THE STATUS OF RADIOACTIVE WASTE MANAGEMENT: NEEDS FOR REASSESSMENTS

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The purpose of this paper is to examine several aspects of the radioactive waste problem in the hope that so doing may emphasize the need for a fresh examination of not only the examples to be given, but the entire multifacited subject.

Wastes from Biomedical Clinics and Laboratories

It has been estimated that U.S. biomedical laboratories shipped a total of 2487 curies of radioactive waste to the burial grounds in 1978 (1). Relatively short-lived nuclides such as P-32, I-131, I-125, and S-35 contributed appreciably to the total. Because these nuclides have half lives measured in days, the reported annual shipment must be corrected for decay. Assuming that the wastes are generated at a uniform rate throughout the year, and allowing for decay, the total accumulation at year end would have totaled about 1300 curies. Seventy-two percent of the radioactivity would be due to two nuclides, tritium (720 Ci) and carbon-14 (221 Ci).

These quantities of tritium and carbon-14 are insignificant as a potential source of public exposure. Both nuclides are produced in nature by the interaction of cosmic rays with the atmosphere and both have been produced in even greater amounts in the testing of nuclear weapons. The worldwide steady state inventory of natural C^{14} is estimated to be 230×10^6 Ci, which delivers a dose of about 0.7 mrems per year to the world's population (2). It is estimated that by 1972 a total of 5.8×10^6 Ci were injected into the atmosphere as a result of weapons testing. This one source was equivalent to more than 2000 years of natural C-14 production.

If all C-14 used in biomedical laboratories in the United States were incinerated to $^{14}CO_2$, the steady state environmental inventory would eventually increase the dose from C-14 by less than 0.007 millirem per year.

Tritium accounts for about 55% of the waste radioactivity produced in 1978 by the biomedical facilities, a total of about 720 curies. This nuclide is also produced naturally by cosmic ray interactions, and the worldwide steady state inventory is estimated to be 34×10^6 Ci (2). The dose from naturally-occurring tritium is estimated to average 0.001 mrem per year. Tritium released without restriction by biomedical clinics and laboratories would gradually diffuse into the environmental hydrogen pool and its contribution to the human dose would be proportional to the amount present. The increase in dose would be about 0.002% of the tritium background dose of 0.001 mrem/yr.

Tritium, like C-14, was also produced copiously in tests of thermonuclear weapons, which resulted in injection of an estimated 4500 x 10^6 Ci into the environment. This was more than 100 times the steady state inventory from natural sources. The nuclide is also produced by nuclear reactors, which discharge between 0.1 and 1 Ci per megawatt electric (MWe) per year.

The figures given are of course applicable only to the wastes generated in the U.S. However, if the amounts were to be multiplied tenfold, which would be more than sufficient to account for wastes generated by all countries, the global impact of the incinerated emissions would still be negligible.

There remains the problem of evaluating the potential for exposure to individuals who live close to the incinerator and may therefore be exposed directly to the incinerator plume.

For purposes of estimating the potential magnitude of such exposure, it is assumed that a single large facility discharges 1% of the total quantity of radioactive wastes generated by the medical facilities and universities in the U.S. The wastes are incinerated, and the gaseous products are discharged at a uniform rate for 200 days per year, 8 hours per day. The exhaust gases are discharged from the incinerator stack at a rate $\sim 1\ m^3\ s^{-1}$. For planning purposes, it is specified that members of the general population should not be exposed to more than 10% of the limits recommended by the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements.

The concentration of tritium and C^{14} would, under these conditions, be 62 and 3.2 times the target level of 0.1 MPCa at the point of discharge from the stack. Even under the most adverse meteorological conditions, the effluent would be diluted within a few meters to concentrations well below the target level.

From the above, it appears that the biomedical and clinical laboratories could be permitted to dispose of most of their radioactive waste with no regulatory requirements other than those applicable to the wastes because of their chemical or physical characteristics. Instead, procedures established for management of these wastes are of themselves a waste; they waste time, money and resources. The elaborate record keeping, the careful packaging, the shipment for long-distances and the burial practices themselves are an unnecessary ritual.

Some Perspectives on High Level Wastes

The problems associated with the management of high level wastes are of course far more complicated than disposal of low level wastes from biomedical facilities. Apart from the fact that the subject is more complicated technically, a rational approach

to high level waste management has become entangled in a morass of political and quasi-scientific considerations to such an extent that the future of nuclear development in several countries is in jeopardy because of what I believe is a widespread misperception that a feasible way of managing high level radioactive wastes has not been demonstrated. We should not at this point become involved in the question of whether nuclear power development should be encouraged or discouraged. That question is beyond the scope of this paper and, in any case, should be settled independently of the question of how to manage radioactive wastes generated by nuclear power.

One of the most pressing questions is whether high level wastes can be isolated from the biosphere for a sufficient period of time by emplacement in geological repositories. In the debate over this issue, we have lost sight of the fact that mineral deposits in a wide variety of chemical forms remain isolated in nature for hundreds of millions of years under many environmental conditions. Perhaps we have been negligent until now in not having studied the many opportunities provided by nature. The mobilization rate of a deposit, and its rate of entry into the biosphere, should be quantifiable in terms of the properties of the deposit and hydrological and geochemical parameters that are capable of description. We should develop models that describe the physical and biological transport of trace elements from deposits found in nature. Studies of this kind have only recently begun and are few in number.

The natural reactor at the Oklo mine in the West African country of Gabon is one excellent example of what we can learn from nature (4). A study of the Morro do Ferro in Brazil is of more recent origin, having begun early in 1979 (5,6). The Morro do Ferro is a hill in the State of Minas Gerais, near the surface of which is an estimated 12,000 metric ton deposit of thorium that is believed to be as old as 80 million years. Because the deposit is in an advanced state of weathering, and because of the close chemical similarities between thorium and plutonium, studies of the rate at which the thorium is being mobilized from the deposit should provide useful information about the behavior of plutonium in a geological repository that has been breached.

Any conclusion that high level wastes can be isolated from the biosphere requires agreement as to the length of time for which isolation will be required. Pigford and his associates (7) have argued that after only 1,000 years, the potential risk is no greater than that from the ores from which the uranium was originally obtained. This approach is subject to the criticism that the relative hazard of the various nuclides depends on their chemical, physical and biological properties so that, curie for curie, the hazard indices may not be equivalent. Nevertheless, this analysis does serve to drive home the message that although some of the nuclides in high level radioactive wastes may have long half-lives,

they are present in relatively small quantities after a relatively short period of time. Storage times of a few thousand years are well within the range of human experience. There is a need to achieve a consensus as to the length of time during which the wastes must be isolated from the biosphere. It would help to resolve the contemporary controversy if there could be agreement that we are in fact concerned only with the need to isolate the wastes for about 1,000 years.

What Should Be the Role of the Marine Environment in Radioactive Waste Management

I will now turn to the oceans as an example of a neglected environment that deserves a role in any program of radioactive waste management. The oceans cover 70% of the earth's surface and are the recipients of vast quantities of organic and inorganic debris carried into them by the rivers of the world.

More than two decades ago (8,9), the National Academy of Sciences began to examine the problems that would be encountered if the ocean were to be used for disposal of radioactive wastes. These and other studies estimated that huge quantities of radionuclides could be placed in the ocean deeps without hazard. However, a great prejudice has developed against using the ocean for waste disposal of any kind (non-radioactive as well as radioactive) and the U.S., along with many other countries, has stopped ocean disposal, even for low level wastes.

Society must be careful that the oceans as an ecosystem are not damaged by indiscriminate dumping of wastes. We must be careful that we don't allow accumulation of chemicals such as PCBs and DDT that degrade slowly and are known to be toxic to aquatic biota. But if we can find a waste form that can be deposited in the oceans subject to some common sense restrictions that will avoid ecological or cosmetic injury to the ocean environment, then why should we not take advantage of the opportunity.

Testing nuclear weapons has resulted in widespread dissemination of a broad spectrum of radionuclides in the oceans, particularly the Pacific. The total explosive yield of these tests is estimated to be about 366 megatons (MT) of TNT equivalent (10). Of this total, an estimated 72 MT was exploded under ground and can be neglected for the purposes of these discussions. The yields of all explosions conducted above ground (or under the oceans) thus total 294 MT.

Sources quoted by Miskel (11) estimated that 41% of the total yields were due to fusion and the remainder to fission. Using these ratios, it can be estimated that the fusion component of atmospheric explosions through 1978 totaled 122 MT and the fission component totaled 172 MT. As noted earlier, the bombs produced an estimated 4.5×10^9 Ci of H^3 and 5.8×10^6 Ci of C^{14}.

The fission and activation products produced by the explosions have been disseminated throughout the world, have entered the biosphere, and have been the subject of intense study by radioecologists from many countries. The data have been summarized elegantly in the periodic reports from the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). However, reference to these reports shows that the dose estimates to human populations has been estimated from studies of the terrestrial food chains. This, despite the fact that the oceans cover 70% of the earth's surface and that many of the larger tests were conducted on Pacific atolls where fallout in the vicinity of the tests contributed additional radioactive debris to the Pacific. The dose commitments from marine food chains have not been taken into consideration presumably because they do not add significantly to the dose commitments estimated from terrestrial foods.

More than 95% of the total explosive yields of the tests took place between 1954 and 1962, at which time a limited test ban agreement was consummated which prevented atmospheric testing among the major nuclear powers. Deposition of the principal nuclides (H-3, C-14, Sr-90, Cs-137, and Pu-239) has been well documented and most of the debris has by now deposited on the earth's surface.

Despite the fact that the oceans have been the recipient of enormous quantities of radioactivity, marine sources of food have not contributed significantly to the dose received from fallout in those countries of the world for which data are available. The UNSCEAR emphasis has been on the terrestrial food chains because most food is derived from land sources. For example, in San Francisco, where representative diets have been monitored for strontium-90 for many years, fish and shellfish account for no more than about 0.2% of an annual strontium-90 intake that has ranged between about 1,000-3,000 pCi/yr. Similar data have been reported from diet studies in New York.

The lifetime dose commitment to endosteal cells of persons in the temperate zones from all strontium-90 produced in nuclear explosions up to the end of 1975 is estimated to be 116 mrad (13). Based on the San Francisco and New York data, the contribution of marine foods to this dose commitment would be about 0.1%, or 0.116 mrad. Note that this is the dose commitment, i.e., the dose that will accrue to an individual over his lifetime. The dose would of course be higher in populations which consume more seafood than people in New York or San Francisco.

Measurements of Pacific albacor during the period 1965-71 showed an average Cs^{137} concentration of 74 pCi Kg^{-1} wet (14). If a person consumes 1 Kg of albacor per week, the dose commitment will be about 1 mrem for each year of fish consumption. This would amount to total dose of about 30 mrem for a lifetime of fish consumption--a dose that is approximately 0.4% of the lifetime dose

received from nature. The dose from consuming albacor is probably representative of the dose to individuals who subsist on a high proportion of Pacific fish. It is the dose that has resulted from deposition (without precautions) of an estimated 27 million curies of Cs^{137}.

The British have set a unique example by the rational manner in which they have utilized the marine environment for disposal of radioactive wastes from windscale. They used critical pathway analysis to identify the limiting nuclides and the ecological pathways by which the nuclides can reach humans. Their preliminary studies began nearly 30 years ago, and a 10,000 Ci experimental release of wastes took place in 1952 over a period of about six months. Based on studies of the ecological behavior of the radioactivity releases during this and subsequent experiments, the quantities released were gradually increased, so that during the period 1955-65 the releases ranged from 3742 Ci to 7659 curies per month. The critical nuclides in these releases was shown to be Ru^{106}, which has a half life of 1 year (15).

Summary

Policies that dictate the procedures for management of radioactive wastes are being influenced by superstitions and prejudices that have no place in modern society. Even innocuous low level wastes are subject to absurd regulations that should be re-examined. For example, the recent problem encountered by biomedical facilities in the U.S. because of the closing of low level burial grounds could have been avoided in the first place since most of the wastes could be disposed of safely by onsite incineration or other methods applicable to the nonradioactive wastes from the laboratories.

Many forms of wastes can be safely emplaced in the marine environment where an inadvertant experiment resulting from the fallout of massive quantities of radioactive debris has provided us with information about the ecological behavior of the individual nuclides.

Several aspects of the high level waste management problem requires reexamination. Perhaps most important is the question of how long it is necessary to isolate the wastes from the biosphere. Plans for waste management would be greatly simplified if, as some believe, an isolation period of 1,000 years will be sufficient. If longer periods are required, we should look to nature for guidance. There are many mineral deposits that have remained in place for tens of millions of years under a variety of environmental conditions. Knowledge of the factors that influence the mobilization rates from those deposits should greatly assist construction of models to predict the behavior of long-lived nuclides in a geological repository.

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