QUESTIONS ABOUT
SOME NUCLEAR FUEL WASTE
LONG TERM MANAGEMENT METHODS
RECEIVING INTERNATIONAL ATTENTION (NWMO)

The Nuclear Waste Management Organization mentions a number of long-term management methods for nuclear fuel waste which have received some degree of international attention. The following questions were posed by an Inuit woman who was involved in some of the NWMO dialogue meetings. Gordon Edwards attempted to give some answers.

1) **Boreholes**: *What effects would it have on the environment? With wastes buried underground would this have any pressure on the soil or earth with disturbances on the ground? Has there been any research regarding long term effects on the environment, wildlife & humans?*

2) **Direct Injection**: *As there would be no control of the injected material after disposal, are there any health concerns we need to be worried about, i.e.: cancerous health risks.*

3) **Rock Melting**: *With this method of melting of the rock, does this process affect the environment and will there be any pollution from the rock that will go into the air and ozone layer?*

4) **Sub-Seabed Disposal**: *Although doing this process and contamination would be very little. Was the thought of marine life taken into consideration? Also, the plankton and plants on the ocean floor, would they be affected first and die off, which in effect would affect the food chain?*

5) **Disposal at Sea**: *With this method was there a reason why it was stopped in the early 80's. Also, why would it be thought of now?*

6) **Disposal in Ice Sheets**: *With global warming happening all over the world. The ice in the arctic is slowly becoming smaller; has this been brought into consideration? Also, I really don't think disposal of Nuclear Waste in the Arctic is a very good idea due to the environment and humans.*

7) **Disposal in Space**: *Has there been any research done about this issue? What if there was any problems transporting the most toxic waste, i.e.. Failure to eject into space, problems storing the waste. Would any of the waste leak back to earth while transporting?*

Gordon Edwards' Response to these questions (2005):

The questions posed are good and sensible ones. Unfortunately there are not equally good and sensible answers.

The questions straddle two quite different scientific domains: the physical sciences and the biomedical sciences. Although humans have made great and impressive strides in both of these scientific domains, we remain ignorant of many important aspects of the natural world, particularly on the biomedical side. That's why these questions are so hard to answer.

In particular, when one asks about "long term effects on the environment, wildlife and humans", or "health concerns we need to be worried about", or effects on "plankton and plants on the ocean floor", one is asking questions that transcend science. These are referred to as "trans-scientific" questions. Science can provide some information or insight that can be helpful in understanding what might happen, but is very poorly equipped to say exactly how or even whether such things might happen, and what the long-term consequences might be.

The predictive sciences are, for the most part, restricted to a few of the physical sciences, such as Physics, Chemistry, and the applied science of Engineering. These are the sciences that have traditionally dominated the nuclear industry, and continue to do so. In these fields, mathematical methods are so successful that they have come to play an enormously important role in predicting the outcomes of situations. Psychologically, the scientists in these fields come to place an exaggerated importance on mathematical calculations, using them to make predictions which are then treated with an extremely high degree of assurance. Some practitioners become rather arrogant in this regard, and the nuclear industry certainly has its share of them.

The percentage of scientists in the nuclear industry that come from biological or medical fields is minuscule. Prediction is much less certain in these latter disciplines, in which mathematics plays an important but greatly diminished role. In the biomedical sciences, predictions made on the basis of mathematical calculations must always be treated rather skeptically, because the biological systems (e.g. ecosystems) are often much more complex than the mathematical analysis is.

For example, there is very little reliable scientific knowledge about the long-term reproductive effects of radioactive contamination on a large scale. Radiation exposure has been shown to damage eggs and sperm in all species that have been studied; this happens even at very low doses, and there is no evidence for a "safe dose" below which such damage does not occur. This microscopic damage to the reproductive cells can result in developmental damage (that is, birth defects) not only in the offspring of the generation directly exposed, but also in subsequent generations who may not be directly exposed, because of the transmission of defective genes and chromosomes through many generations of offspring.

Radiation exposure delivered directly to a fetus during pregnancy or incubation can also lead to developmental abnormalities (that is, birth defects) in the immature organism. The most significant of these abnormalities is brain damage. In animals, prenatal brain damage may be manifested by subsequent behavioural problems including partial or complete loss of nesting instincts and/or mating behaviour patterns. In humans, prenatal brain damage is generally manifested by a loss of intelligence (IQ) that is more or less proportional to the amount of prenatal radiation exposure to the unborn child. This "mental retardation" effect has been confirmed by the UN Scientific Commission on the Effects of Atomic Radiation (UNSCEAR) and the US National Academy of Sciences BEIR Committee. (BEIR stands for Biological Effects of Ionizing Radiation.)

However, there is insufficient scientific knowledge to integrate these and many other isolated bits of information into a comprehensive analysis of the progressive effects on species and ecosystems, which might occur if there is chronic exposure to radiation at levels significantly greater than the radiation levels experienced over the last several million years of evolution.

Radiation exposure at chronic levels has also been shown to cause all kinds of cancers, and many kinds of blood diseases. In these cases also, independent scientific bodies have found no evidence to suggest that there is a "safe dose". It seems that every dose of radiation will cause some increase in cancer incidence if a sufficiently large population of people is exposed. Not everyone so exposed will get cancer, but those that do will be just as sick and just as dead if the cancer is a fatal one. As the radiation dose is diminished, the number of cancer victims will also diminish; but the risk of excess cancer will not reach zero until the radiation exposure also reaches zero.

In the nuclear industry, almost all of the effort has gone into the Physics, Chemistry, and Engineering aspects. The physical scientists who permeate the nuclear enterprise believe that by focusing their efforts almost exclusively on machinery and measurements, they can prevent radioactive poisons from ever reaching the world of living things, and therefore it will never be necessary to deal with the consequences because there won't be any. This effort has been so monolithic that there is virtually no meaningful discussion of the possible long-term effects on ecosystems of plants, animals, birds, micro-organisms, fish, crustaceans, insects, and humans.

Ironically, the industry's attempt to harness the powers of accurate prediction and total control -- powers that seem to be inherent in some physical sciences -- has been frustrated by the necessity to deal with other non-predictive aspects of the natural world. Chief among these is geology.

Geology is not primarily a predictive science. It is a descriptive science. Many branches of biology and medicine are also more descriptive than predictive in nature. For example, no one can predict accurately where the next earthquake or tsunami will strike, or how powerful it might be. No one can predict which rock formations will fail in the next million years and which ones will remain intact. The fact that a rock formation has been intact for millions or even billions of years offers no proof that it will remain intact for a similarly long period of time in the future (although, of course, one can always hope!)

It appears that things which may seem inanimate in the laboratory, such as water and rock, behave more like living things when they occur in the real world as river systems and mountain ranges. The earth itself seems alive and therefore unpredictable, as attested by geysers, volcanoes, glaciers advancing and retreating over thousands of miles, and rivers cutting huge canyons through solid rock by a slow and steady process of erosion.

Thus the quandary : what to do with radioactive waste? Nuclear scientists (and others) would like to believe, and would like us to believe, that they can plan something so clever that nature -- the great re-cycler -- will be unable to recycle these poisons back into the environment of living things. But there is a hitch. They cannot prove that their plan will work. It is beyond the powers of science to provide such a proof. It requires a kind of belief or faith that is, in itself, not scientific.

For this reason, more than 30 years ago, a Nobel-Prize-winning physicist, Dr. Hannes Alfven, said this about the problem of radioactive waste disposal:

> "You cannot prove that a problem has been solved, simply by pointing to all the efforts that have been made to solve it."

Nobel-Prize winning physicist Dr. Hannes Alfven, 1972,
quoted in "Nuclear Energy and the Environment" (1976),
UK Royal Commission on the Environment, Report #6

Similarly, when the California Energy Resources and Conservation Commission reported back to the California Legislature on the subject of radioactive waste disposal, the Chairman of the Commission said:

> "If everything worked perfectly as far as they are concerned, if every one of their ideas were correct, and we were able to proceed on a timely basis, waste disposal will not be demonstrated ... until sometime around 1987.
>
> "We, however, have a more fundamental problem. We think it probable that it will never be demonstrated.
>
> "Excessive optimism about the potential for safe disposal of nuclear wastes has caused backers of nuclear power to ignore scientific evidence pointing to its pitfalls.
>
> "That's the real crux of what we found -- that you have to weigh scientific evidence against essentially engineering euphoria."

Commissioner Emilio Varanini , Chairman
of the California Energy Commission.
[quoted in the Los Angeles Times,
Thursday January 12, 1978]

So, most of the research on radioactive wastes has centered on finding a physical containment scheme, which might offer the prospect of perfect or near-perfect containment over a very long period of time -- much longer than the span of recorded human history. The various options discussed by NWMO are just various ideas for getting rid of the stuff ("out of sight, out of mind") -- ideas that have been explored in more or less detail (often less rather than more) by nuclear scientists.

(1) Boreholes

Deep boreholes have been studied in Sweden, Finland, and Russia, as possible repositories for some kinds of radioactive waste -- but not usually for irradiated nuclear fuel. If this method were to be adapted for nuclear fuel waste, the boreholes would typically have a diameter of less than one meter, and they would be drilled several kilometers deep. Packages of irradiated nuclear fuel would then be stacked one on top of the other in the borehole, separated by layers of bentonite or cement.

It is hoped that the depth of the repository would provide adequate assurance that these radioactive poisons will not find their way back to the surface. However this assumption cannot be proven scientifically. Moreover, retrieval of the irradiated fuel would be extremely difficult if not impossible. There are many unanswered technical questions, such as the physical integrity of the waste packages under the high pressures and temperatures to which they would be subjected in the boreholes.

It is unknown whether the combination of high temperature and high pressure could create some kind of geyser effect through which dissolved radioactive wastes might be returned to the surface. Or whether vertical migration under pressure might be followed by horizontal migration through subterranean fracture zones, eventually leading back to the surface or contaminating groundwater,

As for possible long term adverse effects on the environment, wildlife and humans, such harmful effects have been studied only in a very abstract manner, using rather simplistic mathematical models.

While deep borehole emplacement is regarded by the industry as a possible idea for managing small quantities of radioactive waste, it is by no means sufficiently well developed to be considered as a management option for the very large quantities of irradiated nuclear fuel under consideration by NWMO. No country is currently pursuing this option.

(2) Deep Injection

Similar comments apply to direct injection, together with the fact that this method presumes that the wastes are in a liquid form. The only way irradiated nuclear fuel could end up in a liquid form is due to reprocessing of spent nuclear fuel. Reprocessing involves chopping the fuel bundles into small pieces, dissolving the pieces in hot nitric acid, chemically separating out the plutonium from the hundreds of other radioactive poisons (for re-use in reactors or in bombs), resulting in the creation of millions of gallons of highly corrosive high-level radioactive liquid waste. The reprocessing operation is itself a major threat to the environment.

Direct injection of these liquid wastes into underground rock strata would be problematic as liquids are much more mobile than solids. Since there is no manmade control once the material has been injected, the method would require a godlike knowledge of the subterranean geologic features, not only now, but also for thousands of years into the future. This idea is not being pursued by any country as a serious option, although the former USSR used it in a number of locations in the past. No other country has ever done so.

(3) Rock Melting

This bizarre idea involves placing the high- level radioactive waste in a concentrated form in an underground cavity or borehole, sealing it up, and allowing the heat generated by the radioactivity to build up to the point where it would literally melt the surrounding rock, dissolving the radioactive wastes in a growing (and glowing) sphere of molten material which would eventually cool down and crystallize, thus incorporating the radioactive material into the rock matrix.

A variant form of this idea would be to enclose the waste in containers that would not melt; then the molten rock would congeal and provide a tight and very strong protective shell around the radioactive waste in its containers.

Research on this idea was carried out in the 1970s, and interest was briefly revived in Russia in the 1990s (where the idea was also explored of using an underground nuclear explosion to melt the rock around the waste material), but this idea is not currently being investigated as part of the national program of any country. There have been no practical demonstrations that rock melting would be feasible, safe, or economically viable. With such heat goes much energy and pressure, opening the possibility for some pretty powerful steam explosions.

(4) Sub-Seabed Disposal

This is a kind of "advanced dumping" option. It has often been suggested that the oceans are so vast that nuclear waste could be safely disposed of at sea; the radioactive poisons would become so diluted and so dispersed, reaching such a low level of concentration, that the danger would become negligible.

This idea dramatizes the difference between physical sciences and biological sciences. In a non-living environment, material that is dissolved in water spreads out uniformly in all directions, resulting in very low concentrations at any one place. However, living organisms have the ability to seek out and concentrate dilute materials (nutrients) into their bodies. Thus biological organisms can often reverse expectations that are based on the study of non-living systems. This is the principle behind bio-accumulation and bio-magnification. Many radioactive materials that enter the food chain can be re-concentrated by factors of thousands or hundreds of thousands as they work their way up the food chain. Think of mercury concentrations in fish, or DDT concentrations in birds of prey such as eagles or falcons. Thus we cannot predict the end result of a "dilute and disperse" approach, and no nation is pursuing this idea.

It is important to remember that there are literally hundreds of different radioactive materials in irradiated nuclear fuel, and these materials behave exactly the same as their non-radioactive cousins. Thus radioactive iodine behaves just the same way as non-radioactive iodine -- it goes straight to the thyroid gland. Once there however, the radioactivity damages the thyroid; it can cause thyroid disorders which impair the growth, well-being, or even the intelligence of a child, as well as causing tumors (both cancerous and non-cancerous).

Other radioactive materials mimic non-radioactive materials. Our digestive system cannot tell the difference between potassium and cesium, so radioactive cesium is stored in our muscle tissues when it gets into our food supply. Similarly, radioactive strontium is stored in our bones, teeth, and mother's milk, because our body cannot tell the difference between it and non-radioactive calcium. In short, our bodies have not evolved in a way that will allow our digestive systems to detect or reject radioactive materials in our food; the same can be said for all other living things, as far as we can tell.

Sub-seabed disposal would involve placing the wastes in containers below the seabed, so that it will take a long time (hopefully thousands of years) for the containers to disintegrate and the waste materials to be dissolved in the ocean water. Thus it is a "dilute and disperse" option with a time delay built in.

Sub-seabed disposal was investigated extensively in the 1980's by the Nuclear Energy Agency of the OECD (Organization for Economic Cooperation and Development). Canada participated in this work, along with Japan, USA, UK, and other countries. This research was ended in the 1990s when it became clear that there would always be intense political opposition internationally to such an option.

(5) Disposal at Sea

Thirty years ago, Britain and some other countries were in the habit of dumping barrels of radioactive waste (not irradiated nuclear fuel!) into the ocean directly off the decks of ships at sea. This practice was protested by Greenpeace, who called world attention to the situation by paddling rubber boats right up to the ships that were dumping barrels of radioactive waste into the ocean. As a result of the ensuing international publicity, and due to the initiative of nations like Spain that depend heavily on ocean fisheries, an international convention came into force outlawing the deliberate dumping of radioactive wastes into the sea. Another convention was adopted later that would specifically prevent sub-seabed disposal.

(6) Disposal in Ice Sheets

It was long ago suggested that nuclear waste could be disposed of in Antarctica by placing the waste on an ice sheet and letting it just melt its way down deeper and deeper into the ground. Since Antarctica is a continent, it was assumed that this would be a safe way of getting the wastes out of sight, out of mind, and out of harm's way. It was later discovered that there are pockets of brine below the surface ice. When the radioactive wastes hit the salty water there would be steam produced, rapid corrosion due to the salt, and possible dispersal of radioactive waste materials into the atmosphere and hence into the ocean by a geyser-like effect.

In a different context, nuclear scientists have always been fond of the idea of burying radioactive wastes in salt formations on land, because salt is soluble in water and therefore the very existence of the salt formation argues that there is no significant circulating groundwater. Upon drilling into a salt formation in Carlsbad, New Mexico, researchers struck a pocket of pressurized brine which sent a geyser up through the surface -- just like striking oil for the first time! It was subsequently discovered that there are always pockets of brine in salt formations, and that the heat given off by the radioactive waste actually forces these brine pockets to migrate towards the waste, where they would eventually arrive and create steam and attack the waste containers with corrosive hot brine.

(7) Disposal in Space

It would be a great expense to launch nuclear waste into space (which requires huge 70-ton shipping containers each equipped with its own cooling system). There are also the dangers associated with surface transportation of high-level radioactive waste over large distances. But worst of all is the record of rockets that have exploded on the launch pad or in the atmosphere; it is quite appalling. Think of the Space Shuttle that exploded over Florida, killing all those on board. Such an accident would disperse the radioactive waste into the environment in the worst possible way.

No country is seriously pursuing this option.

Conclusion (2011)

As the NWMO makes clear in discussing these options, none of them is considered to be an acceptable long-term “solution” to the problem of keeping these dangerous high level nuclear wastes out of the environment of living things forever. Likewise, there is no scientific way to prove that geological storage is going to be permanently safe either.

The word “disposal” has no scientific definition. The human race has never successfully disposed of anything. Many people believe that nuclear power should be phased out in order to stop producing any more of these indestructible radiotoxic materials. Nuclear wastes that already exist should be carefully guarded and monitored. It is irresponsible to place these wastes beyond human control in the absence of a genuine proven solution.