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NUCLEAR ENERGY, PUBLIC HEALTH AND PUBLIC POLICY[1,2]

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Introduction

There are many among us who would hope that certain of the newer energy technologies will ultimately provide the substitute for the oil and natural gas that will eventually run out---solar power, fusion, wind, tides, and others. Each of these technologies has a role to play in the future and they should all be pursued and developed vigorously. But none is sufficiently advanced technologically at the present time to supply even a modest part, let alone a significant fraction, of our energy needs, at least during the rest of this century. When considering the time necessary for research and development for any new technology, we cannot count on them for the practical generation of electricity---particularly solar and fusion---perhaps for the next two or three decades. If the objective is to replace oil and natural gas in as many ways as is practical for all our energy needs in this country, then it is the presently developed energy technologies, coal power and nuclear power, which must bring us to the year 2,000 and beyond, since these two represent the principal alternatives for power generation for the rest of the present century (1).

The use of coal power plants and nuclear power plants to generate electricity inevitably result in risks to human health, both real and potential (2). The kinds of health risks are well known, and in large measure, their prevention is well understood, but the extent of these risks remains uncertain, and it is this that is the subject of considerable controversy. To be meaningful in connection with public policy decisions, these health risks cannot be considered in isolation, but must be compared with the risks associated with alternative options, including the risks of abandonment (3). In addition, the availability of both coal and nuclear energy technologies, directly and indirectly, provide more food and better housing for millions of Americans, and thus also effect a significant reduction in risks to health in the general population.

The Normal Operation of Nuclear Power Plants

When a nuclear power plant is operated under normal conditions for a long period of time, over many years, it generates a large amount of radioactivity in the core of the reactor. This radioactivity is contained by at least three engineering barriers which have proven to prevent the inadvertent loss of hazardous levels of radioactivity into the environment. Nevertheless, if a substantial fraction of this were accidentally released, the potential does exist for an accident with serious health consequences. When all health and engineering safeguards in nuclear technology are considered in perspective, then the current scientific and engineering studies---the best avaiable in the world---indicate that the probability of occurrence of an accident associated with release of radioactivity with serious health consequences in the general population is extremely small, if not negligible (4). When all technological, societal and political factors are considered---available alternative energies, probabilities of accidents, wars and military readiness throughout the world, space power satellites, radioactive waste disposal, emphysema and black lung disease, acid rain and carbon dioxide, transportation, nuclear proliferation, degradation of the environment, economics, industry, and politics---does the radiation as sociated with the operation of nuclear power plants in the United States present an unacceptable risk to the public health? The scientific, medical and public health evidence compels only one conclusion. It does not.

There are certain major factors to consider when judging the potential health risks from commercial nuclear reactor power plants in the United States ---each bears heavily on the health risks of low-level radiation and public health policy. It would be best to examine these factors in relation to three important events in the nuclear fuel cycle: that of normal operation of a nuclear

reactor; that of a nuclear reactor accident; and that of radioactive waste management. When each of these factors are placed in perspective over the 25-year history of commercial nuclear power for the generation of electricity, the evidence once again compels the conclusion that the radiation emitted from nuclear power plants in the United States present a neligible risk to the public health.

The Safety Record of Commercial Nuclear Power Plants

The first fact to consider is the safety record of commercial nuclear power plants and the regulatory agency, and the manner of normal operation of nuclear reactors. All but one of the 71 commercially licensed and operating nuclear power plants, which currently supply about 11% of the nation's electric power, are light-water reactors. The key mechanisms for nuclear reactor safety are control or regulation of the reactor, cooling, and containment of the radioactive fuel and its chain-reaction fission products. All nuclear reactors must be designed, constructed, and operated with only one goal in mind: to protect the public health and safety simply, so that the probability of failure of these mechanisms---control, cooling and containment---with consequent release of radioactivity to the environment affecting the public health is extremely low, and the health hazards are negligible.

These objectives are being pursued vigorously at all levels---government, industry, engineering, universities, and society---in the United States against a background of more than 700 reactor-years of experience by government, industry, and universities, in the operation of commercial nuclear reactor power plants (5). Thus, some 71 commercial power reactors have been designed and constructed in the United States and have operated for more than 700 reactor-years without

an accident involving serious radiation exposure to the operating staff of the nuclear power plant or members of the public. Seven hundred reactor-years is the sum of all the years of operation of all the reactors in the United States up to the present.

This is a record of past safety---it is in no way a guarantee of future safety, and it is in no way proof of an acceptable low probability of accidents. To illustrate this point, the two nuclear reactor accident about which we know most might be recalled---the Windscale accident in Cumbria, England in 1957 and the Three Mile Island accident in Pennsylvania in 1979 (6).

A severe accident occurred in a prototype gas-cooled nuclear reactor at Windscale some 25 years ago, in which the nuclear fuel over-heated and large activities of fission products were released to the atmosphere. The most important was iodine-131. In 1979, a pressurized light-water reactor at Three Mile Island suffered nuclear core damage, which resulted in the release of moderate amounts of gaseous radioactivity to the environment (6). In neither circumstance was any one acutely injured. It can be assumed, on the other hand, that each accident created a finite risk, however samll, of harmful late health effects in the general population.

Since the events of Three Mile Island are sufficiently recent, it is worthwhile to consider the main findings of the President's Commission on the Accident at Three Mile Island (6). The March 1979 accident at Three Mile Island revealed that to have nuclear safety there not only must be reliable equipment, but also there must be competent and qualified people. At Three Mile Island there were equipment malfunctions, but the vital safety equipment performed well and without error, preventing a very serious acccident. A nuclear accident with radioactive release to the environment and core damage occurred---not because of systems control failure, but because the control room operators mistakenly stopped the

flow of emergency cooling water. The levels of radioactivity released to the environment were moderate, but the radiation doses to the population were very low. Thus, the health effects from radiation exposure to the public were negligible. Furthermore, there will be no detectable late or delayed health effects in the 2,163,000 people living within 50 miles of the nuclear power plant, since the average radiation dose was less than 1 percent of natural background radiation levels annually.

Continued loss of flow of emergency cooling water during the accident could have led to core melting, but the evidence is that the containment barriers would have survived and protected the public from exposure to any additional radioactive releases. In other words, had there been core melting, there would, nevertheless, have been no additional radioactivity released to the environment. Serious mental stress and psychological trauma resulted from technical errors and public announcements based on these errors a few days after the accident. In large measure, these circumstances were aggravated by the unrelenting news media. Earlier experience from other reactors and analyses dating back to 1971 should have alerted the nuclear industry, the nuclear regulatory agency, and the operators, and thereby could have avoided the accident altogether.

The experience from the Three Mile Island accident provides many valuable lessons in the management of nuclear safety to protect the public health---the three most compelling are that the TMI safety equipment performed better than had been expected, that a nuclear reactor accident can be serious, even if the radiation health effects are negligible, and that there is a continued need to pursue fundamental changes in the current regulatory approach to reactor safety. This is being done---by government, by industry, and by society (7).

But a record of the past safety is based on engineering technologies---methods, safeguards, and design---of nuclear power reactors built with limited experience during the first two decades since the original introduction of commercial nuclear power plants for the generation of electricity. That safety record would have an analogy to our present use of commercial aircraft carrying passengers across a continent and ocean---at just below the speed of sound---but in a flying machine designed just prior to World War I and built before the Treaty of Versailles! Since 1957, when the first commercial electric power version of the pressurized light water nuclear reactor, built by the Westinghouse Electric Company, went into service in Shippingport, Pennsylvania, there have been extraordinary advances in nuclear technology and engineering. In the last decade alone, there have been much advanced designs in different types of reactors ---one, the gas-cooled nuclear power reactor, used extensively in Great Britain and France, has a background of more than 600 reactor-years of operating experience in more than 50 power plants, with demonstrated exceptional safety and reliability. These have an attractive safety feature: a loss-of-coolant accident such as the one at Three Mile Island is all but impossible (5). Thus, while we examine the safety record of the past 25 years of nuclear reactor plants in the United States, we must be aware that the future will be based on the development of far more attractive features in new reactor designs which are simple and conservative, and with demonstrated outstanding thermal efficiency, better energy utilization, and vastly improved and exceptional safety advantages. This assures that with future production of the more advanced nuclear power plants in the United States, Europe and Japan over the coming decades, the safety record will enter many thousands of reactor-years of operating experience marked

by such exceptional safety and reliability, thereby further minimizing the probability of the occurrence of a nuclear power plant accident affecting the public health and safety.

Emergency Planning

Even if it were assured that the probability---that is, the mathematical chance---of a nuclear reactor accident is extremely low, the wisest course for industry, government, and society requires that appropriate emergency planning must be established and maintained for the operation of commercial nuclear power plants. This is not for normal operations, but rather, in the event of an accident associated with the release of excessive levels of radioactive materials to the environment.

At the present time, emergency preparedness plans for evacuation from defined areas of populations at potential risk are required by law and exist for each commercial nuclear power plant in the United States (8). This is not the case for the chemical industry, the petroleum industry, or for other power plant systems where a serious accident which threatens the health of the public could occur. Each emergency plan relates to a designated nuclear power plant, but has the same basic process that depends on careful and informed cooperation between the staff of the utility, the local community ---county and city--- authorities, the state authorities and state and local emergency services. The administration of such plans is expected by local organizations, together with the local, city, county and state organizations, all of which are involved, directly or indirectly, in protecting the public health and safety---the general population---in the event of a nuclear accident associated with the release of radioactivity. If the accident is serious, however, one can expect central control at a federal level rapidly becoming involved, since the resources and expertise for health protection and safety are very much greater.

The essential information to effect these plans appropriately---at the present time---depends on a knowledge of the accidental radioactive releases requiring an early assessment of the magnitude and nature of the release, its dispersion in the environment, and the radiation doses that might arise, given the demographic distribution of the population in the immediate region (4). Emergency preparedness implies appropriate planning for the event of a nuclear reactor accident with the accidental release of radioactivity to the environment occurring in order to protect the health of the general population. It is not to be equated with and does not necessarily demand evacuation of small or large segments of that population. Depending on the real or projected levels of radioactivity released, and thus the radiation dose, counter measures much less complex than evacuation can readily be employed (9). These may include requiring persons to remain indoors, issuing medications such as stable iodine to protect the thyroid, banning and removal of local foodstuffs such as milk, and possibly the evacuation of some very defined areas or special high risk populations. These measures are designed to protect the public health, and for reasons and circumstances other than for nuclear power emergency planning, similar measures have proven effective in protecting the health of individuals and large populations in the event of natural or industrial accidents throughout the technologically advanced nations.

Choosing a Site for a Nuclear Power Plant

Much controversy centers on where to build a nuclear reactor power plant---some argue for remote sites away from population density and others for proven geologically stable regions (10). There are many societal and technical factors involved---all of which are designed to protect the general population, and thus are all central to the issues of public health and safety. The most important

of these factors are now the density of the population---it should be low---and the readiness that evacuation can be carried out if necessary in the event of a serious accident---it should be efficient and safe.

Early nuclear power reactors in the United States were located in remote sites, and with advancing engineering safeguards and a trouble-free safety record, bolder designs for locations closer to major cities were undertaken. The matter was an economical one. In the 1950's Consolidated Edison proposed siting a commercial nuclear power plant in the middle of Queens, New York. However, since Three Mile Island, we are returning to the previous cautious policy of locating new reactors remotely. Such criteria evolve continually, and at the present time, reactor siting policy and its relationship to emergency planning remains under continual review by the government, by the regulatory agency, and by the industry (11).

Radioactive Wastes and Public Health

The levels of radioactivity in normal discharges from nuclear power plants are carefully monitored, and the levels of radioactivity permitted to enter our environment under normal operating conditions are stringently regulated by law to prevent any potential hazards to the health of the public (12). The present nuclear reactors can, with improved design and efficiency, lower still the levels of radioactivity in normal discharges---providing less radioactivity at lower concentration, perhaps by several orders of magnitude. Advanced engineering technology, such as in the gas-cooled nuclear power reactor, incorporates features of gas purification and recovery that will ensure that releases of radioactivity from the plant to the environment are essentially zero (5).

The concern of radioactive waste disposal, however, and the associated potential health effects deserves to be raised, and some myths should be dispelled. A large nuclear plant of the pressurized light-water reactor design generates about two cubic meters of radioactive waste each year---the volume is quite small. This reactor design is probably among the least efficient; new plants of advanced design differing from the pressurized light-water reactor produce much less waste. However, the material in the two cubic meters could be quite hazardous to health in its initial waste form because of its radioactivity, and it must be sequestered off and disposed of in such a way that it cannot return to the biosphere before it decays to lower levels which do not present a hazard to health. For most of these radioactive waste materials---primarily cesium and strontium---the time period is a few hundred years. Only a very minute fraction will be around for a thousand, a hundred thousand, or perhaps a million years. And thus the site of waste disposal becomes important.

While there is no possible way of guaranteeing the integrity of disposal site for a million years, it is nevertheless possible to place that stored radioactive material in inaccessible locations deep underground, in geological formations that have proven to be stable for the last 250 million years. Thus, the chances become vanishingly small, if not non-existent, that any high-level radioactivity would return to the biosphere for a few hundred years.

In this process, therefore, radioactive uranium has been removed from the earth, used to produce energy, and is then placed back into the earth. However, the very long-lived isotopes in the radioactive waste produce about the same amount of radiation as the naturally-occurring ore body does. There has been no significant change in the dose level when compared to the naturally-occurring radioactive ore in the earth. Furthermore, the waste is placed back in less

soluble form than the ore, and farther from ground water. The radioactive waste properly disposed of in stable sites deep in the earth presents no greater health risks to present or future generations than if the radioactive ore had not been disturbed at the outset (13).

The Acceptability of Risk

The question of acceptability of the potential risks of radiation is being raised because of certain broad societal issues which require resolution (14). Within the last year the National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation---the BEIR Committee---produced a new report summarizing present knowledge of the effects on populations of exposure to low levels of ionizing radiation (15). This report revealed some disagreement among certain members of the committee, not in the scientific facts, but in the interpretation of the available scientific facts, implying that doubts and uncertainties prevailed. In addition, the United Nations Scientific Committee on the Effects of Atomic Radiation---the UNSCEAR Committee---which also reviews knowledge about radiation effects regularly (16), is scheduled to produce a new report within the next few years.

At the moment the estimates of dose from the main source of epidemiological data on the effects of radiation on man, that on the survivors of the Hiroshima and Nagaskai atomic bombs, are being reviewed and risk estimates reassessed in the light of recent new information (17). There is extensive public inquiry into plans to build new nuclear power reactors in the United States, and there is substantial public interest in the government's programs for radioactive waste disposal.

But it is worthwhile pointing out that we probably know more about the effects of ionizing radiation than we know about any other physical and chemical agent in the environment. Central to many of the decisions on risk estimation

are the issues of the shape of the dose-response relationships derived from epidemiological surveys, particularly for low-LET radiations, such as x-rays and gamma rays, of the validity of the extrapolation to low doses, and of the uncertainties that should be attached to the resulting risk estimates. However, in spite of such uncertainties, there is substantial agreement in the scientific community that the risks in the general population are presently being estimated with considerable precision, and that it is unlikely that they are being underestimated by more than an order of magnitude. It is much more likely that the values currently being used, which assume a linear relationship, are conservative and that the health risks of low-dose radiation are extremely low.

The important issue which emerges therefore is how to determine whether it is reasonable that individuals should be exposed to these risks, no matter how low they may be. It is a basic recommendation of current radiation protection phiolosophy that no radiation practice should be adopted unless it produces a positive net benefit (18). At the present time those on government decision-making committees and agencies and the public in general view commercial nuclear power for generation of electricity as giving a positive net benefit---and when all factors are considered, this may be the case. But this is not necessarily the case for other segments of society, who, for example, may be greatly and appropriately concerned with a problem unrelated to energy, such as the proliferation of nuclear weapons.

The problems of energy in all its facets are difficult to understand in perspective even for an informed public, and for the widespread appreciation of the economic, social, political and environmental consequences of nuclear power, arguments for and against various energy options must be formulated in a way that are clearly perceived and understood by members of an informed public.

In many cases, the environmental and political issues are, at present, being obscured by emotional rhetoric of an uninformed public on the one hand, and by complex technical details of nuclear engineering and quantitative epidemiology on the other. There is, in general, too little in the way of critical discussion and presentation of the relevant material in a way that those not directly involved with the subject can understand. This area merits further attention by all if substantial public acceptability of the nuclear industry is to be achieved.

Science and Public Policy

Is it appropriate for expert scientific advisory committees on radiation to exceed the scientific presentation and interpretation of the facts? Should these same scientists then go on to interpret these facts in the best way they can using approaches such as dose-limitation or cost-benefit analysis? It may be argued, as it was among members in the BEIR committee, that there should be not straying outside the strict scientific area, and it should not be within their limit to make recommendations. Making recommendations which impact on public policy by any individuals assumes that social, economic, as well as all scientific factors have been taken into account, and implies a measure of political and governmental judgement that is not necessary for assessing risks (19). It would appear to some that the presentation of scientific facts should be separated from the making of recommendations. Others believe that the role of scientific experts is to express a scientific opinion, particularly regarding protection of the public health. If recommendations are technical, then this should present no difficulties. But if there is an element of societal judgement, then such scientific experts must understand their limitations.

But should risks be the basis for recommendations, since the term itself is emotive, and implies a danger exists that in many cases is, in fact, negligible?

It leads to discussions among scientific experts of doubts, uncertainties, and even unresolvable controversies, which may be unimportant or unrelated to risk assessment and decison-making. However, this leads the layman to assume erroneously that there exists a lack of knowledge or worse, incompetence, and regrettably, leads and encourages the news media to act irresponsibly.

Conclusions

It has never been axiomatic that if we decide to accept innovative socio-technological change, as in the case of nuclear energy, that we design such programs so that the probability of any risk, no matter how remote, is eliminated. The probability of a nuclear accident involving the release of radioactivity to the environment, thereby involving a potential risk to public health, must nevertheless be extremely low in absolute terms in relation to health risks created by other industrial plants and human activities, not only those associated with energy production, but in other areas as well, such as manufacturing, transporation, construction, agriculture and food production (20).

We do not live in a risk-free society. There cannot be absolute assurance of the complete safety of any technolgical development in a modern society, and that includes the safety of nuclear reactors. However, potential health risks can be and are being reduced by improved nuclear engineering design, by complete thoroughness in prior fault analysis, by careful consideration to plant siting, by improved care and quality control in reactor construction, by vigilance and training in operation, by comprehensiveness in emergency planning, and by rigorous and careful surveillance in licensing and regulation. This reduces to a process of exceptional safety and reliability equal perhaps only in our times to the manned space program in the United States. But, it is society

that must decide whether it is capable and has the resources to depend on advanced scientific and engineering skills and safeguards in nuclear power to achieve an acceptably low level of risk to health. Such dependence is not unique to nuclear engineering. It is a universal dependence which we identify with all risk assessment and decision-making processes.

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