several water streams and their sterilization with the necessary extent of reliability. Water-insoluble ingredients of the media are directly introduced into the fermentator. There may only be leakage of chemical components or their partial evaporation such as ammonia and low molecular weight alcohols which is not so dangerous from a short-term perspective.

Maintaining pure cultures is attained through the constant presence of an active producer and it is reproduction for the sowing of industrial devices. The first task requires laboratory operations and is not dangerous if performed accurately. The second can proceed in an apparatus of 1 and even 10m volume. Such volumes make it necessary to protect the environment from cells which can be released with the stream of gases emitted from the sowing fermentators, as we shall see below.

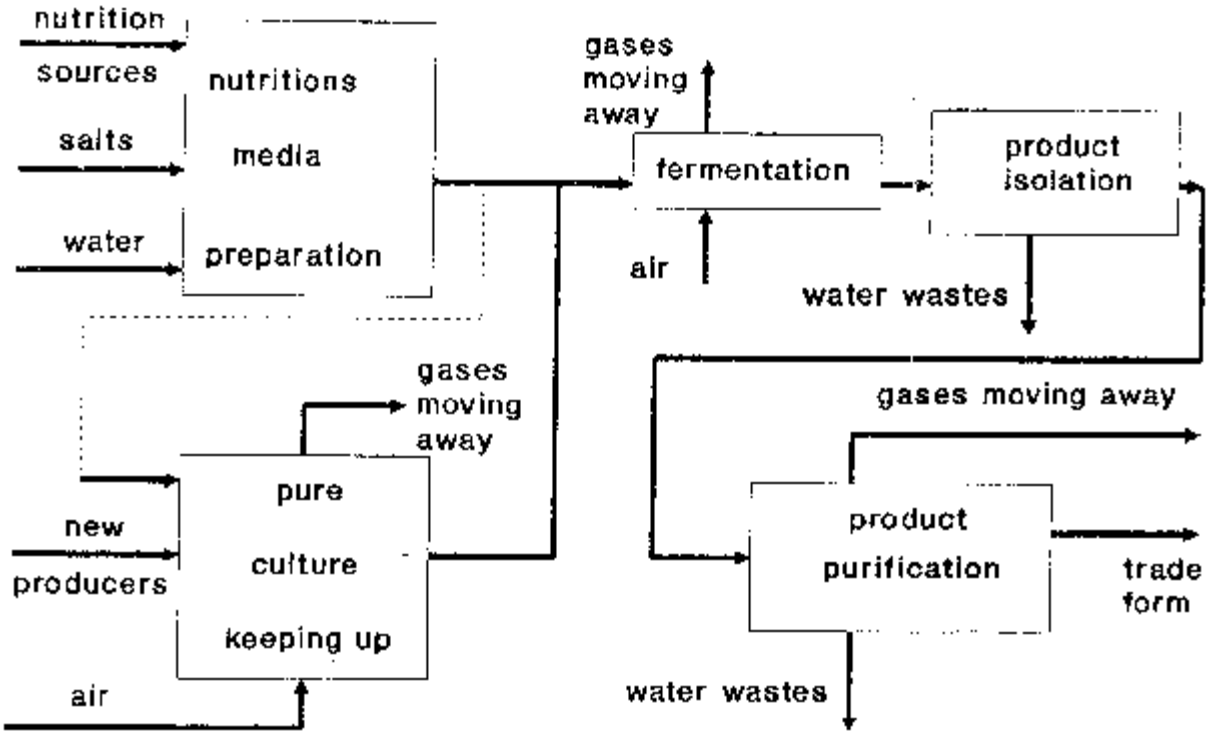

Figure 1: Ecological appraisal of biotechnological industry.

The main industrial stage is fermentation. It carries a serious potential danger for the environment and requires special measures of safety during exploitation. Though it is impossible to exclude the probability of leakage of liquid from the devices or communications, one can nearly avoid it if the exploitation is proper. This is not the case with gaseous streams carrying cells. Sooner or later they find their way into the atmosphere. The process of cultivation of huge masses of microorganisms in rich nutritious media combines two closely connected tasks. The first is to protect the environment from the producer and it's metabolites. The second is to defend the content of the fermentator from contamination by the outside probably pathogenic microorganisms. Let us state that a solution can be provided using modern methods of sterilization of liquid and gaseous streams and by the maintenance of measures preventing contamination.

The first task can be addressed, but it requires very complicated and expensive technological decisions which compromise and provide minimum protection. It has to do, for example, with sterilization and huge amounts of gases being thrown out, something requiring high material and energy expenditures. As a rule, it suffices to maintain "top permitted concentration" of cells which is hardly substantiated and often unreliable.

The stage of isolation of the product from cultural liquid or cell biomass contains various technological methods such as evaporation, extraction, ionic exchange, precipitation, and so on. Here, from the ecological point of view, one must normally only take into account enormous amount of water wastes. Frequently, no gases are disposed when the evaporating apparatus is being explored properly.

The purification and acquisition of the biotechnological product's commercial form are connected with the process of removing moisture by drying in various devices. Here we come across vast streams of drying agents in gaseous phase, carrying cells and dust particles of various composition. It's commonly considered that gases moving out of dryers do not contain living producer cells, although it's impossible to exclude this event with absolute certainty. However, it should be noted that dead cells often pose no less of a danger to the allergic staff members and the human population in general than do living cells. Sterilization and even purification of gaseous streams leaving the dryers are commonly difficult to carry out; for some constructions it is almost impossible to do.

Therefore, the typical biotechnology plant may be considered dangerous, primarily for bringing cells of the producing culture into the environment. The most dangerous are the stages of preparing sowing culture, fermentation and the product's drying. Experience in the U.S.S.R. shows, however, that technological methods exist which can entirely preclude the introduction of the culture into the environment. This involves drying with a closed cycle of drying agent and water, washing and burning of fermentation gases. The use of enormous amounts of water as a base of nutritious media in biotechnological industries is also a very important problem. It results in the waste of great amounts of

water containing organic and inorganic compounds and characterized by high values of chemical and biological consumption of oxygen.

In spite of reliable data about the possibility of using such water for irrigation in some cases, it requires a developed system of purifying devices. At the same time it's obvious that this water contains metabolites and nutritious salts only. That's why it is not ecologically dangerous.

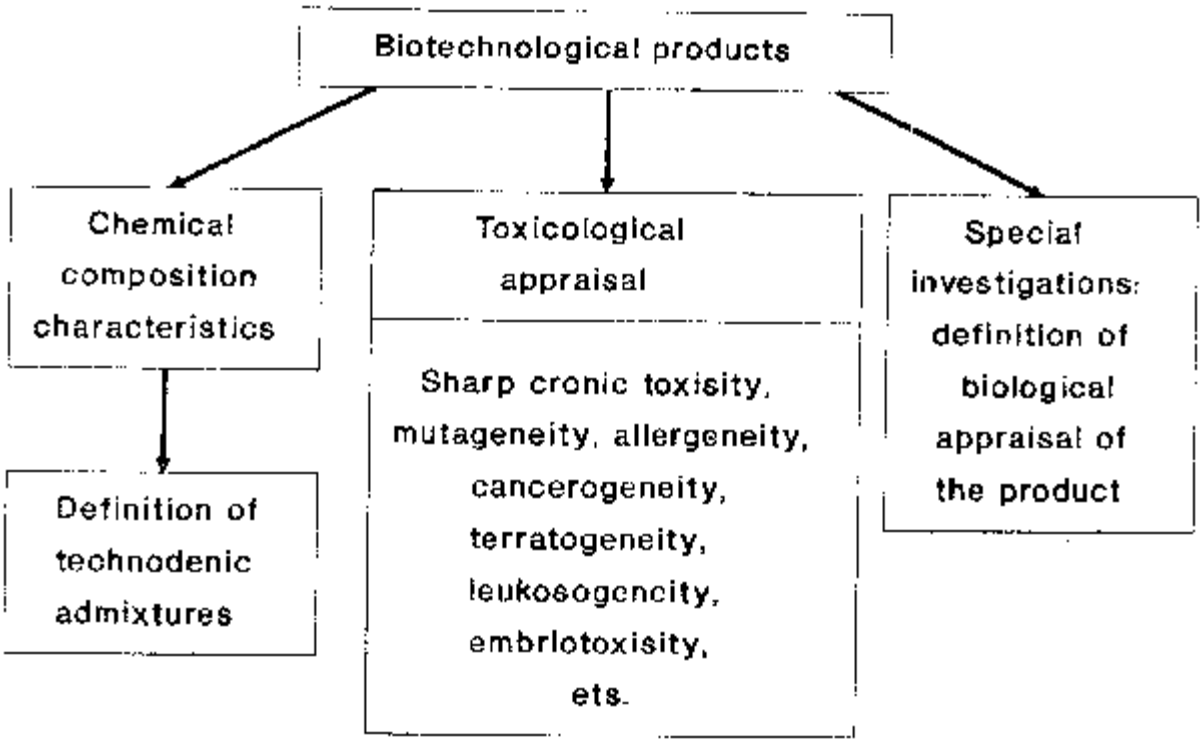

Figure 2: Determination of harmlessness and biological appraisal of products.

Nowadays, it's possible to speak about the creation of biotechnology plants with a closed metabolic water cycle, maybe without purifying devices. This new principle of industrial manipulation is being realized in industrial biotechnology in particular.

Ecological control of biotechnology plants

The experience of the construction and exploitation of large biotechnology plants in the U.S.S.R. and the whole world shows that the maintenance of the ecological safety of industry and of its products is quite attainable. It concerns such industries as lysine and glutamic acid biosynthesis and single cell protein obtained from different natural as well as synthetic materials. At the same time, no one doubts that constant quality control of the product and its ecological characteristics is needed. The main requirement for biotechnology plants using microbiological objects is giving them ecological-hygienic appraisal (Figure 2).

Quality control of the biotechnological product includes careful and comprehensive chemical, medical and biological (veterinary) investigations of its properties and ways of using it. It takes place during the period of pilot testing and is regarded as finished after the decision of the State Control Committee. The last step is the statement of the standard of the product.

Further control at the stage of production commonly includes only the checking of accordance of the chosen part of the product to the standard. As a rule, standards include not only indices characterizing the lower threshold of main compounds' content and the upper limits of undesirable admixtures' concentrations, but also properties which are important from the point of view of the product's keeping and the safety of its usage. These standards are stated based on the results of the preliminary investigations as shown in Figure 3.

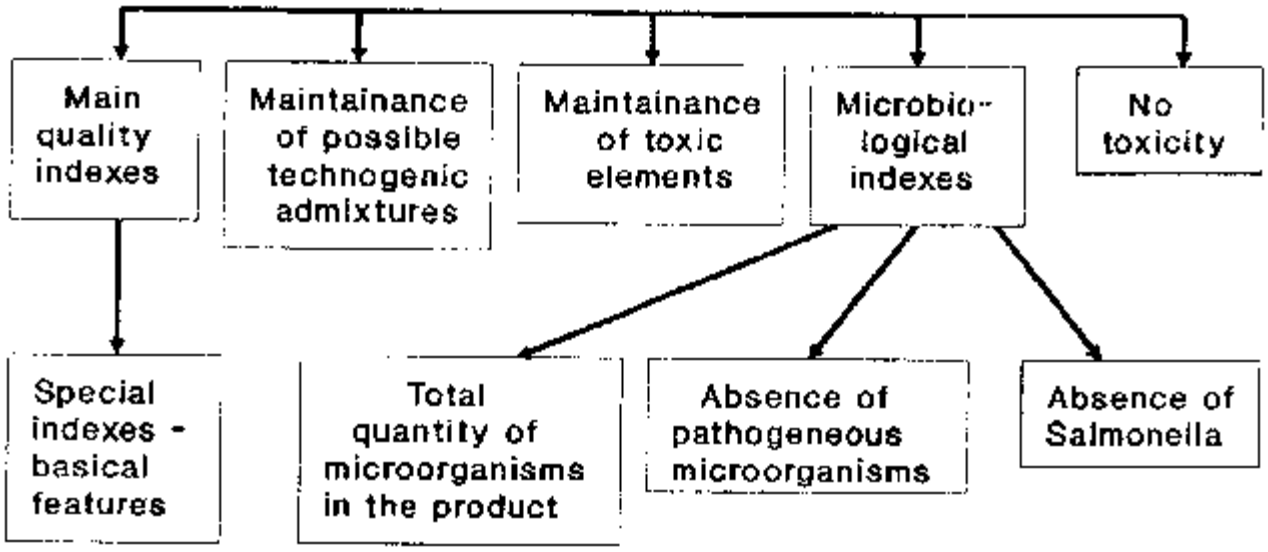

Figure 3: Standard of products' quality.

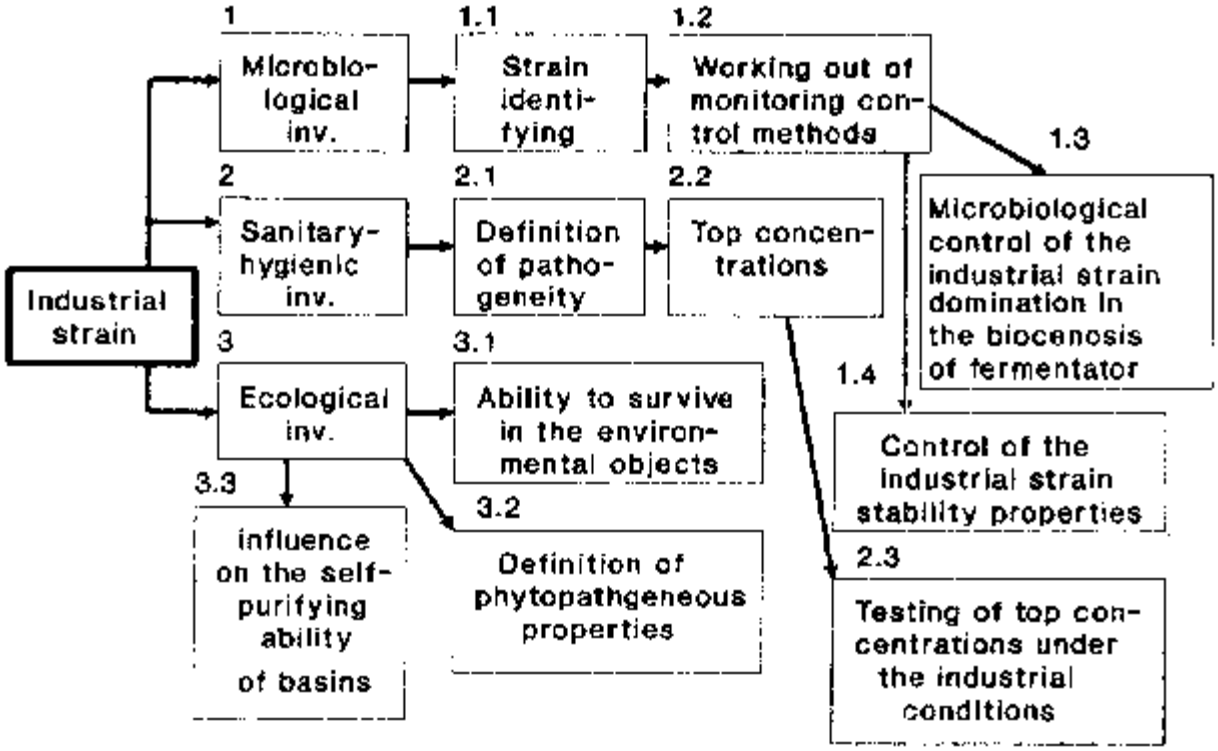

Figure 4: Ecological and hygienic investigations of the industrial strain.

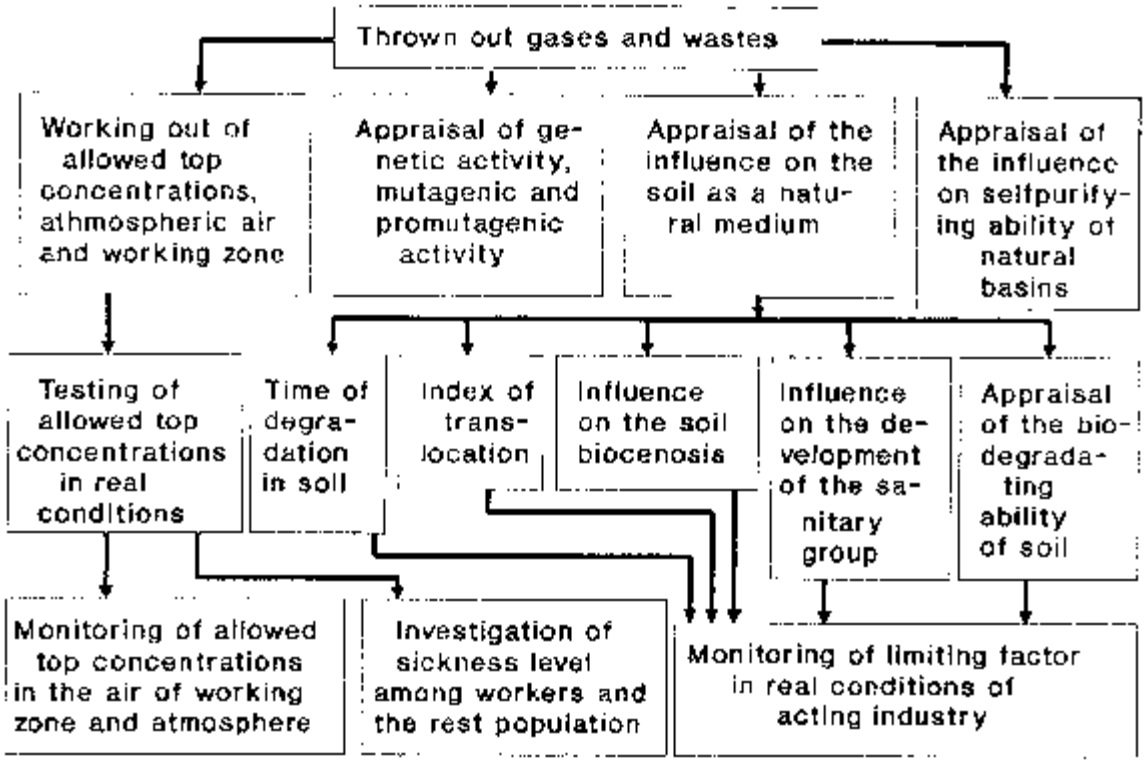

Figure 5: Ecological and hygienic appraisal of technogenic factors, thrown out gases and wastes.

Recently, ecological control assumed great importance for industries producing biotechnological products which were quiet, safe and permitted for application. This phenomenon is related to changes in the appraisal of the safety of compounds and microorganisms by certain industries. Before, biotechnology used the experience of chemistry and operated with the definitions of "top permitted concentrations" for microbiological objects as well as for biochemical ones. Today, the situation has changed dramatically. The experience of plants' exploitation showed the unreliability of such approaches and the need for additional investigations. This is also true for the chemical industry and industry in general.

Figure 4 illustrates the modern approach to the ecological appraisal of any industry. As for biotechnology, it is based on biotestingöthat is the appraisal of the real influence of the ecologically significant industrial factors of a certain situation in the certain region. The most important stages of control are:

- A safe level, top permissible concentrations and main specific gaseous wastes (dry mass of inactivating microorganism cells and their components, products of their metabolism) rate being established for the worker and in the atmosphere using the limiting index (according to toxicity, allergiogeny and other factors);
- appraisal of the influence of the main gaseous and solid wastes of industry on the composition of soil biocenosis, soil biodestructive properties and on the development of sanitary-significant groups of microorganisms;
- appraisal of the influence of possible water wastes on the self-clearing ability of basins and on the general sanitary index of their condition;
- a time definition of disintegration in the soil and in the water of natural basins accounting for their level of entry during the regulation regime or in case of emergencies;
- a definition of translocation properties;
- monitoring methods for the control of wastes influencing the environment;

Monitoring systems which control the safe exploitation of biotechnology plants include:

- Setting top permissible concentrations of the main technogenic product in the working zone and in the atmosphere;
- disclosed limiting index monitoring in the soil and in the water of natural basins.

The acute problem of monitoring the organization of biotechnology plants is working out effective methods of discovering the bio-technological factors that affect the environment. Using plants means dealing with food yeasts (Figure 5), showing that the specifications of bio-technological factors stipulate the perspectival use of immunochemical and immunoenzymic methods for monitoring. It is obvious that such control gives much more useful results than the simple shadowing of the top permitted concentrations. But at the same time, it further

complicates matters by requiring highly qualified staff. One should also note that the methods of investigation necessary for such control haven't been worked out sufficiently. Their creation seems to be the main task of the scientists using industrial biosynthesis in their work. One should pay special attention to the industries using genetically changed strains, hybridomas and other products of modern molecular biology.

Ecological education as the most important task of biotechnologists

The practice of creating and exploiting plants producing single-cell protein and amino acids in the U.S.S.R. shows that these enterprises may elicit negative reactions by people, although the working personnel does not find its working conditions uncomfortable.

Thus, understanding the necessity and value of food, fodder and medical products in conditions of shortage does not guarantee a positive or at least a neutral attitude of people with respect to the plants producing these products, even though these may employ modern biotechnological methods. We see the reason in this contradiction between the latest achievements of biochemistry, microbiology and molecular biology and the educational level of people who have no information about these sciences. That is why they easily reject positive statements of the scientists and fall into panic, thinking of possible diseases.

It became obvious in the U.S.S.R. that such kinds of ecological conflicts may be a serious obstacle in the development of biotechnology and scientific and technological progress overall. Scientists and practical workers who deal with biotechnology pay more and more attention to the perfect ecological safety of biotechnological industries. They also unite their efforts in popularizing the safety and effectiveness of biotechnology among non-professionals, including people living near plants and deputies of the Supreme Soviet. Numerous organizations have been formed with this aim. The most important are the Soviet Biotechnological Society and the Russian Academy of Biotechnology. A new specialty of "biotechnology in environmental protection" has been functioning in schools of higher learning since 1991.

We are certain that international collaboration in terms of the Biopolitics International Organization will lead to the successful maintenance of the human right to live in safety. At the same time it is hoped that it will contribute to the dramatic increase of the level of ecological safety of industrial biotechnology.

Professor Mikhail N. Manakov is currently Director of the Institute of Food Substances of the Russian Academy of Science, and Head of the Chair of Industrial Biotechnology at the Mendeleyev University of Chemical Technology. Author of more than 200 scientific papers and patents in the field of chemical technology and biotechnology, his current interests are in the microbiological synthesis of biologically active substances, food chemistry and biotechnology and ecological problems in industry.