

Radioactive Waste Disposal

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Radioactive wastes vary widely in their concentrations of radioisotopes. In general there are more than 900 radioisotopes of 100 elements and they are immune to outside influence. Each isotope decays at its own particular rate regardless of temperature, pressure, or chemical environment and continues to do so no matter what is done to it. All practical methods of handling radioactive wastes, such as processing and storing, must therefore be considered as intermediate steps leading to final disposal by decay.

Radioactive wastes all have their basic characteristics—radioactivity. It is convenient to classify radioactive wastes according to their levels of radioactivity upon which their potential hazard is dependent.

Somewhat arbitrarily three levels have been defined—low-level wastes, intermediate-level wastes & high-level wastes.

1. Classification of radioactive wastes

For clarity, the classification is tabulated as below, and followed by a brief description for each class of wastes.

Class	Radioactivity Level	
	Ci/l	
Low	$<10^{-6}$	($\sim 10^{-6}$)
Intermediate	$>10^{-6}$,	$<10^{-1}$ ($\sim 10^{-3}$)
High	$>10^{-1}$	(~ 1)

LOW-LEVEL WASTES have a radioactive content sufficiently low to permit discharge to the environment with reasonable dilution or after relatively simple processing. They have no more than about 1000 times the concentrations considered safe for direct release. In liquid form low-level wastes usually contain less than a microcurie of radioactivity per liter.

INTERMEDIATE-LEVEL WASTES have too high a concentration to permit release after simple dilution, yet they are produced in relatively large volumes. Their

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radioactivity is approximately 100 to 1000 times higher than that of low-level wastes. In liquid form they may contain up to a curie of radioactivity per liter.

HIGH-LEVEL WASTES may contain several hundred to several thousand curies per liter in liquid form and result from chemical processing of irradiated nuclear fuels. High-level wastes pose the most severe potential health hazard and the most complex technical problems in management.

2. Low and intermediate-level wastes—sources and handling

(a) Liquid wastes—refer to the Figure to illustrate the uranium fuel cycle for sources of the following low-level wastes:

- (1) Small laboratories (educational, industrial, hospital, and medical)—generally produce liquid wastes of low activity, containing only traces of a few isotopes, can usually be released by dilution, treated by filtration or ion exchange
- (2) Uranium mines and ore mills—produce relatively large quantities of low-level liquid wastes requiring minimal treatment. From ore mills, liquid wastes are detained in ponds to settle out the solids & the liquid overflows to stream. In some cases, chemical treatment may be needed.
- (3) Fuel fabrication plants—produce modest quantities of low-level acid wastes that are diluted, neutralized, stored to permit decay & then discharged to waterways.
- (4) Nuclear power plants—produce low-level liquid wastes (coolant & wastes from supporting laboratories & facilities). These wastes, if necessary, are treated via treatment systems, such as evaporators, ion exchangers, decay hold-up tanks, fixation in concrete. The concentrates & ion exchange resins are disposed of off-site.

The following table is given to illustrate the treatment processes available for removal of low and intermediate-level radioactive wastes. Please refer to P. 1703 of "Environmental Engineer's Handbook, Volume 1—Water Prelution" edited by B. G. Liptak.

(b) Solid wastes

Most solid radioactive wastes are of moderately low level & are disposed of by burial at carefully selected & thus designated burial sites. The wastes are generally buried in unlined pits & trenches & covered with several feet of earth over the wastes to hold surface radiation at a safe level.

Treatment Processes For Removal of Radioactive Wastes

Process	Decontamination Factors ^a	
	Individual Radionuclides	Mixed Fission Products ^b
Conventional		
Coagulation and settling	0-100+	2-9.1
Clay addition, coagulation and settling	0-100	1.1-6.2
Sand filtration	1-100	
Coagulation, settling and filtration	1-50	1.4-13.3
Lime-soda ash softening	2-100	
Ion exchange, cation	1.1-500	2.0-8.1
Ion exchange, anion	0-125	
Ion exchange, mixed bed	11-3300	50-100
Solids-contact clarifier	1.9-15	2.0-6.1
Evaporation	1.00-10,000	
Nonconventional		
Phosphate	1.2-1000	125-250
Metallic dusts	1.1-1000	1.1-8.6
Clay treatment	0-100+	
Diatomaceous earth	1.1-∞	
Sedimentation	<1.05	
Activated sludge	1.03-8.2	4.8-9.8
Trickling filter	1.05-37	3.5-6.1
Sand filter	8.3-100	1.9-50
Oxidation ponds	<1.1-20	

^a Decontamination factor = $\frac{\text{initial concentration}}{\text{final concentration}}$

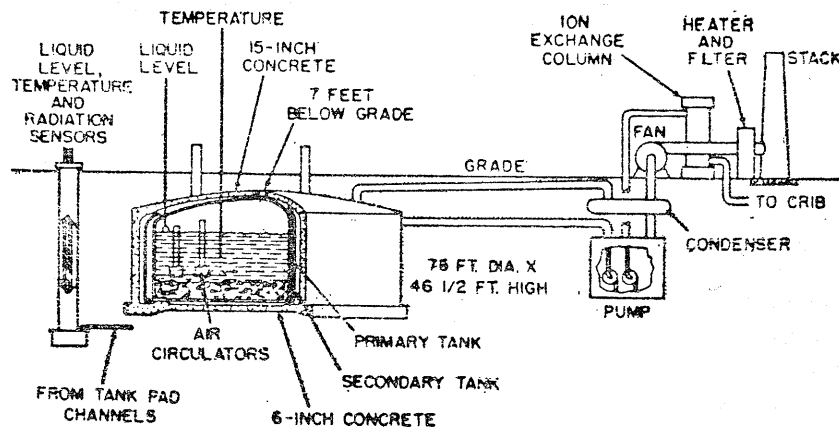
^b Where no data is listed it implies lack of information and not the unsuitability of the process.

Intermediate-level wastes may be disposed of in concrete-lined wells or stored to permit decay prior to disposal.

3. High-Level Wastes—Sources of nuclear wastes and how they are handled in U.S. .

(a) Defense wastes (highly radioactive)

Spent fuel rods from some types of nuclear reactor are reprocessed for extracting plutonium and uranium, by which liquid high-level wastes are produced. These wastes are being stored in underground steel tanks at places like Hanford, Washington, Savannah River (near Aiken, S.C.), and Idaho Falls. The storage tanks (see following figure) are with two steel liners, one inside the other. Should the high level waste eat through the inner steel liner, & leak into the back-up liner, an alarm would sound. The tank contents would then be pumped into a back-up tank. These below-ground storage tanks are not a long-term solution (only for 25-50 yr safe storage). Something must be done to find a permanent solution.

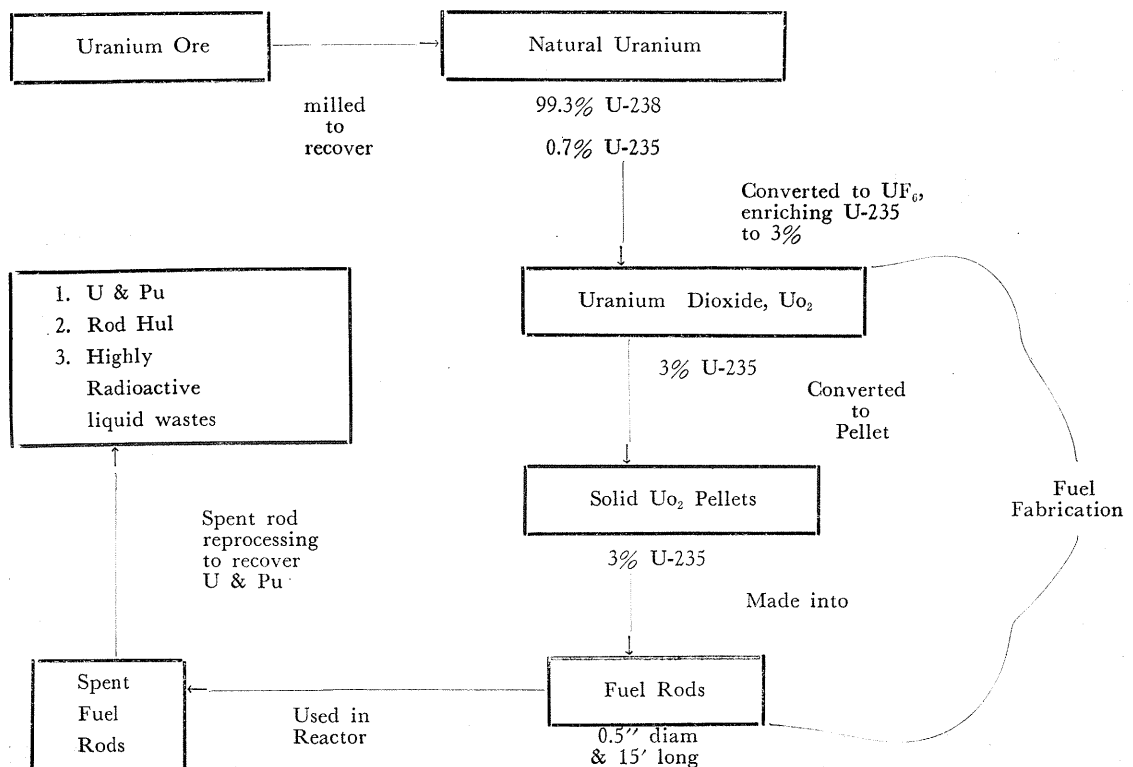


Storage of high-activity nuclear wastes in tanks

(b) Wastes from nuclear power plants

As compared with defense waste, the volume of wastes from nuclear power plants, essentially spent fuel rods, is small, and the wastes is presently stored in water pools at plant site. There is no immediate nuclear waste crisis.

(1) Uranium fuel cycle



- (2) Spent fuel rods, highly radioactive, giving off much heat are stored in a pool of water on the waste plant site. So far the on-site storage of highly radioactive spent fuel rods has not harmed any body or the environment. The water in the pool shields the radioactivity and carried away heat. The water is cooled & recycled. Storage of spent rods in water pools is a temporary (or intermediate) measure. The rods must be permanently disposed of so that they would be isolated from the biosphere for thousands of yrs, if not forever. They could be permanently disposed of
- before reprocessing, as they are deemed to be waste
 - after reprocessing to recover U and Pu, in which case highly radioactive liquid wastes will be produced.
- (3) To find a "best" way to permanently dispose of these highly radioactive wastes is not an easy matter. It includes:
- To locate a best site for the repository.
 - To find the best way to prepare the repository, which would depend upon its geological formation and ground water flux.
 - To find the best pre-disposal handling of the wastes which would depend upon the characteristics of the wastes & the geological formation of the site.

(c) Ultimate waste disposal

The present technology in U.S. .

- (1) Either liquid (e.g. from fuel rod reprocessing) or solid (e.g. spent fuel rods) highly radioactive wastes are enclosed in canisters. So the problem becomes: how best to dispose of these highly radioactive & hot canisters, so that they remain isolated from the biosphere for thousands of years.
- (2) The ultimate disposal has several possibilities as follow:
- Emplacement in very deep drill holes—canisters placed in a 4000 ft tall column at least 25,000 ft below the earth's surface.
 - Emplacement in a mined cavity in a way that leads to rock melting—liquid highly radioactive wastes would be pumped into a cavity in a very deep & impermeable geologic formation. Heat from the radioactive waste would melt adjacent rock, the radioactive material ultimately becoming an integral part of the rock (no canisters).
 - Ejection into space
 - Emplacement in deep ocean sediments—canisters implanted several tens of meters in deep, thick, and stable ocean sediments.

(3) The most feasible ultimate disposal

By far the most immediately feasible disposal is "emplacement in mined repository".

The mined repository would be built deep underground (1000 to 3000 ft beneath the earth's surface) in salt, granite, shale, basalt or other geologic formations, using conventional mining methods.

Several barriers would separate the radioactive wastes from the biosphere.

- glass or other matrix (if wastes are liquid)
- stainless steel canister
- the backfill material (e.g. clay or bentonite)
- hundreds of feet of rock or other overburden

To find and evaluate a suitable site.

- Identify & characterize possible geologic sites in salt or some other geologic media.
- Develop the technology needed to design and construct these deep repositories.
- Perform in-site tests in the geologic media, using heaters and nuclear waste canisters to see what the impact of heat is on the geologic media.

(d) The pre-disposal handling—canister

(1) Liquid wastes—If reprocessed, there would be a highly radioactive liquid waste generated.

- First converting the liquid to solid granules (known as calcining)
- Dissolving the granular material in a matrix of molten glass (or other material)
- Pouring the molten glass into a stainless steel canister (1 ft in diam & 10 ft long)

(2) Solids wastes—If spent fuel rods are to be disposed of, they would also be enclosed in a similar canister.

(e) The most important barrier

(1) with the canister & glass to deteriorate with time, the more important barrier is the geologic strata of the repository to insure that the waste does not get back to the biosphere.

(2) These will always be some doubts about the geology, it will require to develop a zero-release canister.

(3) The above are the two extremes of the spectrum. The middle of the spectrum believes a multi-barrier approach:

glass
canister
backfill
geology

While each of the barriers may well be sufficient in itself, but, if not there is defense in depth.