WORKING PAPER

ECOLOGICAL PROBLEMS:
THEIR STUDY AND SOLUTION IN THE USSR

Academician A.L. Yanshin

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FOREWORD

This paper is to appear in the Proceedings of the Workshop on Ecological Sustainability of Regional Development, held in Vilnius, Lithuania, USSR, 22-26 June, 1987. The author Academician Yanshin is a distinguished ecologist and friend of IIASA who always has something important to say. That is why this work is being published as a IIASA Working Paper, i.e., to provide earlier publication and to reach a wider audience.

Academician Yanshin gives an interesting account of the work of the Soviet Scientific Council on Problems of the Biosphere, citing very concrete examples of its success in the field of environmental management over the last decade. No doubt this is due to the leadershop of Academician Yanshin himself.

The paper also provides some interesting perspectives on Vladimir Vernadsky, the great Soviet ecologist, whose book *The Biosphere* (1926) is a classic.

R. E. Munn
Leader
Environment Program

ECOLOGICAL PROBLEMS: THEIR STUDY AND SOLUTION IN THE USSR*

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The term "ecology" was suggested one hundred years ago by the German Darwinist Ernst Haeckel to denote a science that includes studies of the relationships of plants and animals with certain physico-geographical conditions. Studies of these relationships were then being carried out but the relationships themselves were assumed to be unchangeable. In the XIXth century the problem of their changes, and of the evolution of ecological relationships, had not yet been formulated; even the problem of human ecology had not arisen. This probably resulted from old religious notions that human beings are above nature and human society develops according to its own laws independent of the laws of the development of nature. Only the most intelligent people at that time reflected on what we now call "human biosocial nature", believing that human society should develop according to the laws of nature and not contrary to them. That idea was expressed most clearly by Friedrich Engels, who was one of the greatest natural scientists.

The time foreseen by Engels has now come. The general laws of evolution that are common to both human society and living and non-living nature which surrounds us have been considered by our contemporaries—including the Soviet scientists V.G. Afanasyev, N.N. Moisseyev, D.K. Belyaev, I.T. Frolov, S.P. Mikulinsky and others, by the scientists from the Club of Rome, and in the recently published book by Ervin Laszlo *Evolution: The Recent Synthesis*. In these works an attempt has been made to consider the social evolution of human society as a historically inevitable natural process. Some personalities can slow down, or hinder that process, but they cannot stop it.

The first scientist who considered human society as part of the history of the biosphere of the Earth was Vladimir Vernadsky. The 125th anniversary of his birth will be celebrated in March 1988 in the Soviet Union and many other countries, e.g., Czechoslovakia, France, and the United States of America, although Vernadsky's work is not sufficiently known in western countries. In his early papers at the end of the XIXth century, V.I. Vernadsky pointed to the huge and rapidly growing scale of human activity, quite comparable with the most powerful geological and geochemical processes occurring in the upper shell of the Earth. In these papers Vernadsky warned that a dramatic growth of human activity would inevitably produce situations dangerous for mankind itself, if that activity did not proceed in accordance with natural processes, but conflicted with them, disrupting the natural course of events. He warned that ignorance of natural processes and of the ways of their development and neglect for these processes may result in

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conflicts between human society and nature.

In his later works at the turn of the century, Vernadsky focused on the problem of a new science—geochemistry, which was emerging at that time and of an old science—mineralogy, which he had considerably renewed by his genetic approach. In these works Vernadsky carefully studied the behavior of each element in the biosphere—the Earth's shell where living matter exists; he discovered the role of each chemical element in human activities. At that time some of the chemical elements of the Mendeleyev's periodic system were not known to be of practical value. Now, all of them are not only used, but also chemical compounds of these elements are created that do not occur in nature. For instance, such elements as gold and silver were never found in a natural state but only as compounds. Now, pure aluminum, iron and titanium are produced in vast quantities. People have obtained these absolutely new forms of chemical elements unknown in nature.

At the General Assembly of the Academy of Sciences in 1911, Vernadsky presented a very interesting report. He pointed out that in future, mankind will definitely learn how to use the energy of atomic fission and thus get a source of energy of such a power that was not known before. That is very significant since the report was made only about 10 years after Becquerel and Pierre and Marie Curie discovered radioactivity. In 1911 no scientist took this prediction seriously. In 1922, Vernadsky repeated that prediction and said that the time of mastering nuclear energy was at hand. For the first time he raised the question: will mankind use this tremendous source of energy for increasing its wealth or for self-destruction? A clear warning was issued by Vernadsky back in 1922! A little later, in 1923, Vernadsky left Russia for Prague and Paris where for two years he lectured in geochemistry. In his lectures he revealed the role of each chemical element in the processes in the biosphere including human activity; that activity was considered by Vernadsky to be a biospheric process.

As a result of his investigation, a new science appeared—bio-geochemistry, i.e., geochemistry associated with life, with the activity of living organisms and living matter of the biosphere.

During the following years Vernadsky paid a lot of attention to the investigations of all the parameters of the biosphere and not only to the chemical processes in it. The questions he studied included: how much solar energy is consumed by green plants; what is the mechanism of the formation of elementary organic substances by plants powered by solar energy; and, what is the mass of living matter in the present biosphere. At the same time the first step had been taken in investigations of the evolution of the biosphere as part of the history of the Earth.

In 1926, Vernadsky's fundamental work *The Biosphere* was published. I regret very much that this work has not yet been published in English. We will do it in the nearest future. The lectures Vernadsky held at the Sorbonne were published in Russian and French in his book *Essays on Geochemistry*. Having generalized in these works his early studies of the biosphere, Vernadsky continued to study these problems until his death in 1945.

In 1940, another large and very important paper was published in Russia entitled *On the Autotrophy of Mankind* (this was published in French in 1925). The term "autotrophic" was introduced by the German physiologist W. Pfeffer to denote green plants, because only these plants consume solar energy by chlorophyll grains. Then these plants produce elementary organic substances, mostly carbohydrates, and in minor quantities, proteins and various fats using carbon dioxide, water and mineral substances that are extracted together with water by the roots of the plants. All animals are heterotrophic; they cannot produce organic substances out of inorganic ones, they either feed on plants or prey on each other. Human beings are also heterotrophic, as were the primitive people of the Stone

Age. They were entirely dependent on the natural environment, dressed in animal skins, living in huts of stakes covered by animal skins, and fed on plants and animal meat. Vernadsky pointed out that in the process of the development of civilization people gradually acquired some autotrophic features. They learned to build their houses of bricks and concrete. Modern people are increasingly using synthetic fabrics for their clothes and even produce synthetic furs out of natural gas and other inorganic substances. I recall meeting with our late President, Alexander Nesmeyanov, to discuss the organization of new reserves for preserving fur-bearing animals. He asked us, *why do we need fur-bearing animals when chemistry is now able to produce fur*?

V.I. Vernadsky followed very closely the early attempts to create synthetic food. We now know that microbiological processes permit production of proteins out of gas, and leaven out of timber wastes. Vernadsky believed that the creation of synthetic food will be a big step toward the autotrophy of mankind and its independence from the environment. Following his idea we can formulate a problem of synthesizing green chlorophyll plastids by which green plants consume solar energy. When people learn how to make synthetic chlorophyll, they will be able to produce unlimited amounts of food and fodder. This problem has not yet been properly formulated by scientists; however, it will undoubtedly happen in the next 100 years.

In the middle of the 1930s, during the last decade of his life, Vernadsky paid special attention to problems of the evolution of the biosphere, its qualitative changes beginning from the Earth's early days when only microbes inhabited the seas and oceans and the land was devoid of life and until the latest stage in the development of the biosphere when human beings appeared to change the biosphere. Returning to his earlier works Vernadsky studied the scales of human activity in more detail than before. He believed that collective human intellect will transform the spontaneously organized biosphere into a rationally controlled *noosphere* (noos is "intellect" in Greek). The noosphere is that stage of biosphere development where a collective human intellect has transformed it to meet the material, spiritual and esthetic demands of mankind.

In 1977, long after the death of V.I. Vernadsky, his paper *Scientific thought as a planetary phenomenon* was published. There he formulated 12 conditions essential to the transformation of the biosphere into the noosphere. I will not discuss all 12 conditions, and merely say that according to Vernadsky the main condition for the formation of the noosphere is removal of the threat of wars. As long as the possibility of wars exists, the biosphere cannot be transformed into the noosphere. Only the abolition of wars, only a friendly and peaceful life of all the people of our planet can ensure the right conditions for a noosphere.

Vernadsky died on January 5, 1945. A few months later nuclear bombs exploded over Nagasaki and Hiroshima. Vernadsky's prediction had come true: the energy of nuclear fission had been mastered. Unfortunately up to now a considerable part of the efforts of mankind has been spent on stockpiling nuclear weapons. Yet we trust that an agreement will be reached on uses of nuclear energy for peaceful purposes. At the same time, during the 42 postwar years, peaceful uses of nuclear energy have been increasing. In earlier times fearless explorers reached the North Pole. Nowadays ice-breaker ships with powerful nuclear engines easily pass through ice hummocks and polar ice on their way to the North Pole. By means of these ice-breakers a free passage is opened through the ice of the Arctic Oceans--from Europe to the shores of the Far East. Nuclear water distillers are working in deserts, on the coast of seas and salt lakes. They provide water for drinking and for technical purposes and generate considerable amounts of water for irrigation and planting of gardens and vineyards in deserts. A considerable amount of

electric energy is now produced by nuclear power plants (50% in France and 17% in the Soviet Union). The Chernobyl tragedy warns all people of the Earth that they should deal with nuclear energy extremely carefully. We cannot, however, stop developing new sources of energy. Scientists in many countries are working hard on controlled nuclear fusion. We will probably be able to use the energy of nuclear fusion in the foreseeable future. The power of mankind will increase tremendously if we agree to use this energy only for peaceful purposes.

The past 30 years can be rightfully called "the Age of the Scientific and Technological Revolution". This is due not only to the tapping of nuclear energy. People have gone into outer space and hundreds of satellites are now orbiting the Earth, studying both space and the Earth's surface. An entirely new science has appeared—studies of the Earth by space methods to monitor the condition of forests, correct topographic maps, forecast snow melt and river floods, and assess crops. Earth studies by space methods are useful in many ways.

The dream of Jules Verne has come true: people have walked on the Moon. Space instruments acquire data about all planets of the solar system and comets that stray into it. We now have an idea about the physical conditions and the surface relief of Venus, Mars, Jupiter's satellites and the structure of Saturn's rings. At the same time, during these 30 years, detailed studies of the microcosm, of the elementary particles have been conducted. New branches of industry have appeared as electronics and microbiology have continued to advance. The molecular mechanism of the transfer of hereditary features has been discovered. On that basis a completely new science has emerged, i.e., genetic engineering, that has already brought important practical results. During this 30-year period powerful computers have been built; no research center can now work without them.

The changes that have occurred during the past 3 decades are tremendous. They benefit mankind. Great advances have been made combating infectious diseases. In the XIXth century, smallpox wiped out the whole population of many islands in the Pacific. Twelve years ago, the World Health Organization in Geneva announced a reward of $6,000 for the doctor who would report one case of smallpox. The reward has not been claimed. Smallpox has been eliminated from our planet. Strides have been made in combating other infectious diseases.

Mankind's impact on nature has at the same time resulted in those conflict situations that V.I. Vernadsky warned against at the end of the last century. The sheer scale of cultural activity resulted in the pollution of the atmosphere, the hydrosphere (including the ocean) and the upper crust.

At the same time a rapid growth of the population began, leading to serious ecological problems. In my youth nobody thought or wrote about these problems, except V.I. Vernadsky, a scientist of true distinction.

A number of new global ecological problems have appeared. I will only mention some of them. It has now been accepted by all the climatologists of the world that the increase of carbon dioxide concentrations in the atmosphere is due to the burning of vast quantities of fuel in internal combustion engines of vehicles, coal-fired power stations, etc. We know that the carbon dioxide concentrations have not been constant throughout the history of the Earth. I recently had great pleasure in presenting to the IIASA library the book *The History of the Atmosphere* that I wrote in collaboration with Corresponding Members of the Academy of Sciences of the USSR, M.I. Budyko and A.B. Ronov. We followed changes in the concentrations of various gases in the atmosphere during the past 500 million years since skeletal life forms appeared on Earth. But, let us not go so far back. Let us dwell on what has happened during the past 50 million years. From the geological point of view that is a very short period. Recent carbon dioxide concentrations are within 0.03%; 50 million years ago it was 0.4%, i.e., greater by one order of magnitude. We

know definitely that at that time even the Antarctic had no ice cover and that it was inhabited by animals whose skeletons have been found. There were no drifting ice-floes in the Arctic Ocean. High forests were growing on Spitsbergen; this is borne out by coal deposits in Barentsburg. At that time, at 0.4% of carbon dioxide, the greenhouse effect was so intense that the climate of the Earth was everywhere warm, mild and there were no ice caps near the poles. We are of course very far from these conditions now. The concentration of carbon dioxide is increasing, however. And it is increasing not only in the urban areas but near the South Pole (according to the measurements of the Amundsen-Scott station) and on small coral islands in the Pacific, as well. These measurements show that in some cases the concentration of carbon dioxide is 0.045, i.e., it has increased by 50% in comparison with what it was in the first half of the century. Climatologists have revealed an increase in the average temperature of the lower atmosphere. It is still not large, only one or two tenths of a degree, but the temperature is increasing. Nobody doubts it and climatologists are now studying how this warming will influence the distribution of precipitation. Certain theories seem to be developing in this connection. They need of course checking.

In the Soviet Union three Institutes work in this field: the Central Hydrographic Institute of the State Committee for Hydrometeorology in Leningrad, the Institute of Geography, and the Institute of Physics of the Atmosphere of the Academy of Sciences of the USSR in Moscow. The latter has a big laboratory on the theory of the climate. The three Institutes have reported interesting data; the signs are that by the year 2000 a strip of climate more arid than at present will form in the south of Europe, to cover Spain, Italy, the northern Balkans, and the Ukraine in the Soviet Union. It will not stretch further to the east, however. North of this area and, what is very important to us, south of it, i.e., in Central Asia the amount of precipitation should considerably increase. We now observe that the snow cover near Moscow reaches 80-90 cm. The run-off of the Volga has considerably increased: it was especially large in the first half of 1986, when the level of the Caspian Sea rose by 8 cm. That amount of water was provided mostly by the Volga and to a lesser extent by the Ural River. Not everything is clear, however; absorption of carbon dioxide by the World Ocean has not been determined accurately enough, various scenarios are still being developed, but the general trend of the climatic processes has already been revealed. One of the most important problems of our times therefore is to work out a scenario of future climatic changes not only for one country or a comparatively small continent such as Europe, but for the whole world.

Let us consider some other global problems that have appeared recently. I have already said that large-scale air pollution is one of the main negative factors that have emerged during the past 30 years. The International Institute for Applied Systems Analysis is studying the important problem of acid rain. Smoke laden with sulphuric, nitric, and sometimes, hydrofluoric acids is carried by the winds over great distances. As a result, acid rain occurs in all the industrialized countries. When studying this problem, it is very important not only to determine the harmful effect of air pollution on the surrounding landscape but to involve economists in this work to show that control technologies can bring profit. This can be the case when the concentration of the vapor of sulphuric or hydrofluoric acids is sufficiently high. At low concentrations it will be unprofitable. I would like to give you the following example: in the Orenburg region in the Southern Urals large copper deposits were discovered in the 1930s. In these deposits copper is combined with sulphur in the form of chalcosine, chalcopyrite and bornite. A plant and the city of Mednogorsk were built in the Urals, 120 km east of Orenburg. The plant produced high-quality copper; sulphur gases of high concentration were discharged into the air, which resulted in the following consequences: at first,

tree tops withered and then forests underwent a complete degradation over a considerable territory. Our technologists and economists calculated, however, that it would be very profitable for the plant to retain this sulphurous gas and produce pure sulphur rather than sulphuric acid. The plant now produces copper and about 7,000 tons of pure sulphur per year. As a result the plant is more profitable. The Ministry of Non-Ferrous Metallurgy did not accept the project for a long time because sulphur is produced in the USSR by another ministry, the Ministry of Chemical Industry. Sulphur emissions can no doubt be reduced at a profit for those factories and companies that are melting sulphide ores.

Rivers and lakes have been polluted during the recent decades. I will later speak about what has been done to deal with this problem in the USSR. It is especially disturbing that the World Ocean has also been polluted. This is to a great extent due to the increasing offshore extraction of oil and gas from the shelf. The entire North Sea in Europe, the Persian Gulf, the Gulf of Mexico, the South China Sea--all these shallow-water seas are covered by a thick net of oil- and gas-extracting platforms. Such platforms are hugging the northern and southern shores of Alaska, the shores of California, Ecuador, Peru, and Northern Chile, the western shores of Australia, and the shores of India near Bombay. They are located in the Bass Strait between Australia and Tasmania, in the Bay of Siam and in the Gulf of Guinea in Africa.

In 1985, 680 million tons of oil were extracted off shore. More was extracted in 1986. I do not know the exact figure but it should be over 700 million tons. Moreover, many countries that have no deposits on land extract hundreds of thousand tons from hydrocarbon deposits under the sea floor. These are, e.g., Nigeria, Norway, Denmark, and the Netherlands. These oil fields are in fact the main polluters of the World Ocean, since a certain amount of oil is lost due to drill failures, and in the process of pumping oil into tankers. Of course shipping has increased and this also pollutes the ocean. Here is an example. In 1947, Thor Heyerthal sailed on the "Kon-Tiki" from Peru's shores to a small island in the Paumotu Archipelago. On his way he saw clean water, plenty of fish and other animals. Twenty-three years later in 1970, he made a trip on the sailing boat "Rha" from Morocco to the shores of Venezuela. All the way across the Atlantic Ocean he saw no flying fish, but observed oil slicks and encountered drifting plastic bottles and wastes.

The upper crust of the Earth and underground water are also being polluted. In many cases, under the influence of human activity, karst processes develop. This has occurred even in Moscow as a result of water leakage out of sewage and water-supply systems.

A mass movement for environmental protection began in the 1960s, about 25 years ago. In 1972, a special session of the United Nations focused on this problem. It was decided to form an international body on environmental programs--UNEP--that now has its headquarters in Nairobi. UNESCO also adopted a number of international environmental projects while the Soviet Union began to introduce environmental protection measures at about the same time. A society for nature conservation was organized in the Soviet Union back in 1923, but it was a nongovernmental organization. In the 1960s and 1970s the USSR Supreme Soviet adopted a number of laws on soil protection, water protection, air-space protection and also resolutions on the protection of the Black and Baltic Seas. The Council of Ministers established a commission on environmental protection to enforce the laws. This commission does no research but it ensures that ministries and factory managers abide by the adopted laws. Moreover, the commission can impose large fines and dismiss offenders from their posts. The head of the commission is one of the first Deputy Chairmen of the Council of Ministers of the USSR, presently V.S.

Murakhovsky.

An interdepartmental committee for environmental protection was established at the State Committee for Science and Technology at the same time. In 1972, the Scientific Council on the problems of biosphere was organized at the Academy of Sciences of the USSR. Academician A.P. Vinogradov, its first chairman, was a well-known geochemist. After Academician Vinogradov's death in 1976, Academician A.V. Sidorenko was appointed to the post, and now I am in charge of the Council. I shall describe some aspects of its work.

We organize fact-finding conferences in various regions of the Soviet Union where abnormal ecological situations arise. I have participated in a number of such conferences: in Yakutsk on protecting the tundra and defining conditions for mining minerals in the tundra; in Kishinev, Moldavia, and in Yalta on improving the health resort zone in Kislovodsk and on the northern coast of the Black Sea. In 1984 I organized a visiting session in Yerevan. As a result, a governmental noosphere studies center was organized in Armenia. During the last two and a half years, this center has accomplished much: the proposed site for construction of a nuclear power plant has been changed, and it will be built in a remote and uninhabited valley in the mountains; the amount of Sevan water used by a chain of small hydro-power stations has been reduced; factories that polluted the air in the Ararat valley have been closed down. The last meeting of that kind was organized in 1986 in Ashkhabad, capital of Turkmenia. It was devoted to human ecology and natural conditions in the arid zone of Central Asia and Azerbaijan. The meeting considered what should be done to improve the environment in this arid region, where many oil and gas fields have been discovered. The meeting also examined health resorts in piedmontane and mountain regions of Central Asia, the stabilization of moving sands, control of desertification, and the rational use of the limited water in this desert.

In addition to these visiting sessions during the past two years, our Scientific Council on problems of the biosphere prepared the scientific basis for a number of governmental resolutions. We began with a study of a project to transfer waters of the rivers of Northern Europe and Siberia to the South of the country. We have comprehensively studied this question from the ecological and economic points of view, and have managed to prove that the transfer of the waters of the northern rivers (the Northern Dvina and Onega) into the Volga basin is of practically no use due to climatic changes that have begun. Over the past eight years the average Volga run-off has been 26 km^3 larger than that over the preceding one hundred years and is increasing. Building new reservoirs on the Upper Sukhona and Onega on fertile soils wastes money for only 6 km^3 of additional water is transferred into the Caspian Sea. But the Caspian Sea does not need water. Its level has begun to increase. One should start thinking of how to decrease this level, e.g., by transferring large amounts of water to the Carabogaz Bay that earlier evaporated about 6 km^3 of water.

As for the Siberian rivers, the problem has not been removed from the agenda. The population of Central Asia is rapidly growing due to a high birth-rate and the migration of Soviets from Siberia and the Far East to a region with better climatic conditions. Central Asia will need water. The resources of the Amu-Darya are practically exhausted. The completely exhausted Syr-Darya does not reach the Aral Sea. But the project on which work began is not satisfactory. It would give Central Asia only 8 or 10 km^3 of water. This is too little because due to faulty irrigation, Central Asia now loses about 26 km^3 of water. Measures on water economy should be taken there before water transfer from Siberia begins. It is probable that in the XXIst century we shall reconsider this project. In any case, we reported our calculations and presented them to the government and on August 14,

1986 it was announced that the transfer to the South of part of the run-off of the northern and Siberian rivers had been cancelled.

The second problem being studied under the supervision of our Scientific Council is that of Baikal, the wonderful lake, about 2 km (1741 m) deep, in eastern Siberia with amazingly clear water. Baikal waters are clean due to the resident fauna: a tiny swimming crayfish "epischura baikalensis" inhabits the upper layer of the water. It filters water through its body leaving the suspended particles in its tiny shell. Six generations of crayfish live and die during the summer period, and six times these epischura shells with their loads of suspended particles drop to the bottom. This explains the amazing purity of the Baikal waters. In 1955 it was decided to build a pulp-and-paper mill on Baikal. It was supposed to produce cellulose cord for the aviation industry. However, the industry stopped using cellulose cord and began to use a metallic one. The factory began to produce ordinary paper. And though there were water-treatment facilities, the factory polluted Baikal. We suggested moving the production of cellulose down the Angara river to the North where conditions are right for the production of cellulose. In April–May, 1987, our governmental bodies announced their decision to purify not only Baikal itself but all the rivers flowing into it, to enhance the sewage systems of the cities on these rivers, to stop the production of cellulose on Baikal and to move the factory to the new city of Ust-Ilim, being built on the Angara.

A third problem that our Scientific Council has considered is how to keep Lake Ladoga clean. This is the source of the Neva River, which provides Leningrad with water. This problem was mostly considered by our colleagues from Leningrad, but we discussed their proposals at meetings of our Council and then presented them to the government. A governmental resolution on the protection of Lake Ladoga has recently been published. This means that another of our regional ecological projects has been successful.

We are now examining the project to build another water reservoir on the Upper Volga near Rzhev to provide Moscow with water. According to this project, 60 km^2 are to be flooded but we are against building reservoirs in plains (they can be built in montain clefts). Fertile lands are too valuable to be lost to water reservoirs. We have succeeded in demonstrating that underground sources around Moscow can provide more water than could be obtained from this new reservoir. The latter was supposed to give 23 m^3 per second. We have shown that the underground sources around Moscow can give 35 m^3/sec. That was the main argument against building a new water reservoir. The Council of Ministers of the Russian Federation has already considered our proposals and agreed with them. The resolution is under consideration by the Council of Ministers of the USSR and will probably be adopted.

I have used these examples to show how environmental protection is developing in the USSR. Of course, our Scientific Council is not the only body working in this field. We have a powerful Soviet Committee for the International Program "Man and the Biosphere", headed by Academician V.E. Sokolov. This committee has been very successful in establishing nature reserves and saving many endangered animals. During the war, the European buffalo was practically exterminated in the Soviet Union. Now buffalo live in Belovezhskaya Pushcha on the border with Poland, a reserve on the left bank of the Oka River near Moscow, and the Northern Caucasus; a herd of buffalo has appeared in Lithuania. An attempt was also made to introduce buffalo to Central Asia but the buffalo ate the young trees and had to be removed.

The saigak is our steppe antilope. At one time the saigak population fell to 12 thousand but now in Kalmykia and Kazakhstan, it is at 600,000. The population has been completely restored!

Reserves helped greatly in protecting fur animals and the sable, particularly in the Kondo-Sosvinsky reserve on the eastern slope of the Urals and in the Barguzinsky reserve on Baikal. At first, the sables were bred within the reserve but later the animals were allowed to migrate into the forests of adjacent territories where sable hunting has now resumed.

There has been some progress in nature conservation and environmental protection in the Soviet Union, just as in many other countries as well. I am aware of the allocations of the government of the Federal Republic of Germany to clean the Rhine, and I know how many billions of dollars the United States of America has spent to clean the Great Lakes. Efforts in this direction will no doubt continue and should increase, due to the growing population of the Earth.

I have not mentioned some other important ecological problems, such as desertification in tropical countries. A great deal has been done toward solving that problem. I would like to dwell now on the science of human ecology which gradually evolved as the above ecological problems were been studied. In the XIXth century, ecology included plants and animals but not human beings. Today human ecology or the study of human adaptation mechanisms to new, unusual and/or extreme situations assumes great significance. People survive in outer space and at sea depths of up to 200 m. In older times, in the regions of the alpine meadows in high mountains, only shepherds could live for half a year. Nowadays we build permanent settlements and mines for extracting minerals at an altitude of 4,000 m. Living conditions at such altitudes should be studied. A special institute of human physiology and pathology at high elevations has been organized at the Academy of Sciences of the Kirghiz SSR in Frunze. An institute of the same kind in Ashkhabad (Turkmenia) studies human ecology in dry hot desert climates. There are permanent settlements in the Antarctic where living conditions (half a year without sun and with a temperature of minus 60-70° Celsius) also must be studied.

And finally I should mention the problem of large cities. I think that the ecological situation here is no less extreme than in deserts or high mountains. The stress of living in large cities, exposure to X-rays instruments, noise, etc. is definitely extreme. It is not by chance that we have overcome infectious diseases while the deterioration of the human organism's functions intimately associated with city life is growing dramatically. The number of deaths from cancer in a city is proportional to its population. At the same time, in regions where there are no large cities, as in Yemen, our doctors could not find a single case of cancer in five years. Not only cancer, but chronic lung diseases, upper respiratory tract ailments, bronchitis, allergic diseases, malfunctions of the cardio-vascular system are typical diseases of large cities, let alone mental disorders. That is why the study of human ecology under extreme conditions, including those of large cities, are also likely to be given high priority.

I would like to say a few words about the near future. In the Soviet Union we are preparing to merge the many organizations for nature conservation and to establish a State Committee for nature conservation to be headed by one of the Deputy Chairmen of the Council of Ministers of the USSR. This is necessary to ensure that the resolutions of this Committee are obligatory for all firms and all ministries. This year a large program on biospheric and ecological investigations has begun to be drawn up at the Academy of Sciences of the USSR. Mindful of the great importance of biospheric and ecological investigations for the future of the whole mankind, the President of the Academy of Sciences of the USSR, Academician G.I. Marchuk, has agreed to head this program. The program will include the following sections (they have not yet been finalized): a section on the biological aspects of the program, headed by Academician V.E. Sokolov; a section on the geophysical aspects (mostly concerning the expected global changes of the atmosphere and meas-

ures to keep its purity), headed by Yu.A. Israel, Chairman of the State Committee for Hydrometeorology; a section on the ecology of industrial factories, led by Academician B.N. Laskorin, who was instrumental in designing a closed water supply for industrial factories in the USSR; a section on ecology of agriculture, headed by Academician Kashtanov, a Vice-President of the Academy of Agricultural Sciences; a section on conservation and recovery of soil fertility, headed by V.A. Kovda, Corresponding Member of the Academy of Sciences of the USSR; a section on conservation and recovery of forests, not only as a source of timber but as a necessary element of nature as well, headed by Academician A.S. Issayev, from Krasnoyarsk; a section on human ecology, to be headed by myself and some of my assistants; a section on regional ecological problems of Lake Baikal, to be headed by a Corresponding Member of the Academy of Sciences of the USSR, V.M. Kotlyakov, who is director of the Institute of Geography of the Academy of Sciences of the USSR. Finally there is the section on energy and mass exchange in the biosphere, headed by Academician K.Ya. Kondratyev.

I would like to add that the International Council of Scientific Unions (ICSU) has decided that beginning in the next decade, IGBP (the International Geosphere-Biosphere Program) will be a main subject of investigation. This program may cover a period of 500 million years, but attention will likely be paid to the changes that have occurred during the last 2 Ma, i.e., covering periods when glaciers repeatedly advanced and retreated in and out of northern Europe. Sometimes Europe resembled Antarctica and Greenland today but at other times walnut forests were growing in Yakutsk in the north of Siberia (their fruit was found and described by Academician V.N. Sukachev in the sediments of the last interglaciation near Yakutsk). Although the main elements of IGBP are still being considered by the Special Committee appointed by ICSU, it is likely that changes in the Earth's geography, in its climate, and in sea level over the past 2 Ma will be one of the main parts of the program. I think that IIASA, where interesting and important investigations of the biosphere are carried out, should become involved into this international program, it should widen its investigations of the biospheric problems. For example, it might be desirable to expand the IIASA European Case Study, in which environmental changes in Europe are being pieced together for the past 300 years, to include the whole globe and to extend the time scale from 300 years to 300,000 years.

I believe that this is a very important task. That is why I will contribute my own efforts to promote it, but the leading role must be played by the research scholars of IIASA. You can accomplish much and I wish you every success. Resolution of these crucial problems is of vital importance for the future of mankind.