HAZARDS FROM RADIOACTIVE WASTE IN PERSPECTIVE

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The best way to understand the hazards from radioactive wastes from nuclear power is to compare them with the wastes from burning coal. We will compare them by considering the wastes from a 1000 MWe plant of each type.

The principal waste from coal burning is carbon dioxide, produced at a rate of 500 lb/second. It is not ordinarily a dangerous gas, but there are now serious worries that the tremendous amounts of it now being produced may be changing the world's climate and thereby severely affecting hosts of ecological problems. The most important dangerous gases emitted when coal is burned are compounds of sulfur - a ton of these are discharged every five minutes. Their annual effects from our typical plant are to cause 25 fatalities, 60,000 cases of respiratory disease, and $25 million in property damage. Another type of gaseous pollutant from coal burning is nitrogen oxides, best known as the principal pollutant from automobiles; it is the reason why new cars must have expensive pollution control equipment and use lead-free gasoline. But there is as much nitrogen oxide emitted from our single coal-burning power plant as from 200,000 automobiles, and nothing is being done about it. Generally considered to be more dangerous than this is the smoke, consisting of tiny solid particles. There is a widespread impression that smoke from coal burning has been essentially eliminated, but this applies only to the larger particles that are most visible; the situation is much less favorable for the very tiny particles which are the most harmful because they easily get into our lungs. Their effects are generally considered to be comparable to those of the sulfur compounds discussed above. Another class of pollutant released in burning coal is hundreds of different organic compounds, at least 40 of which are known to cause cancer. Perhaps the best

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known of these is benzpyrene, the principal cancer-causing agent in cigarette smoking. And then there is the ashes, the bulk solid material, produced at a rate of 1000 lb/minute, which, while not dangerous, introduces some difficult environmental problems in its disposal. And finally there are the hosts of toxic metals like selenium, cadmium, arsenic, and mercury whose effects have never been evaluated.

There is one very spectacular difference between the wastes from coal and nuclear plants - the quantities in the latter are some five million times smaller by weight and billions of times smaller by volume. In fact the annual waste from one nuclear plant would fit under a typical dining room table. The electricity produced in creating it sells for about $200 million, so we can afford to spend up to $2 million in disposing of this material that would fit under a dining room table without increasing the cost of electricity by as much as 1%. Cost is therefore no object.

Both the coal and nuclear wastes are toxic. One index of their potential danger is the consequences if it all got into people by inhalation or ingestion with food or drink. For the coal wastes, it could kill 100 billion people, which is 500 times more than the potential of the nuclear wastes. But this is an unrealistic comparison. Clearly we have to take into account the ways in which this material can get into people. In doing this for nuclear waste, we will include the effects added up over time; that is, when we give a figure for damage from one year's nuclear waste, we will include all of the eventual effects that may occur many years later. We will not do this for coal because these effects are very poorly understood, but that does not mean they are non-existent. The climate changes from carbon dioxide may last for thousands or even millions of years, and there is evidence that sulfur compounds which eventually settle to the ground are recycled into the air by bacteria metabolism to re-do their damage many times over. Toxic trace elements like selenium, cadmium, and mercury, of course, will be around forever.

The nuclear waste disposal problem has been termed "unsolved," but this really means, of course, that a method of disposal has not yet been selected. There are clearly many solutions to any waste disposal problem if we are not concerned with their consequences. To continue our comparisons between coal and nuclear wastes, we will consider different disposal methods. What if a simple and cheap method were used in both cases, following practices typical of the nineteenth and early twentieth century? For nuclear wastes, it would be simple and cheap to convert them into a glass and dump them in the ocean. This would have no appreciable effect on ocean ecology. The oceans are already full of radioactivity, principally from potassium, a naturally radioactive element which is an important component of salt, so the radiation exposure to aquatic life would not be significantly increased. The principal danger here is that small additional amounts of radioactivity would get into seafood which is eaten by people. This is estimated to cause 0.1 eventual fatality per GWe-year.

For coal-burning wastes, simple and cheap disposal would be following the present (or recent past) procedure of release into the atmosphere without sophisticated treatment which, from sulfur compounds alone, have been causing 25 fatalities per year, 250 times more than the nuclear counterpart.

But perhaps the most meaningful comparison is to consider using the best present or easily developable technology. For nuclear waste this would be converting it into a rock-like form and putting it where the rocks are, deep underground. The danger here is that the buried waste may be contacted by ground water, dissolved, and move with the ground water eventually getting into food or water supplies. These processes would take a rather long time, at least several thousand years, which gives excellent protection over the period when the waste is highly toxic. The long term effects can be estimated from the rate at which rock is eroded, since several hundred year old waste is, in almost every way, like ordinary rock. For average rock at the depth of waste burial, less than one atom in a trillion escapes and gets into human food or drink each year. If this probability is applied to the rock-like buried waste, one year's waste from a single nuclear power plant might eventually cause an average of .001 fatality.

For coal-burning plants, the best available or easily developable technology may be capable of removing 90% of the sulfur which then would reduce the effects to 2.5 fatalities per year. At this level, nitrogen oxides and smoke would make similar contributions, and of course the cancer-causing chemicals would still be unmolested, so it is probably unrealistic to hope to get the fatality rate below five per year, 5000 times higher than for the nuclear case.

In summary, the dangers from nuclear wastes are hundreds or thousands of times less than from coal-burning wastes on every count - for potential danger, for dangers from simple and cheap disposal, or for dangers following use of the best technology. In fact the hazards even from simple and cheap nuclear disposal are far less than we can ever hope to achieve for coal-burning wastes.

Sometimes it is claimed that effects of radiation are not well understood. But radiation effects is a far simplier phenomenon than air pollution from coal burning. Radiation is much more easily detected and measured, it has been the subject of far more scientific research - about $2 billion worth over the last 30 years - and it is far better understood. Radiation effects are under constant study by International and National Commissions on Radiation Protection, a United Nations Scientific Committee, a Committee of the National Academy of Sciences, etc. The figures we have given for fatalities due to radiation are based on highly conservative procedures, judged by all of these prestigeous groups to be much more likely to over-estimate than to underestimate the effects.

The figures we have given for fatalities from coal-burning wastes, on the other hand, represent an average of some very crude guesses of the effects of sulfur and particulates. In fact there is one well-known and never-refuted paper in the scientific literature which gives good evidence that the effects may be ten times worse than these estimates. Even less is known about the effects of nitrogen oxides. Most of the chemical compounds produced in coal-burning have never been investigated for toxicity, and at least a hundred are suspected of being carcinogens. We don't understand the effects of the huge quantities of carbon dioxide being discharged and we don't know what eventually happens to the sulfur that has been released. Clearly the coal-burning wastes are much more mysterious than are the nuclear wastes.

One special fear about the nuclear wastes is that radiation is known to cause genetic mutations and people worry that these may harm the human race. But the genetic effects of radiation are quite mild, comparable to the effect of wearing pants an extra few minutes per year (this produces genetic defects by warming the gonads). There is no evidence for genetic effects among the survivors of the atomic bomb attacks on Japan, even though there were 25,000 of them who received millions of times more radiation than anyone expects us to receive from nuclear waste. The total numbers of eventual genetic defects expected from the latter are less than the number of estimated fatalities we have given in our previous discussion. Moreover, the coal-burning wastes include chemicals that are also quite capable of inducing mutations. So little is known about this that the subject is seldom discussed, but that does not mean that the effects are not important. Six percent of all live births involve genetic defects, and no one believes that more than a tiny fraction of these are due to radiation.

The principal attacks we hear about the safety of nuclear waste are claims that isolation is not perfect, that release is possible, that nothing can be guaranteed. But we have only recently begun trying to isolate some of the wastes from coal-burning, and don't forget - they are hundreds of times more dangerous. In fact they are here and now killing many thousands of people every year in our country, a million people per century. Can anyone devise any possible scenario in which a million people will die from a century's worth of nuclear waste?

Apart from comparisons with wastes from coal, it is useful to make comparisons with toxic chemicals. The nuclear waste that would be produced each year if all U.S. power were nuclear would be about the same number of lethal doses as we now produce of barium or arsenic. One can argue that the arsenic and barium were here on earth already, but the nuclear waste is a new hazard we are creating. But about half of the barium and arsenic we use is imported into our country and hence is being artifically introduced into our environment. We should also consider the fact that the barium and arsenic are not buried deep underground in a carefully chosen rock formation; in fact arsenic is principally used as an herbicide, so much of it is scattered around on the surface of the ground in farmland.

Critics constantly emphasize that nuclear waste will remain toxic for a very long time, but arsenic and barium will remain toxic forever.

Perhaps the worst misunderstanding about nuclear waste is this long term toxicity; it is often said that it will remain toxic for 250,000 years. But let's see how toxic it is after even 500 years. By this time one would have to eat about a quarter pound of it to have a 50% risk of dying from it. But there are minerals in the ground of which one ounce is lethal, and we keep things in our houses of which a fraction of an ounce would be fatal if ingested. Mercury which we have in electric switches and in thermometers we put in our mouths is a hundred times more toxic than 500 year old waste, and selenium which is used in our radios and TV sets is five times more toxic still. Even nickel, chromium, and aluminum which everyone uses by the pound is comparably toxic with this waste.

Another interesting perspective is to compare the waste with natural radioactivity. If we would stand on the ground above a 1000 year old repository, there would be as much radioactivity in the ground between us and the repository as there is in the waste buried in the repository.

Moreover, it can be shown that all the radioactivity in the ground, deeper than a few meters, is probably not causing as much as one fatality per year in the U.S. When we store our waste, we increase the radioactivity in the top 2000 ft of U.S. rock and soil by only about one part per million each year, so its effect is to cause less than one millionth of a fatality per year.

When we consider very long time periods, we should take into account the fact that nuclear power burns up uranium, and uranium is the source of a great deal of natural radiation exposure. In fact, radon gas which comes from uranium within the top 10-20 ft of the surface of the ground, is believed to be causing about 5000 fatalities per year in the U.S. Therefore, by consuming uranium, much of which is surface mined, we are saving lives. It turns out that after a thousand years, the consumption of this uranium is saving ten times as many lives as the waste is expected to be ending. Thus, on any long time scale, nuclear power with geologic waste storage is a technique for <u>cleansing</u> the earth of radioactivity. People who live in the far distant future will be exposed to less radiation as a result of our use of nuclear power today.

We often hear that it is immoral for us to enjoy use of the energy now while our progeny will be burdened with the waste. Actually the burden will be trivial once the repository is sealed; watching it would be a part-time job for one person. But far more important is the tremendous burden we place on our progeny by consuming all the Earth's valuable mineral resources. Within a few generations we are using up all the copper, tin, lead, and a long list of valuable elements, and we are burning up coal, oil, and gas, each at a rate of millions of tons per day, depriving our progeny of feedstock for making plastics, organic chemicals, and fertilizers. The only practical way we can compensate them would be to leave them a technology that will allow them to live in reasonable comfort without these resources. The key to such a technology must be cheap and abundant energy, and the only source of this we can now guarantee is nuclear power from fission.