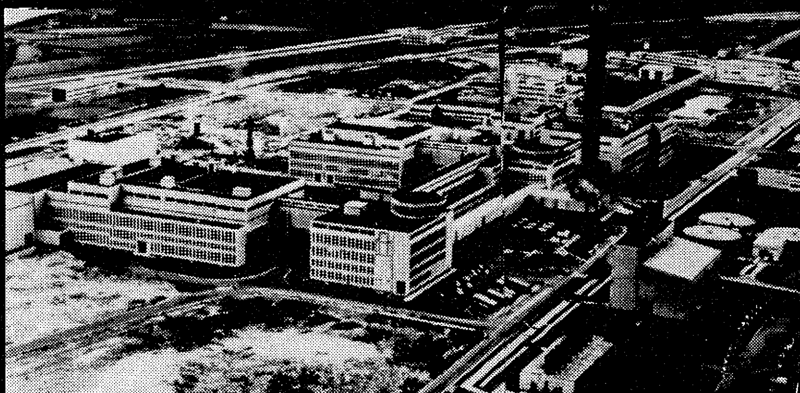
THE NON-PROBLEM OF NUCLEAR WASTES

Petr Beckmann



La Hague, France

Windscale, Britain

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The Non-Problem of Nuclear Wastes

By Petr Beckmann

FIVE WELL-KEPT SECRETS

It may be hard to believe after the ferocious propaganda onslaught against nuclear power, but the vastly superior method of waste disposal is one of the salient advantages of generating electricity from nuclear energy; in fact, if nuclear power were not safer than any other power generation (which it is), if it were not more reliable (which it is), and if it were not more economic (which it would be if it were spared the artificial expenses for delays and litigations), that one advantage of a vastly diminished waste disposal problem might well be enough to give it a decisive advantage over any of its alternatives.

If that sounds crazy, consider the following five well kept secrets:

1. It is utterly untrue that no method of waste disposal is known;
2. It is utterly untrue that nuclear wastes must be guarded for thousands of years;
3. The paramount issue that is being covered up is a simple comparison: Is nuclear waste disposal a significant advantage in safety, public health, and environmental impact over the wastes of fossil-fired power plants (let alone industrial wastes in general) or not?
4. Much of the answer to the question above is contained in two simple statictics: For the same power, nuclear wastes are some 3.5 million times smaller in volume; and in duration of their toxicity, the advantage ranges from a few percent to infinity.
5. Nuclear power does not add any radioactivity to the earth; on the contrary, it reduces the radioactivity that Mother Nature would otherwise be producing.

WHAT HAPPENS TO WASTES NOW?

The reader is warned that the purpose of the following paragraph is quite certainly not a *tu quoque* argument ("Waste disposal is a mess anyway, so it doesn't matter if we make it a little bigger"), but rather a summary against which any waste disposal problem, nuclear or not, should be seen; the real point, namely how nuclear waste disposal can *eliminate* part of the problem, will be made later.

The US produces annually 38 million tons of industrial wastes,of which some 10 to 15% are hazardous, and the amount is growing by about 3% a year.* Most of this goes into unmonitored landfills, of which 100,000 are for industrial wastes (besides more than 41,500 sites for municipal wastes and sewage sludge). No one knows the number of landfills that have been closed (but continue, of course, to be chemically and physically active). Only 10% of the now operating landfills are in compliance with proposed federal regulations; the other wastes are disposed of by lagooning in unlined surface impoundments, in unsecured landfills, in sewers, and in deepwells, by burning in uncontrolled incinerators or by spreading on roads, and a considerable part is disposed of, ask not how, by gypsy haulers and moonlight dumpers.

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* This and the following is based on EPA estimates. See also series of four articles on Toxic Waste Disposal in *Science*, vol. 204, issues 5/25 through 6/22, 1979.

The volume of toxic wastes generated in a single year is more than 1,000 times larger than that of the nuclear wastes accumulated by nuclear power plants since the beginning of the nuclear era 22 years ago. Their toxicity is retained for centuries in the case of the more stable chemical compounds such as polychlorinated biphenyls; and elemental toxins (such as cadmium, beryllium or arsenic) remain toxic forever — unless, of course, they are luckily radioactive, so that they will disintegrate by radiation. Otherwise they will be around long after the last atom of radioactive potassium 40 in Ralph Nader's blood (halflife 1.2 billion years) has decayed.

Yet Ralph Nader's radioactivity is easy to detect; chemical and biological toxins usually make themselves known only by the damage they have already inflicted.

Such was the case at the Love Canal near Niagara Falls, N.Y., which had been used as a dumping ground by the city and several industrial enterprises. It was closed and covered by a clay cap in 1953, but the 21,800 tons of chemical wastes deposited in it began oozing out in the late 70's. In April 1978, investigators found hazardous levels of toxic chemicals in the basements of homes. Young women in some areas near the site had three times the normal incidence of miscarriages, children born there had up to 3.5 times the normal incidence of birth defects, and many adults had incipient liver damage.

In August 1978 an imminent health hazard was declared and 235 homes were evacuated; subsequently President Carter declared the zone a disaster area. It was then found that 10% of the chemicals may be carcinogens, mutagens and teratogens (causing cancer, genetic mutations, or disfigurements, respectively). The houses and school in the area will probably be leveled. The clean-up operation is estimated at more than $30 million, and the lawsuits filed now total more than $2 billion.

You probably heard of the tanks at Hanford, Wash., leaking nuclear wastes for a time (injuring nobody). Have you ever heard of Love Canal, New York?

And you must have heard of the Grand Disaster at Three Mile Island whose only casualties are the roughly one fatality per week in the fuel cycle attributable to the coal-fired power replacing that which used to come from the now disabled reactor. Have you ever heard of Seveso, Italy?*

HOW CAN NUCLEAR WASTE DISPOSAL HELP?

Nuclear waste disposal cannot avert disasters such as Love Canal or Seveso, nor can it improve on the disposal of *every* type of industrial wastes.

But a very significant part of industrial wastes are the wastes produced in the generation of electric power, and here nuclear power can eliminate part, and eventually all, of the voluminous, dangerous, and persistent wastes produced by fossil-burning power plants, particularly coal-fired ones, simply by replacing them by a minuscule volume, and by a far safer, cleaner, and healthier method of waste disposal.

At this point it is time to insert the usual disclaimer. As we shall see in a moment, coal wastes take a shockingly large toll in deaths and diseases; but there is one thing worse than coal, and that is no coal. A glance at the statistics over the last 75 years in 150 countries† shows that coal saves more lives than it takes; the purpose of this comparison is not to fight coal, but to show the millionfold advantage of nuclear waste disposal over the waste disposal that is being practiced now.

* On July 10, 1976, a pharmaceutic factory released a cloud of dioxin, a potent toxin and carcinogen; a 270-acre area was evacuated, fenced off and placed under guard, 87,000 small animals were poisoned by the incident or subsequently killed by the authorities; the furniture of the evacuees was buried in pits, their gardens uprooted, and their homes decontaminated; they were allowed to return to the area only in January 1979, 18 months later. (See feature article in the *Wall Street Journal*, 7/10/79).

† L.A. Sagan and A.A. Afifi, *Health and Economic Development*, Reports RM-78-41 and RM-78-42, International Institute of Applied Systems Analysis, Laxenburg, Austria.

POWER WITHOUT WASTES?

There is no such thing as large-scale power generation without wastes. The nearest to it is hydropower, but even that produces wastes in the manufacture of its machinery, in the construction of its dams, and in the energy conversions for both. In any case, since most hydropower sites in the US have already been used up, hydropower does not really offer much of an alternative choice for large-scale power generation.

Solar power is not only not without wastes, but the construction of its collectors produces some three orders (one thousandfold!) more wastes than that of any other electric power conversion — a direct consequence of its diluteness.* The construction of a 1,000 MW solar plant would need a thousand times more materials than a conventional plant of equal capacity, whether fossil-fired or nuclear: 35,000 tons of aluminum (at an energy cost of 75 million BTU per ton), 2 million tons of concrete (at 12 MBTU/ton), 600,000 tons of steel (at 56 MBTU/ton), 75,000 tons of glass (at 18 MBTU/ton), etc.†

If the 1,000 MW are not produced centrally, but are distributed over many small, domestic units, the imbalance becomes worse — for the same reason that a central large bakery wastes less flour per loaf than 10,000 housewives who bake one or two loaves each.

Moreover, unlike conventional sources of electricity, solar power is not self-sustaining: It cannot now (nor in the foreseeable future) produce the electricity needed to manufacture solar power components. In practice, therefore, the wastes produced by solar power are merely pushed off to non-solar manufacture and generation, and of these wastes the only ones that are capable of permanent removal from the biosphere are nuclear wastes.

COAL WASTES

Sunday supplements and pop lecturers have repeated the equation $E = mc^2$ for atomic energy *ad nauseam*; but few people are aware what the *absence* of that equation means for coal and other fossil fuels. It means that no energy is liberated by "annihilating" mass; it is liberated by a chemical reaction in which the mass of the input products must exactly equal the mass of the output products. In other words, all the tons of coal that go into America's power plants must come out as tons of wastes with not a single ounce forgiven: Physical laws admit no exceptions.

And just how much coal goes into America's power plants?

480 million tons per year.‡ 913 tons a minute. About 15 tons since you began reading this paragraph. Did you stop reading in surprise? Whether you did or not, there went another 15 tons. But wait! That is just the coal going in; the wastes coming out are more than twice that weight: A power plant consumes not only coal, but also atmospheric oxygen (and a little nitrogen) to produce its wastes. Surprised? There went another *thirty* tons of wastes.

Somewhere near you there is a coal-fired power plant, perhaps a big one with 1,000 MW capacity or more. The coal comes in by unit train, with cars carrying 100 tons each. Each car is grabbed by a rotary dumper that turns it upside down to empty its load onto transporters, and then puts it back onto the rails. It dumps one 100-ton truck every two minutes for much of the day shift; twice as fast if the cars have the new couplings that allow the dumper to handle them without uncoupling them from the train.

100 tons a minute! And all those 100 tons must end up in one of two places: a landfill or the atmosphere. There is nowhere else for it to go. Some of it will reappear in your drinking water; and some of it will be disposed of in your lungs.

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* *Why "soft" technology will not be America's energy salvation*, see inside front cover of this booklet.

† K. Lawrence, *Review of the environmental effects and benefits of solar energy technologies*, Solar Energy Research Institute, Golden, Colo., 1978.

‡ 1978 figures (National Coal Association).

The coal enters the inner plant in only one place — it is taken by transport belts to the boiler furnace. The wastes exit at several places: The stack disgorges gases and particulates; the bottom ash (from the furnace) and the sludge from the scrubbers go into lined settling ponds, where the water evaporates and the dry residue is then taken to landfills; most of the fly ash is prevented from exiting through the stack by electrostatic precipitators or by mechanical filtering in baghouses (the hot gases are forced through bags of fairly finely woven textile). In either case it is dry enough to be trucked to landfills directly.

Solid wastes, in a 1000 MW unit, are produced at the rate of some 30 lbs *per second.** They include 19 toxic metals (such as arsenic), carcinogens (such as benzopyrene), and as recently discovered, some mutagens.†

Oh, yes, and they are radioactive, too, as are the stack emissions; up to 50 times more than the routine emissions from a nuclear plant. If coal-fired plants were subject to NRC regulations, most of them would have to be shut down for exceeding radioactive limits. The radioactivity is due to the uranium, thorium, pollonium, radium, and other radionuclides in the coal (some of them are soluble in water and chemically active); however, it is not the radioactivity that makes coal wastes dangerous, for the radioactivity from coal-fired plants, even if 50 times greater than that from nuclear plants, is still minute; it is merely an amusing point to ponder what the Sternglasses and Caldicotts would do if it really were low-level radioactivity that is bothering them.

All these goodies are dumped in landfills, where nobody monitors them, and their health effects appear only after they have been leached out of the dump. Except for the radioactive isotopes, the halflife of the toxic elements like arsenic or mercury is infinite. Their volume is stupendous: The sludge from the scrubbers alone will amount to 240,000 acres 6 ft deep by the end of the century (and proportionally more if coal use is increased as planned by the Carter administration).

And yet the solid wastes are much the smaller problem. The real health hazard are the wastes disgorged by the stack. Per 1,000 MW unit, they include:

• 600 lbs of carbon dioxide *per second* — not toxic, but possibly responsible for climatic changes.

• 30 lbs of sulfur dioxide (and some sulfur trioxide) *per second* — linked to lung, heart and bronchial diseases by striking correlations (though a direct cause-effect relationship need not necessarily follow).

• As many nitrous oxides as 200,000 automobiles running simultaneously — producing photochemical smogs, and recently linked (via nitrosamines) to cancer in urban areas.

• Particulates — the ones that get past the precipitators and other filters because they are too small are also too small to be held back by the filtering mechanisms of the human body, and they reach the bronchi and the lung. Even if the precipitators are 99% efficient, 18 lbs of this fine stuff comes out of the stack every minute.

The carcinogens, mutagens and toxins (or for that matter, the radioactivity) of these particulates are not tied to size; they are present to the same degree as in the bottom ash and fly ash, which is so abrasive that if used in a jet it can cut metal. Some of it is "disposed" of in people's lungs.

That is the waste "disposal" we have now.

The results of such a waste disposal should therefore not be surprising, yet they come as a shock to most people: According to a recent report by the Office of Technology Assessment (a scientifically competent and widely respected agency of the US Congress),

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* Waste quantities in the following assume a capacity factor of 75%, coal with 18% ash factor (Midwestern bituminous), and a conversion rate of 2,500 kWh per ton of coal.

† C.E. Chrisp, G.L. Fisher, J.E. Lammert, "Mutagenicity of Filtrates From Respirable Coal Fly Ash," *Science*, 6 Jan. 1978, pp.73-75.

the number of premature deaths due to coal combustion are estimated in the table reproduced directly from the report:*

Table 32.—Annual Projected Mortality From Coal Combustion

Year	Quads of coal use	Expected mortality
1975	11.3	48,120
1985	22.5	49,543
1990	25.7	55,835

NOTE: Proportional Mortality Model—3.25 deaths/yr/100,000 populations/(1 $\mu g/m^3$—annual average for sulfate).

SOURCE: Based on population exposures from: Meyers, R. E., Cedarwall, R. T., Kleinman, L. I., Schwartz, S. E., and McCoy M., "Constraints on coal utilization with respect to air pollution production and transport over long distances: summary," Oct. 2, 1978 (draft report), Brookhaven National Laboratory.

These numbers will not startle anybody who has been studying the effects of power generation on public health; they are startling only in the way the national news media have been covering them up in their lynch campaign against nuclear power.

The figures are the best that are currently available, based on recent work at the Brookhaven National Laboratory (Divisions of Atmospheric Sciences, and of Biomedical and Environmental Sciences). Though they are carefully calculated from the measured correlations with sulfate exposures in each of a 20 by 20 mile square of a grid covering the US, they are not certain, but probabilistic values subject to a statistical range of error. The numbers given in the table above are, in fact, medians, so that there is a 50% chance that the true death toll is *greater* than 48,120 per year.

Electric power generation now accounts for about 77.5% of coal use, so that the prorated part gives the cost of coal waste disposal into the atmosphere: 37,293 premature deaths per year.

And that does not include the human costs from waste disposal in landfills, nor the other human costs of coal (deaths and injuries in transportation, industrial diseases and accidents in the mines, all of which are vastly greater than for the uranium producing the same energy).†

NUCLEAR WASTES

Against this background nuclear waste disposal would come as a deliverance even if — which is not suggested — the wastes were to be dispersed into the oceans or if — which is not suggested, either — they were to be buried in random places without monitoring or even records. (Even in these purposely absurdly chosen cases the health damage could be shown quite small, and negligible compared with the presently practiced methods of waste disposal.)

But, of course, nuclear waste disposal can be performed infinitely better than that.

A fuel rod containing uranium oxide pellets is replaced after about three years of service. The reason for replacement is not that its energy has been used up, but that the

* *The Direct Use of Coal*, Report by OTA, 411 pp., 1979; $7 from Government Printing Office, Washington, DC 20402, stock no. 052-003-00664-2.

† Neither does it include the spectacular, but relatively uncommon disasters linked to coal wastes: On February 26, 1972, a coal waste embankment failed on Buffalo Creek at Saunders, W.Va., the resulting flood killing 125 people; on Oct 21, 1966, a 120-ft high heap of coal slag collapsed at Aberfan, Wales, and the resulting mudflow buried a school, killing 144 people, most of them schoolchildren.

fission products block the flow of neutrons necessary for an efficient chain reaction. These rods are "hot" not only in the sense that they are radioactive, but they are also thermally hot, and are therefore cooled for some time at the cooling ponds on the site of the plant to let the short-lived components die away. (The shortlived components are the dangerous ones, since their short life is spent in radiating away their energy more intensely; they also include some products that are dangerous for additional reasons — for example, iodine 131, with a halflife of 8 days, which is trapped and retained by the thyroid gland, where it may give rise to cancer.)

After the fuel rods have been in the cooling ponds for some 6 months, they should be taken to a reprocessing plant, where they are cut up into short pieces and dissolved in nitric acid, in order to extract the remaining fissile uranium and the plutonium formed in the rods, and to recycle it into fresh fuel. (Yes, plutonium is formed in the rods of conventional light-water reactors, too. As much as 1/3 of nuclear power is generated from plutonium now, before the advent of plutonium breeders.)

Now this is not what is actually happening in America now. President Carter has prohibited reprocessing, and the plant at Barnwell, S.C., ready to perform it, lies idle. Amidst the worries about nuclear safety, the fuel rods have been piling up in the cooling ponds, and power plants are running out of space; amidst the talk about energy conservation and energy shortage, quadrillions of BTU's locked up in these fuel rods go untapped; and amidst the talk about proliferation and terrorism this energy is proposed to be wasted in a "throw-away cycle" by burying these rods in tombs until the whole country is littered with little plutonium mines in honor of President Carter's non-proliferation policy. History may relate how Americans in the 1970's, though acutely short of energy, self-sacrificingly denied themselves this treasure so that the Charles Mansons and Boston Stranglers of the 21st century might have a little plutonium to play with.

However, all of this is merely politics; US policy in this area may be based on Rosalynn's hunches, but it is not based on any technological constraints. Reprocessing technology is not only well developed, but in commercial operation in Britain (Windscale), France (La Hague), and the USSR (location undisclosed, but quite likely in Dimitrovgrad on the Volga). All three countries also have full-sized breeder reactors on line in the public power net, and reprocessing is particularly advantageous for breeders. Two other countries, Germany and Japan, now send their spent fuel to France for reprocessing, but both have far advanced plans for reprocessing plants (as well as for breeder reactors).

After reprocessing, with most of the uranium and virtually all of the plutonium (more precious than gold) extracted chemically from the acid, there remain the high-level wastes which are responsible for 99% of the radioactivity, but amount only to 1% of the volume. (One of the favorite tricks of the anti-nuclear brainwashers is to talk about this total volume and imply that all of it is as dangerous as high-level wastes.)

The high-level wastes are then solidified and sealed into a permanent leach-resistant medium such as boron-silicate glass, which is then itself sealed into a permanent container such as a stainless-steel canister, and after some years of cooling in interim facilities, the canisters can be buried, retrievably, in stable geological formations. All of these points need further explanations, and we will return to them presently, but first we note the two outstanding features of these wastes: their ludicrously small volume, and their temporary toxicity.

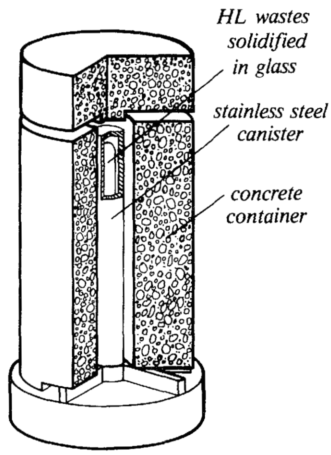
Even though the high-level wastes are diluted with twice their own volume of inert material as they are solidified into glass or ceramic, the grand total of these wastes for a 1,000 MW unit amounts to no more than 2 cubic meters per year — a volume that would comfortably fit under a typical dining room table. (A coal-fired plant of equal capacity produces some 10 tons of waste, not per year, but *per minute.*)

As for toxicity, the "nuclear priesthood that will have to guard the wastes for thousands of years" is very descriptive of Prof. Commoner's qualifications in nuclear engineering, but not of the toxicity of the wastes. In 500 to 1,000 years (depending on how completely the transuranics are recycled at the processing plant, and also on the concentration of the comparison ore), their radioactivity will have decayed to below that of the ore that they originally came from.

In the long run, nuclear power does not add any radioactivity to the earth; on the contrary, some of the energy that would have appeared as radioactivity of the ore, had it not been mined, will have been used up to give people light and warmth.

Now let us return to some of the technical details of disposal.

The stainless steel canisters holding the wastes solidified in glass or ceramics will be 1 ft in diameter and 12 ft long. Before going into their ultimate repository, they will be stored for an interim period of about 10 years to let them cool in air-cooled vaults or water basins. The only place where this is now being done in the US (as a pilot project, because there are no commercial wastes yet ready to undergo this treatment) is the Idaho Chemical Processing Plant, where underground concrete vaults are used. If all the wastes produced by the nuclear power industry up to the end of the century were to be stored on a single site in above-ground, massive (3 ft thick) concrete casks of the type shown on the right, shielding the radiation and providing protection from accidents (aircraft crashing into them) and sabotage, the entire site, including supporting facilities and security areas, would occupy about 1,000 acres, or about 3% of the area of a single 1,000 MW solar plant.



Module for interim waste storage

PERMANENT REPOSITORY

The advantage of delayed burial is a drastic easing of the cooling problem: The heat generated by the wastes will have died down to less than 3.5 kW per canister, or less than is released by the typical home laundry dryer.

The canisters can now be buried deep (1500 to 1800 ft) in stable geological formations, where, separated by about 10 yards (to provide cooling air flow and access for possible retrieval), they would take up a tiny area as waste disposal sites go: If not 11%, but 100%, of the US power capacity were nuclear, the annual increase would amount to less than 100 acres.

A typical geologically stable formation is a salt formation, of which the US has many. The very existence of the salt shows that no water has been present for as long as they have been there (some 100 million years), or they would have dissolved. And if water were to get in after all, the salt would seal up and prevent more water getting in.

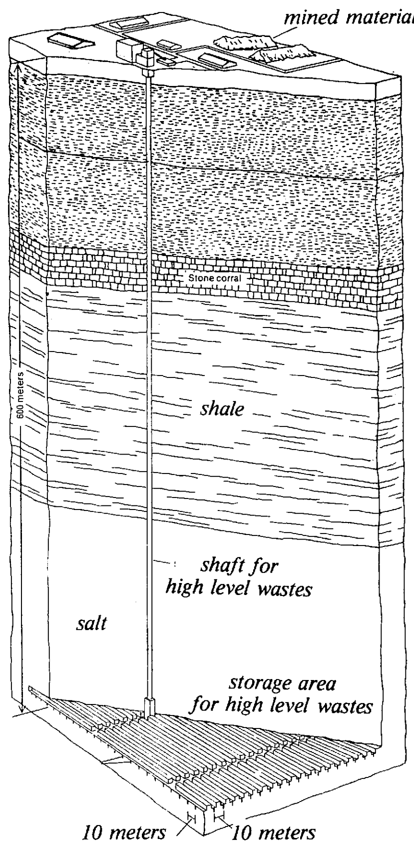
And if the water kept coming? If all the ground water now flowing near the proposed repository site in New Mexico were diverted by an evil genius to the proposed repository site, it would take 50,000 years to dissolve the salt enclosing a single year's deposit of wastes, the canisters would corrode in 10,000 years or more, the glass would be leached away in another 30,000 years, and the wastes carried by this water would take another 1,000 years to reach the surface in the 931st century A.D.*

* Estimates taken from B.L. Cohen, "The Disposal of Radioactive Wastes from Fission Reactors," *Scientific American*, June 1977, pp.21-31; and from *Nuclear Power and Safety*, Report by the (Norwegian) Nuclear Power Commission to the Royal Ministry of Oil and Energy, Oslo, 1978; English translation, Columbia University Press, Irvington-on-Hudson, New York, 1979.

All of this assumes that our descendants 91,000 years hence would just stand by and do nothing, even though this improbable migration by the wastes could be traced every inch of the way, for thank God, they are radioactive. The funny thing is that quite plausibly they might indeed do nothing: Not only will the radioactivity have decayed to harmless levels, but if and when a cure (or better, immunization) for cancer is found, these wastes will have lost the only danger they ever harbored.

Freakish as this penetration by ground water may be, it is considered the "most probable" natural threat by the scientists who have studied the problem intensely. Earthquakes would not damage a solid structure like a glass-filled canister in a plastic medium like salt, and volcanic activity, which is extremely rare in tectonically quiet regions and is limited to small areas, is not a credible danger.

Saboteurs? Surely there is no better place for them than 1500 feet below the surface, threatened by searing radioactivity if they penetrate the shielding, with no way of getting the stuff to the surface, stuck with a weapon that will kill only 10 to 40 years after it is used (the latency period of cancer).



But suppose that there are several nuclear wars that wipe out civilization together with the records where the repositories were (no nuclear bomb can penetrate 1500 ft below the surface); after a few centuries civilization rises again, miners drill into a repository, overcome by curiosity they saw into the encapsulation, and who are you to say that one of them will not eat half a pound of wastes for lunch? (That would be the amount, after 600 years, that would eventually kill the hungry miner with a 50% probability). There is no need to argue that this scenario is not very credible: At that depth, the far bigger probability would be drilling into one of the many flooded coal mines; since the pressure of the water depends only on the height of the column, not on the quantity of water, the unfortunate drilling crew would need no more lunches. Going nuclear means a few less flooded mines to drill into.

SO WHERE IS THE TROUBLE?

We are not yet through with all technical aspects of nuclear waste disposal, but even so, it should already be clear from this brief account that there are no major engineering problems in disposing of nuclear wastes in a manner whose safety is unrivaled by any that can be applied to other wastes, in particular, to the fossil wastes whose high costs in public health can be eliminated by nuclear power.

No method of nuclear waste disposal has been *adopted* and *legalized* by the bureaucrats and politicians in Washington; that does not mean that no method is available. It is true that the need for permanent waste disposal is not very pressing; but for interim storage and reprocessing, the spent fuel rods are piling up in the cooling ponds at power plants at an alarming rate, while the Washington bureaucracies, whose favorite word is "planning," are studying this non-problem to death.

ARTICLE 10.5

Radioactive Waste Disposal

25-10.5-101. Radioactive waste disposal prohibited. No radioactive waste or material shall be disposed of in any manner within the state of Colorado. For the purposes of this article, "radioactive" means any material, solid, liquid, or gas, which emits ionizing radiation spontaneously.

25-10.5-102. Violation - penalty. Any person who violates

Many states have legislated against transportation or disposal of nuclear wastes as politicians seek popularity by catering to the antinuclear hysteria. The sample above, from a 1979 Colorado bill which was defeated, gives a definition of radioactive wastes by which the sponsor of the bill would have been guilty of a class 1 misdemeanor every time she went to the toilet.

Quite similarly, members of Congress such as Udall, Hart, Kennedy or Weaver are using nuclear power, which could save up to 37,000 lives per year, as a scare bogey with which to make political capital. But then, in fairness to their humanity, it should be said that 37,000 lives is not very much for politicians who yawn as they observe the hundreds of thousands of victims drowned in the Auschwitz of the South China Sea.

ENGINEERING PROBLEMS

Although there are no major problems and, indeed, there is one case giving 1.8 billion years of experience with nuclear wastes,* their disposal is not without minor problems, most of which are of the "Couldn't it be done even better?" type. There are few who believe that burying the wastes below the sea bed is a better way than the one described, and fewer still who would melt them into the arctic ice cap (let alone shooting them into outer space). But there is a spirited controversy over the encapsulation to be used.

France, and probably Britain, have settled on boron-silicate glass, and the steady stream of data emerging from the French commercial vitrification plant at Mercoule is bound to give glass an edge. Yet there are reasons to believe that ceramics are better, and they may yet be adopted in the US. Meanwhile, scientists led by Prof. A.E. Ringwood at the Australian National University in Canberra have developed and patented the manufacture of artificial rock that will so mesh with the crystalline structure of the waste that it will immobilize it for up to two *billion* years. (How do they know? From the geology of stable isotopes: Radioactivity is a nuclear phenomenon and cannot possibly affect chemical or macrophysical behavior.) The Swedish company ASEA has succeeded in encapsulating waste canisters under high pressure in artificial corundum, fully compatible with natural corundum, the hardest mineral occurring in nature. It will last for millions of years, because nothing short of diamonds is hard enough to cut it open.

The details of these alternatives make for fascinating reading, but they do not belong in this booklet: Imagine arguing the relative merits of this versus that anaesthetic at a time (only 120 years ago!) when people were convinced that to ease the pain of amputation there was nothing better than making the patient drunk, and if he could stand it, hitting him over the head with a club.

DISASTER IN THE URALS

When in 1977 the Soviet dissident biochemist Zhores Medvedev brought word of a disastrous radioactive release at a waste disposal facility in the Urals in 1957 or 1958,

* This refers to the "Oklo phenomenon." Oklo, in Gabon, Central Africa, is the place where five natural nuclear reactors had been in operation for half a million years 1.8 billion years ago, producing 2 tons of plutonium and 5 tons of fission products. Almost all of the plutonium has now decayed, and the "wastes" have not budged for 1.8 billion years.

anti-nuclear activists were jubilant (for they fervently yearn for the most horrendous nuclear disasters), and nuclear supporters tended to dismiss the story as nonsense.

It may not have escaped the observant reader that this writer is a supporter of nuclear power, but as one who lived 15 years behind the Iron Curtain, he found Medvedev's story as originally published in the *New Scientist* highly probable.

There is no such thing as verifiable truth in the Soviet Empire; it is a world of speculation, rumor, and indirect evidence for what is plausible. Soviet safety standards are meaningless window dressing, as one would expect in a country where public scrutiny is nonexistent, and where human lives have little value. Western concepts of logic are not applicable: A system in which the highest motivation of the citizen is to stay out of trouble has a logic of its own. The illogic and diseconomy of communism is, moreover, compounded by the traditional sloppiness of Russia, whose crash industrialization has not drastically changed its basic character of a backward and immature country.

Medvedev's indirect evidence consisting of a series of articles on lakes and fish contaminated by radioactivity in the Soviet *Journal of Ichtiology* is as good a proof as is likely to be obtained in the Soviet Empire, and it persuaded this writer, for one, that *some* kind of nuclear disaster must have happened. This impression was strengthened by Medvedev's recently published book;* but what remains a mystery is what exactly had spread the radioactivity. His original two articles said very little on this, and the book is equally deficient. His detective work is very masterful in pinpointing the time and place of the disaster, but he presents little acceptable evidence that the release came from nuclear wastes; his theory of plutonium stratification is speculative and naive.

The more probable explanation, which needs neither additional hyptheses nor questionable physics, is that one of the Soviets' military reactors breeding plutonium for nuclear weapons suffered an uncontained meltdown. Until recently, the Soviets did not provide even their civilian reactors with emergency core cooling systems or containment buildings, and anyone who has seen as much as a public toilet in the Russia off limits to tourists will marvel that this meltdown should have been the only one.

Or if it was indeed nuclear wastes that "exploded," it could have been water seeping onto the hot wastes buried, with Soviet sloppiness, in a shallow landfill, until a steam explosion spread the wastes over a large area. (An accidental explosion of a nuclear weapon would have been registered in the West, where this type of secret is not kept for long.)

But the details of the disaster are not relevant to nuclear waste disposal: We don't need Soviet disasters to tell us that nuclear wastes are highly dangerous and must be treated with respect.

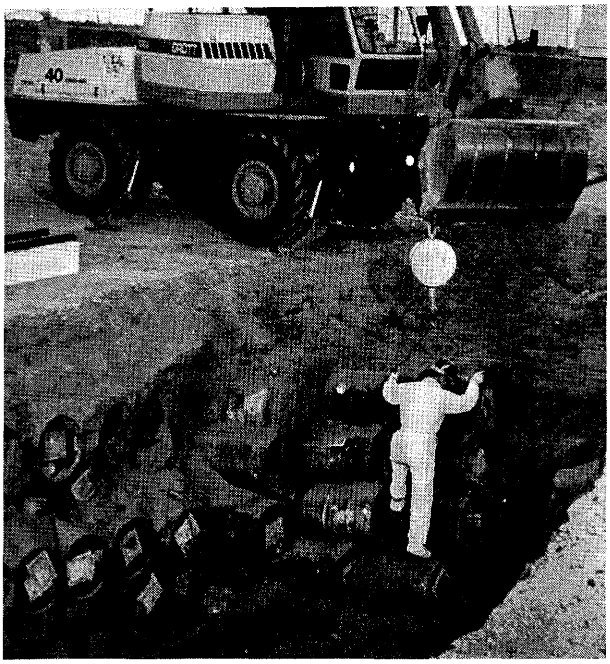
An air disaster in the Azores in 1977 killed more than 500 people; another in Chicago in 1979 killed 278. Does that make aviation an intolerable risk?

LOW LEVEL WASTES

Low and medium level wastes account for only 1% of the radioactivity of all wastes, but for 99% of the volume, a disproportion manipulated with religous fervor by the antinuclear brainwashers. Low level wastes are usually defined as those with less than 10 millicuries per kilogram. They consist of discarded workers' gloves, paper, plastic, textiles, glass, etc., that have been (or may have been) contaminated with radioactive isotopes and otherwise resembles normal household or industrial waste. Only about 0.01% by weight of this waste is actually radioactive.

This material is put into drums and disposed of under controlled and monitored conditions in a repository a few feet underground, with asphalt flooring and other methods of ensuring their isolation — in the US. Many, perhaps most, other countries using nuclear power simply dump these drums into the sea, which is no great abuse, for it is

* Zhores A. Medvedev, *Nuclear Disaster in the Urals*, Norton & Co., New York 1979.



Radioactive waste being buried in Idaho

190,000 tons of it by the year 2000.

This photo was published by *Time*, 10/31/1977, as part of an article "The Atom's Global Garbage." Nowhere in the article was a distinction made between high-level wastes which account for 99% of the radioactivity, and low-level wastes which account for 99% of the volume, nor was it mentioned that the photo shows burial of low-level wastes.

probably negligible compared with the total radioactivity of sewage and other wastes dumped into the oceans. For example, whiskey consumption in this country now stands at almost 200 million gallons per year. After it has been consumed, most of its ingredients (other than the pure water which may evaporate) quickly find their way into the sea. Since whiskey is radioactive with about 1.2 nanocuries per litre, the contribution to the radioactivity of the oceans by America's whiskey drinkers alone is of the same order as 1 ton of low-level waste from the nuclear industry.

MILL TAILINGS

When a nucleus of uranium disintegrates by natural radioactivity, it may turn into one of the fission products that itself turns into radium, which begets radon, which begets a further chain of unstable elements ended by stable lead. The most dangerous in the chain are radon and its daughters, which are highly radioactive, and as gases, have easy entrance into the human body by inhalation. Radon is, in fact, the most serious natural radioactive health hazard in the natural environment, causing some 10,000 cancer deaths per year in the US;* it is also the main cause of lung cancer among uranium miners. (Although radon is shortlived, it is constantly being replenished by its grandmother uranium, which has a halflife of 4.5 billion years.)

Tailings near mills that extract uranium oxide from uranium ore have a relatively high concentration of U 238, and thus form an open source of radon gas. This was used in the one and only attempt ever made to claim that nuclear power generation is more hazardous than coal fired power.† (The far more usual tactic is to brush the issue under the carpet.)

Even assuming that the tailings would simply be left lying around and houses built on them (as has happened in some cases), the author of the theory had to let this source of

* This is based on figures from *Sources and Effects of Ionizing Radiation*, United Nations Scientific Committee on Effects of Atomic Radiation, UN, New York, 1977.

† R.O.Pohl, "Health Effects of Radon 222 from Uranium Mining," *Search* (Australia), August 1976, pp.345-354.

danger accumulate for 80,000 years before it overtook the fatalities due to coal-fired power. That puts it well beyond the next ice age and makes it the type of theory that is so bizarre that it no longer matters much whether it is right or wrong.

It is, however, not only wrong, it is, so to speak, suicidal: Coal turns out to be worse even in this freakish issue of what today's mining will do to the radon emissions over the next couple of million years. Uranium is one of the elements that is ubiquitous; it is mined only where its concentration is very high, but it is present virtually everywhere, and it produces radon everywhere. Radon is an inert gas that does not react with other chemicals in the ground, but diffuses upward and is diluted in the atmosphere. When a hole is dug into the ground for any reason at all, the flow of radon into the human environment is increased, and this aspect of coal mining alone might be enough to defeat the theory, but it can be defeated on less: Coal contains an average of 1 ppm of uranium, which is released to the environment as a source of radon. Although the hazard is quite small, it is one thousand times greater for a coal-fired plant than from the wastes of a nuclear plant of equal power.* The reason is not that the nuclear plant uses less uranium (it uses incomparably more), but that in producing electric power it *prevents* most of its uranium fuel turning into radon which it would otherwise have produced. What it produces instead is also radioactive, but the total dose to the environment is ultimately smaller than if the uranium had been left to decay on its own.

Since the fatalities chargeable to this year's mill tailings will be drawn out over the next 80,000 to 2 billion years (with one fatality per year in the "worst" of these years), the prime importance of this theory is to show how far the anti-nuclear crusaders will go when they are bankrupt of arguments. On the other hand, the radon trapped by buildings, especially unventilated ones, due to the uranium in its walls and foundations can more than double the outdoor background radiation, which itself is some 1000 times higher than the average US resident gets from nuclear plants, and this radon enters the lungs of the building's occupants not in 80,000 years, but here and now. If your room is not well ventilated (for example, in order to use less energy for heating or cooling it) you may well be breathing it as you are reading these lines. Why is this never mentioned by the antinuclear brainwashers?

Because it is one of the health hazards of energy conservation.

DECOMMISSIONING

Any energy facility must, at a certain age, be taken out of service again; the reservoir behind a hydroelectric dam will eventually silt up, and a fossil-fired plant has a life of about 30 years. Nuclear plants are licensed for 40 years and may have to be decommissioned after that time or earlier. In a sense, this is a case of waste disposal, too.

Some parts of the plant will have become radioactive. Surface contamination can be removed by chemical cleaning or sandblasting (as has been done in Chalk River, Canada, and as will soon be done at Three Mile Island, Pennsylvania), but the induced radioactivity bound within the material of the pressure vessel, for example, cannot be removed in this way. For the induced activity of steel, the dominant source is cobalt 60, and it would take 50 to 100 years before it dies down to a level where the massive pressure vessel can be dismantled without special precautions.

The three ways of decommissioning a reactor are mothballing (blocking the entrances by pouring them shut with concrete and some other security measures), entombing (burying the plant under a hill of earth), and dismantling by remote control. All three methods have been tried in practice and are technically feasible, so that the choice, when the decommissioning age is reached, is dictated by economic considerations.

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* See Cohen's article quoted in footnote on p.7. The uranium used for nuclear power is that close enough to the surface to be mined, which is also close enough to the surface to release radon to the human environment whether it is mined or not.

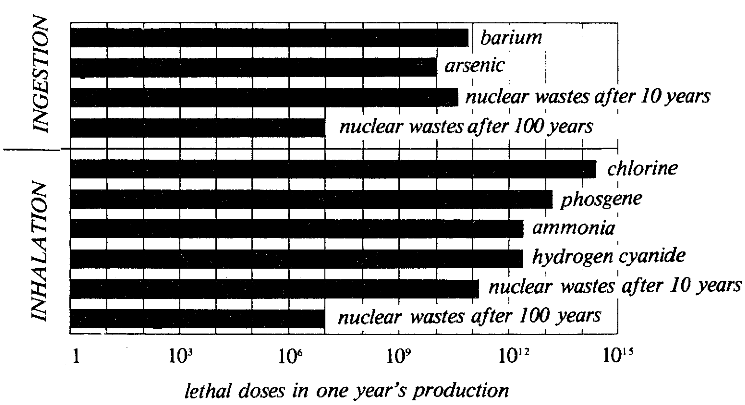
Since 1960, 65 reactors have been decommissioned in the US, including 5 power reactors, though none of the large units (1,000 MW or more) have yet been dismantled. Since the reactor building is only a small part (less than 1/10) of the usual 25-acre site of a nuclear plant, mothballing would not prevent a new reactor being used on the same site, and one of the favored options is mothballing for 100 years followed by straightforward dismantling and removal, at an expense of under 2% of the cost of the plant. Immediate dismantling under remote control has been shown feasible in an experiment performed in the Nevada desert, but for a 1,000 MW unit it could cost as much as $300 million if performed immediately, or $150 million if delayed for 30 to 40 years.*

TRANSPORTATION

If nuclear waste disposal is so safe, why can't conventional waste disposal be made as safe or safer?

Because the sheer quantity is overwhelming. As in all other aspects of nuclear power, its superior safety is ultimately due to the concentration of danger in small volumes that can easily be guarded and protected by multi-layered safety systems. Such systems are simply not thinkable for containing other dangers.

Transportation is a good example of this principle. Between 50 and 100 Americans are killed every year in hauling close to 500 million tons of coal from the mines to the power plants. (Nobody, to my knowledge, has ever been killed by the handful of automobile trucks shipping nuclear fuel.) If you can't protect the public from those 500 million tons when they lie as a pretty harmless solid on railroad trucks, how are you going to protect it after they have changed to particulates and gases most of which are disposed of into the atmosphere?



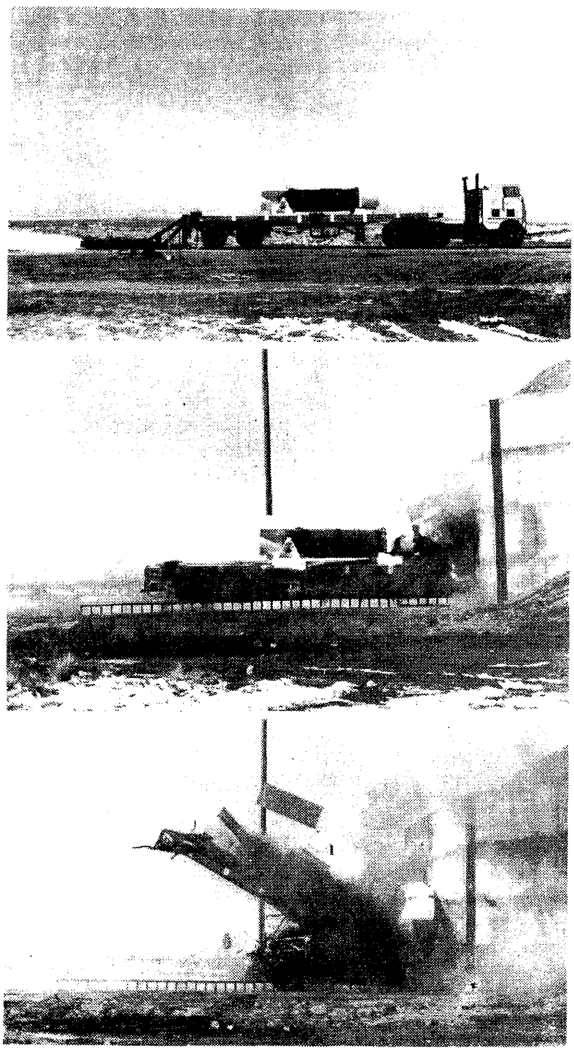
An industrial society is well used to handling large amounts of toxins, as shown by this comparison based on Prof. Cohen's figures (see footnote p.7 for source). These toxins are not buried carefully deep underground; arsenic, for one, has a halflife of infinity and is mainly scattered around places where food is grown.

Hardly a week goes by without an evacuation somewhere because a train carrying chlorine or ammonia or some other toxin has derailed. The amounts produced (and presumably transported) in the US every year are 16 million tons of ammonia, 9 million tons of chlorine gas, 32 million tons of sulfuric acid... the list could go on for pages.

* Sources: News release of 12/27/1976 by AIF on decommissioning report; estimates by Electricité de France and Verein Deutscher Elektrizitätswerke as quoted in Norwegian Report (footnote p.7); and estimate by United Kingdom Atomic Energy Commission for the Windscale Reactor (*Atom*, Nov. 1978).

These vast quantities simply cannot be protected from leakage, derailment, fire, and other hazards.

But nuclear wastes are so minute in quantity that it is perfectly possible to design containers that will withstand crashing into concrete walls at 60 m.p.h., dropping onto spikes from a height of 30 ft., and surviving prolonged periods in the open flames of a fire. Theoretically, the same could be done for chlorine gas. But for 9 million tons of it?



Sandia Labs at Albuquerque, N.M., used two pairs of rockets to fire this truck carrying a 22-ton fuel container into a concrete wall at 60 miles per hour. The container was filled with water colored with a blue dye so that leaks would show up. The truck (and in another experiment, a railroad engine) was smashed to splinters, but the container came through unscathed.

But how can I guarantee that nothing will ever go wrong?

I can't. Something will eventually go wrong, and the iron laws of probability say that if one waits long enough, nuclear wastes will one day kill a one-armed professor of Rumanian poetry called Zebulon McSchwammelfuss in Oshkosh, Wisconsin.

But here is what I *can* guarantee: The waste disposal used for non-nuclear generation of electric power will kill more than 30,000 Americans this year; 60,000 in two years, 90,000 in three years...

Should you worry all that much about Zebulon McSchwammelfuss?

IS IT ALL WASTE?

Most of nuclear waste is useless, and its most important aspect is replacement of far more voluminous and far more damaging waste, which is more than enough to justify it. Yet some of it is useful now, and some more may be useful in the future (making a case for storing nuclear wastes retrievably).

Some fission products can be used as tracers: Since the chemical properties of an isotope do not depend on whether it is radioactive or stable, the former variety can show where a chemical is located. (How is iron distributed over the cross-section of a tomato?)

The same idea of chemical equivalence has been tried to produce chemicals that will seek out cancerous cells and kill them with radioactivity. (In the anti-nuclear brainwashing onslaught it has pretty well been forgotten that radioactivity is used to *cure* cancer.) In preliminary experiments, 70% of the rats so treated recovered from breast tumors, whereas the untreated animals died.*

Food decays due to the action of bacteria which can be killed by radioactivity without affecting the food. Grain, fruit and vegetables can thus be preserved without the use of chemicals. (Only South Africa has so far been courageous enough to use this method commercially.)

The sludge produced by sewage treatment plants can also be irradiated in order to destroy the disease-spreading bacteria breeding in it; it does not itself becoming radioactive. This will not only sterilize the sludge, but make it useful as a fertilizer and even as animal fodder.

A particularly intriguing point is the recovery of rare metals essential for some alloys and other applications, but now available only from Rhodesia and South Africa (sources that thanks to US appeasement policies may soon be lost, too). In particular, rhodium, palladium and ruthenium, each of which is more valuable than gold, is present in the fission products, where latter-day alchemy has produced them from cheap uranium ore. It is not yet economic to extract these elements from nuclear wastes, but one day it evidently will be. Besides, when the US wakes up to its need for energy independence, it will have to look into its mineral independence, too.

A MATTER OF MORALITY

"The best practicable technology" is a phrase inserted into most environmental regulations. It is being abused by politicians and pseudo-environmentalists to harass utilities and other sectors of the economy that do not make a living by alloting or receiving government handouts. (For example, the EPA requires electric utilities in the East and Midwest to install scrubbers even when they burn Western coal which has less sulfur before scrubbing than their local coal has after it.)

But politicians and parasites aside, "the best practicable technology" for the wastes arising in the generation of electricity is to generate it by nuclear energy in the first place. The present method of disposing of those wastes kills some 37,000 Americans a year. The victims of nuclear waste disposal, if any, will be quite negligible compared with that number, and the studied concealment of the comparison by those who have been told (such as the Interagency Review Group on Nuclear Waste Disposal or the National Council of Churches) and those who should not need to be told (such as Dr John Gofman or Dr John Cobb, the latter a professor of preventive medicine) is strong evidence that it is not human welfare that the concealers are after.

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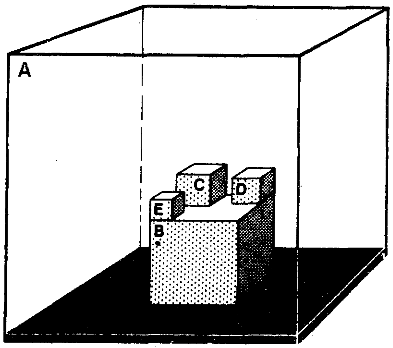
* Edward Teller, *Energy from Heaven and Earth*, Freeman & Co., San Francisco, 1979; p.182. (A very wonderful book, by the way.)

Nuclear power, will of course, ultimately replace our present methods of generating electricity. The reason for this inevitability, which has little enough to do with morality, is evident at a glance from the figure below:



US ENERGY RESOURCES
in quads (*Economist*, London)
(1 quad = 1 quadrillion BTU)

A	uranium 238 for fast breeders	130,000
B	coal	12,000
C	uranium 235 for light water reactors	1,800
D	oil	1,100
E	natural gas	700

The Gofmans and Cobbs can no more stop nuclear power than John Ludd could stop the Industrial Revolution. But they can hold it back for a year, two years, perhaps even for a decade or two.

There is no telling whether they actually believe in the morality they preach in their harangues. But the simple fact is that during the 60 minutes in which they beat themselves in the breast, four more American victims of the present method of electricity-linked waste disposal are dumped onto the coroner's slab.

ABOUT THE AUTHOR

Petr Beckmann is professor of electrical engineering at the University of Colorado. He was born in Prague, Czechoslovakia, where he obtained his Ph.D and Dr.Sc. degrees in electrical engineering and worked for a research institute of the Czechoslovak Academy of Sciences until 1963, when he was invited to the University of Colorado and did not return behind the Iron Curtain. He is the author of 12 books and more than 60 scientific papers. Originally working in electromagnetics and probability theory, he became strongly interested in questions of energy and now publishes the monthly newsletter *Access to Energy* in his spare time.

Dr Beckmann is a Fellow of the Institute of Electrical and Electronics Engineers, a Registered Professional Engineer in the State of Colorado, and member of several professional organizations.

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