Environmental Effects of Nuclear Power

In considering environmental effects, let's look at the effects on air, water, ground, and the biosphere (people, plants, and animals) - and let's also look at what can and is being done to minimize those effects. In the United States, it is important to realize that the law - Title 10 Code of Federal Regulations (CFR), Part 20 - governs any radioactive releases from nuclear power plants. If you want to find any federal regulation by title and part, use the Title 10 CFR Index or National Archives & Records Administration (for all sections of the Code of Federal Regulations). This section addresses commercial nuclear reactors regulated by the NRC (or similar agencies in other countries) and does not address the myriad of effects due to government activities, e.g. at Hanford, where the Hanford Tanks Initiative is correcting problems stemming from activities in the 1940's to 1970's timeframe.

Air- Gaseous Releases

Nuclear plant gaseous releases fall into the following categories:

- Water vapor from cooling towers
- Ventilation exhaust from those buildings that do not have any processes with radioactivity
- Diesel generator exhaust
- Gases and steam from the air ejectors, that are in the main steam system
- Ventilation exhaust from those buildings that do have processes with radioactivity
- Gases removed from systems having radioactive fluids and gases.

The first two release paths are non-radioactive. Often, news photos of nuclear plants tend to focus on the tall (400 foot high) dry cooling towers (e.g. Three Mile Island, Perry). The major effect of these cooling towers is heating of the air around the plant. Warm water vapor is all that is released (unless chemicals are injected for biological treatment). The cooling towers are often required by state and/or federal regulatory agencies to reduce the thermal impact if a river of a lake is the primary cooling source. The second source - ventilation exhaust from those buildings that do not have any processes with radioactivity - are just like releases from ventilation systems from any office building.

Nuclear plants use diesel generators (and some times gas, or combustion, turbines) for emergency electrical power. These diesels or turbines are typically started and run at least once a month to ensure they can function as backup power, if required, during a loss of power condition or accident condition. When these diesels or turbines startup, usually black plumes of exhaust gases are released. Operation of these diesels or turbines is the only source of greenhouse gases (e.g. carbon dioxide, sulfur dioxide, carbon monoxide, nitrous oxides) at a nuclear plant.

The air ejector exhaust at PWRs is usually non-radioactive. Only in those cases where there may be leakage through a steam generator tube could that exhaust have any radioactivity. At BWRs, the air ejector exhaust is radioactive, but that exhaust must also pass through delay pipes, storage tanks and a hydrogen recombiner before being released to the environment from the very tall stack that you sometimes see at BWRs. Ventilation exhaust from buildings containing radioactive processes have radiation monitors that sample for particles and gases. If unacceptable levels are reached, special fans start, the normal ventilation system is shutdown, and the exhaust is routed through special particulate, high efficiency particulate, and charcoal filters before being exhausted. These systems are designed to reduce the release below acceptable levels.

Radioactive gases may be removed from the systems supporting the reactor cooling system. These gases removed are compressed and stored. The gases are periodically sampled and can only be released when the

radioactivity is less than an acceptable level according to the 10CFR20regulation. Releases of this nature are done very infrequently.

All potential paths where radioactive materials could be released to the environment are monitored by radiation monitors.

Water-Liquid Releases

Nuclear plant liquid releases fall into the following categories:

- Non-radioactive
- Slightly radioactive

Water that has been used to cool the condenser, various heat exchangers (e.g. to cool oil, steam, water) used in the turbine-generator support processes, or that has passed through the cooling towers is non-radioactive. Some or all of this water may be discharged to a river, sea, lake. The thermal discharge of any type of power plant, nuclear or fossil fuel, using a steam cycle operating under the same conditions (e.g. steam pressure, inlet condenser water temperature) should be the same. In some cases, a coal plant may operate at higher temperatures and steam pressures than a nuclear plant, thus it may have a slightly higher efficiency, with slightly lower release of thermal discharge to the environment.. One way to reduce thermal pollution is to make use of more of the hot water and steam using cogeneration principles.

Usually water released from the steam generators (called blowdown) is also non-radioactive. Very low levels of leakage (e.g. less than 400 gallons per day) may be allowed from the reactor cooling system to the secondary cooling system of the steam generator. However, in any case where radioactive water may be released to the environment, it must be stored and radioactivity levels reduced through ion exchange processes below levels allowed by the 10CFR20 regulation.

Within the nuclear plant, there are a number of systems that may contain radioactive fluids. As noted above, those liquids must be stored, cleaned, sampled, and verified to be below acceptable levels before release may be done - AND - mistakes are not tolerated by the NRC. Effluent requirements are specified in Appendix B Table 2 of 10CFR20. As in the gaseous release case, radiation detectors monitor release paths and isolate (close valves) if radiation levels exceed a preset setpoint.

Some BWR facilities maintain a "Zero Release" management practice to not discharge radioactive liquids.

Solid Releases-Ground Effects

Solid radioactive materials only leave the plant by three paths:

- Routine non radioactive office, process, and building material waste via traditional means
- Radioactive waste (e.g. clothes, rags, wood) is compacted and placed in drums. These drums must be thoroughly de-watered. The drums are often checked at the receiving location by regulatory agencies. Special landfills must be used.
- Spent resin may be very radioactive and is shipped in specially designed containers.

For introductory information on low level waste, see Low Level Waste and More on Low Level Waste.

Currently, the used fuel assemblies are stored underwater in large cooling pools at the plant. In some cases, where storage has become limited, dry cask storage on-site may be used. This storage is covered by the regulation 10CFR72 for Independent Spent Fuel Storage Facilities. For introductory information on high level waste, see High Level Waste and More on High Level Waste.

Ultimate Disposal of Spent Fuel

Originally, the intent had been that the spent fuel would be reprocessed. The limited amount of highly radioactive waste (also called high level waste) was to be placed in glass rods surrounded by metal with low long term corrosion or degradation properties. The intent was to store those rods in specially designed vaults where the rods could be recovered for the first 50-100 years and then made unretrievable for up to 10000 years. Various underground locations had been considered - salt domes, granite formations, basalt formations - and finally - Congress designated Yucca Mountain in Nevada. The desire was for a geologically stable location with minimal chance for groundwater intrusion. There is currently some controversy regarding the suitability of Yucca Mountain as a final repository.

The intent had been to recover the plutonium and unused uranium fuel, then reuse it in either breeder or thermal reactors as mixed oxide fuel (also called MOX). Currently, France, Great Britain, and Japan are using this process.

Impact on the Biosphere

In the 1960's, the Atomic Energy Commission funded research to investigate effects of radiation on people, plants, and animals. Some of the studies were conducted at the Lawrence Radiation Laboratory in Livermore, California and at various government and university laboratories. A number of studies entitled the BEAR (Biological Effects of Atomic Radiation) and BEIR (Biological Effects of Ionizing Radiation) studies reported on these effects. The most recent, BEIR VII Phase 2, "Health Effects of Exposure to Low Levels of Ionizing Radiation", (see summary) was published by the National Academy Press in 2005. A down to earth discussion of radiation is presented in the University of Wisconsin Graduate School's *Whyfiles - Radiation Reassessed*.

Mining, Milling and Enrichment Issues

The original intent of this site was to just address power plants. Treatment of nuclear power would not be complete without discussion of the impacts of mining, milling, and enrichment.

Nuclear-related mining effects are similar to those of other industries - generation of tailings and water pollution. Over time, strengthening of environmental laws, and recognition of prior improper actions, has led to reduced impacts. For example, tailings were used as fill in Grand Junction, Colorado. In the 1970's, this fill was removed when it was recognized that this mined material produced general background radiation levels higher than typical in the US. The fill had to be placed under cover.

Uranium milling plants process naturally radioactive materials. Radioactive airborne emissions and local land contamination resulted until stricter environmental rules aided in forcing cleanup of these sites.

The US has older enrichment plants. These were originally designed to enrich U-235 for bombs, but subsequently were diverted to enrich uranium for NPP fuel. Because they were built in the 1940's and in rural areas, they happen to use coal and oil. Also, the enrichment process requires large amounts of electrical energy to produce enriched material because the facilities use 1940's technology - gaseous diffusion process. That energy, while currently produced by coal and oil, could be produced by nuclear plants. Newer enriching technologies, e.g. gas centrifuges, are used in Europe.

The US Nuclear Regulatory Commission regulates these activities. The Fuel and Materials (3 series) of Regulatory Guides specify their expectations. If you use the NRC Search page, select to search the entire site for 99 documents and then type in - **uranium mining and milling** - for a list of documents covering the issues that the NRC has been handling.

Some Sources on Nuclear Power and the Environment

- *Environmental Aspects of Nuclear Power*, Geoffrey G. Eichholz, Ann Arbor Science, 1977, ISBN 0-250-40138-X
- *Environmental Radioactivity from Natural, Industrial, and Military Sources*, 3rd Edition, Merril Eisenbud, 1987, Academic Press, Inc., ISBN 0-12-235153-3
- *Nuclear Power and Its Environmental Effects*, Samuel Glasstone and Walter H. Jordan, American Nuclear Society, 1980, ISBN 0-89448-024-3
- US Department of Energy Report *Emissions of Greenhouse Gases in the United States 1987-1994*
- US Department of Energy Report *Emissions of Greenhouse Gases in the United States (Archived Reports)*
- US Department of Energy Report *Integrated Data Base Report -- 1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*
- US Department of Energy Center for Environmental Management Publication List

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