

complete freedom must be provided for the development of human culture. Until now in the course of millions of years mankind by means of trial and error has itself found the path towards the development of civilization. And it will find such a path again.

Another opinion, a more constructive one, as many justly consider, is that the necessity of solving global problems will lead mankind to build a society with a socialistic structure, and that only with such an organization of society will it be possible to make compatible the interests of individual states with the interests of mankind as a whole^[8]...

For the solution of global problems it is necessary that a number of sectors of world economy associated with ecological problems should come under international control. There is a tendency towards this already. For example, with ever greater frequency appeals are heard that the exploitation of the world's oceans and, in particular, the extraction of raw materials from their depths, should be controlled by the United Nations.

It is also becoming necessary to solve the problem of the supply of energy and the utilization of energy resources on an international scale. This has already begun to be realized in the creation of the International Atomic Energy Agency whose principal function is the control of resources and of the safety of utilization of atomic energy on a global scale.

An effective solution of global problems will become possible only if their significance for the fate of humanity will be widely understood by people, and this is possible only if these problems receive wide discussion. Therefore scientists must take care that the discussion should be carried out on a strictly scientific basis. Of course, the solution of global problems must be based on the ethical obligations of man toward society.

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⁴Fire at a Nuclear Plant, *U.S. News and World Report*, February 16, 1976.

⁵Les déserteurs de l'atome, *Le Nouvel Observateur*, 1-7 Mars 1976.

⁶Testimony of Dale G. Bridenbaugh, Richard B. Hubbard, and Gregory C. Minor before the Joint Committee on Atomic Energy (February 18, 1976), Washington, 1976.

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Man and environment—problems of the future

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In our time of rapid scientific-technological progress specialists in narrow fields of science can no longer not participate in the discussion of more general problems of the development of science, technology and production and of their effect on the development of human society. There exist two main global problems which relate to our whole planet and which in the foreseeable future will affect the conditions of human life. The first of them is associated with the depletion of natural resources, with this occurring against the background of increasing numbers of population. The other problem is due to the effect of man on the environment. As production increases this effect is intensified and, if it is not controlled, then the pollution of the environment will rapidly exceed admissible limits.

Let us consider these problems in greater detail. As regards natural resources, with present rates of growth in the extraction of useful minerals man is capable with-

in the next one-two hundred years of exhausting many of them. The present methods of energy production are based on chemical types of fuel: the burning of coal, oil, and gas produces approximately 95% of energy. At the beginning of the next century the role of atomic, and then of thermonuclear energy production will have to increase sharply in importance. For the operation of transport it is proposed to develop energy production based on hydrogen. It is based on artificial fuel (for example, hydrogen) which is produced utilizing atomic and thermonuclear energy and which is used in the same manner as gasoline is used at present. In this manner we possibly shall encounter a peculiar situation when mankind shall have to pay for the scarcity of certain useful minerals by a still greater increase in the production of energy. However, energy is not a universal substitute. And the problem of creation of new materials, the search for new technological processes, the problem of recycling of materials all become very pressing ones.

Another characteristic of the immediate future of mankind is associated with the fact that as production increases the scale of the effect of man on the environment becomes ever more pronounced. At the present time over the whole planet the natural emission of impurities into the atmosphere for each of the principal components is on the whole still considerably greater than the artificial emission. However locally in certain individual locations this relationship becomes different. In particular, the climate and the physical-chemical properties of the atmosphere for a large city and for whole manufacturing regions are to a significant extent related to the manufacturing activity of men and differ noticeably from the corresponding characteristics of the surrounding region. As production increases the scale of such influence becomes greater and the problem faced by science is not only the necessity to understand the nature of the influence of man on the environment but also the necessity to understand the consequences of this influence.

At the present time we are insufficiently prepared for the solution of such problems. A vivid example of this is the problem of ozone in the stratosphere which has suddenly arisen several years ago. Its essence is that the practical activity of men can lead to a reduction in the amount of stratospheric ozone to dangerously low levels. This problem had a great social response (the question was discussed in the U. S. A. Congress). In the course of several years as a result of carrying out laboratory measurements and theoretical calculations it turned out to be possible to make an estimate of the artificial effect of man on stratospheric ozone. It turned out that the greatest danger in this regard is presented by freons produced by man which on reaching stratospheric heights are decomposed there under the action of ultraviolet radiation from the sun. Atomic chlorine liberated in this process participates in a chain reaction leading to the decomposition of ozone. Estimates have shown that if the present rate of increase in the production of freons is maintained, then at the turn of the century the reduction in stratospheric ozone will become noticeable and will exceed the value of natural fluctuations of its content in the atmosphere. If after this the emission of freons into the atmosphere is completely stopped then the initial content of ozone will be re-established only after several decades.

It is much more difficult to estimate and predict the danger to man of such alterations in nature. In this case it has not yet been established as to how the reduction of the amount of ozone in the atmosphere affects people's health. It is only clear that a significant change in the balanced relationships in nature that have been formed in the course of millions of years can lead to undesirable or even to irremediable consequences.

The new scale of production sets before humanity problems that are new in principle. Serious effort on the part of scientists and engineers will be required by the problem of safe disposal of radioactive wastes from

nuclear energy production, and by the problem of safety of nuclear reactors discussed in the preceding article by P. L. Kapitza. The exponential growth of the production of energy can lead to the so-called thermal pollution, a catastrophic alteration in the heat balance of the earth. However, due to the lack of a number of needed data it is difficult to ascertain at what scale of production will the thermal pollution of the environment become dangerous. The accumulation of such data is a serious scientific problem. The creation of technological and energetic processes which enter into the cycles of phenomena occurring in nature without upsetting them will play a prominent role. Examples of such processes are the utilization of such pure energy sources as the energy of the sun, the wind, etc.

In estimating the promise offered by one or another source of energy, technological process or material one should keep in mind that the re-examination of values occurring at present, both in the figurative and the literal sense (increase in the price of raw materials and, in particular, of oil)—will be accelerated. As a result of this much of what appears to be exotic today may turn out to be profitable tomorrow. In this respect the task of science is not only the determination of the nature of the effect man has on the environment, and the estimate of the consequences of this effect, but also the planning of correct solutions.

Physics is called upon to play an important role in the solution of the global problems of the interaction of man with the environment. It is physicists in particular who in the recent past have discovered and developed the principal ideas of atomic and thermonuclear energy production. Modern physics possesses a sufficiently high scientific potential to make significant contributions to the solution of problems confronting humanity. It is sufficient to mention here the quantitative approach to problems which characterizes the posing and the solution of physical problems, the application of physical principles to the creation of apparatus for the control of the environment and the colossal computational potential of modern physics institutes. Taking all these facts into account it must be acknowledged that the role played by physics in the formulation and the search for the solutions of the problems of the future and of the interaction of mankind with the environment is so far unjustifiably small. It is possible that to a certain extent this is related to the insufficient attention which is devoted to such problems in the process of teaching physics, in the process of education of young physicists.

We hope that publication of articles on this subject in our journal will attract the attention of physicists (students, teachers, research workers, engineers) to the problems under consideration, and that this will aid a more fruitful development of science in this direction of pressing importance for mankind.

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