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# Nuclear Dumps by the Riverside

## *Threats to the Savannah River from Radioactive Contamination at the Savannah River Site*

DOE PHOTO

***Constructed pond at the Tritium Phytoremediation Project at the Savannah River Site.*** *"Phytoremediation is an engineered use of trees and plants for consuming certain types of contamination in soil and water. ... To control tritium-contaminated groundwater, the project includes an engineered pond to trap and contain contaminated groundwater seeps and a spray irrigation system to deliver it to a controlled forested area of trees and plants. Trees and plants have a natural process called transpiration that degrades, contains or releases these contaminants to the atmosphere in trace amounts." (DOE Digital Archive)*

BY ARJUN MAKHIJANI AND MICHELE BOYD[1]

The Savannah River Site (SRS) in South Carolina produced more than one-third of the plutonium for U.S. nuclear bombs, almost all of the tritium, and other nuclear materials (plutonium-238, plutonium-242, and neptunium-237) for weapons and non-weapons applications. Past dumping and mismanagement and a failure to implement an adequate cleanup plan at SRS have created extensive water pollution beneath the site as well as risks for the future integrity of critical water resources in the region, including the Savannah River. Current waste management practices threaten to make SRS into a high-level nuclear waste dump by one of the most important rivers in the southeastern United States.

SRS was built by the U.S. government in the early 1950s. Five nuclear reactors and two large reprocessing plants for processing nuclear materials (called the F- and H-canyons) were the most important production facilities at the site, and the sources of most of the contamination.[2]

The Savannah River Site contains the largest amount of radioactivity in waste of any nuclear weapons site in the United States. Roughly 99 percent of this radioactivity is in 49 underground, high-level waste tanks that contain the main waste discharges from the reprocessing plants, including fission products as well as plutonium, uranium and other radionuclides.

The largest volume of waste discharges was in liquid form into seepage basins, which were thereby contaminated. The largest volume of solid radioactive waste is a catch-all category called "low-level" waste.

Broadly speaking, the main threats to water resources arise from the long-lived radionuclides in the waste, including high-level waste, radioactivity in buried

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# Nuclear Targeting

## *The First 60 Years*

BY ARJUN MAKHIJANI[1]

On May 5, 1943, the Military Policy Committee of the Manhattan Project met for the first time to discuss potential targets for the nascent atomic bomb. While Manhattan Project scientists had been pursuing the bomb with the single-minded desire to beat Hitler to the punch, the meeting produced the first official signals that the government was beginning to take a much broader view of the project: Such a weapon could be used not only to deter the Nazis, but to craft and maintain a U.S.-dictated post-war new world order.

Between May 5, 1943 and early December 1944, the bomb acquired a rationale of absolute power and privilege. The exercise of that power on August 6, 1945 bred

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wastes and seepage basins, and radioactivity in the vadose zone[3] and in the groundwater under SRS. Risks from radioactivity are compounded by the presence of toxic non-radioactive contaminants.

Table 1 shows official estimates of the amounts of radioactive waste, both in terms of volume and total radioactivity content.

### TABLE 1: OFFICIAL ESTIMATES OF WASTE AT SRS RESULTING FROM NUCLEAR WEAPONS PRODUCTION

| Type of waste | Volume (cubic meters) | Radioactivity (curies) |
|---|---|---|
| High-level waste (rounded) | 144, 000 | 484,200,000 |
| Total of which: | | |
| *sludge* | *10,600* | *320,000,000* |
| *salt cake and supernate* | *133,500* | *160,000,000* |
| *vitrified waste in canisters* | *1221 canisters* | *4,200,000* |
| Stored transuranic waste | 15,000 | 560,000 |
| Buried transuranic waste | 4,530 | 21,900 |
| Low-level waste – open disposal sites ("active") | 680,000 | Not given |
| Mixed low-level waste (see note) | 7,300 | Not given |
| Stored low-level waste | 1,600 | Not given |
| **TOTAL** | **~852,000** | **~490,000,000** |

Notes: Various official publications cite numbers for wastes that are not consistent. The data above are from various dates from the mid-1990s to 2000. "Mixed low-level waste" is waste that contains radioactive and non-radioactive hazardous constituents.

Numerous landfills, trenches, and burning/rubble pits were used at SRS to dispose of low-level waste, mixed waste, transuranic waste, and hazardous waste. One of the largest and most contaminated areas at SRS is the Burial Ground Complex, which is located between the F-Area and H-Area reprocessing plants. Its principal use was for the disposal of low-level radioactive and mixed wastes. The Old Radioactive Waste Burial Ground may be the most important source of future contamination among the various burial and burning sites because of the large quantity of waste, the variety of waste, including radioactive and non-radioactive toxic materials dumped there.

SRS also used a dozen seepage basins for the discharge of billions of gallons of liquid wastes contaminated with radionuclides and organic toxic chemicals, as well as heavy metals. The largest amount of liquid wastes came from the two reprocessing plants (F- and H-canyons) and the reactors. Tables 2 and 3 provide a summary of the most important seepage basins and of the major landfills, trenches and pits that are contaminating water at SRS.

Past dumping of solid and liquid wastes has severely contaminated the soil and groundwater in the operating areas of the site. This groundwater outcrops into local streams, such as Four Mile Creek (see site map on page 3), from where it migrates into the Savannah River. Threats that will last for decades include those from tritium, volatile organic compounds, strontium-90, mercury, cadmium, and

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## SAVANNAH

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lead. Threats that will last for millennia, far beyond any hope of physical or institutional control, include those from iodine-129, technetium-99, neptunium-237, uranium isotopes, and plutonium-239.[4]

### Tritium

Tritium is the most ubiquitous radioactive contaminant at SRS. Tritium is radioactive hydrogen. In gaseous form, tritium generally presents a low health risk because it is exhaled before it can deliver a substantial radiation dose to the body. However, tritium can displace one or both of the hydrogen atoms in water, thereby creating radioactive water, which behaves chemically like ordinary water. Since water is essential to life, radioactive water can allow radioactivity to seep into all parts of the body and its constituents — cells as well as DNA and proteins, for instance. Tritium that is in organic materials is called organically-bound tritium (OBT). Both OBT and tritiated water can cross the placenta and irradiate developing fetuses *in utero*, thereby raising the risk of birth defects, miscarriages, and other problems. Tritium discussed here is either in the form of tritiated water or OBT, unless otherwise specified.

There are two types of tritium releases into SRS streams: (1) direct releases; and (2) migration of tritium

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***Figure 1: Map of the Savannah River Site, showing operational areas and surface water.*** *Source: Based on Savannah River Site Environmental Report for 2000, Westinghouse Savannah River Company, WSRC- TR-2000-00329, Figure 1-2, page 6.*

**TABLE 2: SUMMARY OF THE PRIMARY SEEPAGE BASINS CONTAMINATING WATER AT SRS**

| Basin | Affected water system | Contaminants |
|---|---|---|
| F-Area Seepage Basins | Groundwater; outcrops into Four Mile Creek | Tritium, uranium-238, iodine-129, strontium-90, curium-244, americium-241, technitium-99, cadmium, aluminum |
| H-Area Seepage Basins | Groundwater; outcrops into Four Mile Creek | Tritium, strontium-90, mercury |
| Old TNX Seepage Basin | Groundwater; Savannah River and swamp | Trichloroethylene |
| New TNX Seepage Basin | Groundwater; Savannah River and swamp | Trichloroethylene |
| M-Area Seepage Basin | Groundwater plume; outcrop into Upper Three Runs Creek | Trichloroethylene, tetrachloroethylene |
| Old F-Area Seepage Basin | Groundwater | Tritium, iodine-129, uranium |
| K-Area Seepage Basin | Groundwater; outcrops into Indian Grave Branch | Tritium |
| R-Area Reactor Seepage Basins | Groundwater | Strontium-90, volatile organic compounds (VOCs) |
| L-Area Reactor Seepage Basin | Groundwater | Trichloroethylene, tetrachloroethylene, tritium |
| P-Area Reactor Seepage Basins | Groundwater; outcrops into Steel Creek | Tritium, trichloroethylene |
| Ford Building Seepage Basin | Groundwater | Lead, mercury, nitrates |
| C-Area Reactor Seepage Basins | Groundwater | Tritium, trichloroethylene |

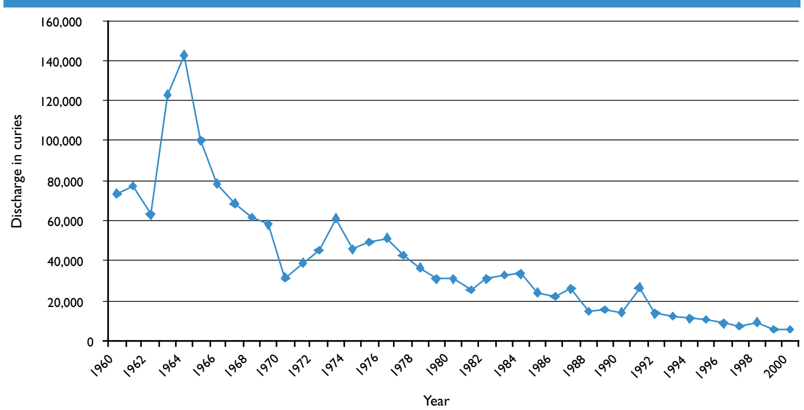
Source: *Savannah River Site Environmental Data for 2000,* Westinghouse Savannah River Company, WSRC-TR-2000-00328; and, *A Report to Congress on Long-Term Stewardship, Volume II-Site Summaries,* DOE.EM-0563, January 2001.

**TABLE 3: SUMMARY OF MAJOR LANDFILLS, TRENCHES, AND PITS CONTAMINATING WATER AT SRS**

| Landfill/Trench | Affected water system | Contaminants |
|---|---|---|
| Burial Ground Complex<br>• Old Radioactive Waste Burial Ground<br>• Low-Level Radioactive Waste Disposal Facility | Four distinct groundwater plumes<br>• Southwest plume contaminated with tritium outcropping into Four Mile Creek<br>• Northern plumes outcropping into Upper Three Runs Creek | Tritium and other radionuclides, volatile organic compounds (primarily trichloroethylene), metals |
| TNX Burial Ground | Groundwater; discharges to the Savannah River swamp and the Savannah River | Trichloroethylene; radionuclides, including uranium and radium-226 |
| A-Area Burning/Ruble Pits | Groundwater | Trichloroethylene, tetrachloroethylene, methylene chloride |
| C-Area Burning/Rubble Pit | Groundwater; outcrops to Four Mile Creek | Trichloroethylene, tetrachloroethylene, vinyl chloride, tritium (the tritium is from other sources in C-Area) |
| Chemical, Metals, and Pesticides Pits | Groundwater; outcrops to Pen Branch | Trichloroethylene, tetrachloroethylene, metals |

Source: *Savannah River Site Environmental Data for 2000,* Westinghouse Savannah River Company, WSRC-TR-2000-00328; and, *A Report to Congress on Long-Term Stewardship, Volume II-Site Summaries,* DOE.EM-0563, January 2001.

**FIGURE 2: SRS TRITIUM DISCHARGES TO THE SAVANNAH RIVER**




Source: *Savannah River Site Environmental Data for 2000,* Westinghouse Savannah River Company, WSRC-TR-00329, p. 72

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from buried wastes to groundwater, which then outcrops into streams. For about the first two decades (1950s and '60s until roughly the mid '70s), the reactors and reprocessing plants were the source of most of the releases of tritium. Over the following three decades, the migration of tritium into the groundwater and from there into surface streams has become increasingly important. Waste management operations and past dumping now account for essentially all the tritium releases from SRS.

Annual releases of tritium to SRS streams from both direct releases and migration ranged from more than 100,000 curies in the 1960s to 3,100 curies in 2002. Figure 2 shows SRS's annual tritium releases from 1960 to 2000.

While the shallow groundwater under SRS is not used for drinking, the tritium in it is a concern because it migrates into the Savannah River, which is used for drinking. More than half of all groundwater monitoring wells indicate tritium contamination at concentrations exceeding drinking water standards in the separations areas (F- and H-Areas) and the waste management areas (E-, F-, H-, S- and Z-Areas).

Because the groundwater is so shallow at SRS, the tritium-contaminated groundwater outcrops into streams and from there to the Savannah River. Historically, the highest tritium concentrations in the Savannah River have been those that flow into it from Four Mile Creek. The relatively large flow of the Savannah River dilutes the tritium and lowers its concentration to well below the drinking water standard, as can be seen in Table 4 below. While most of the tritium discharged into the Savannah River comes from SRS, a commercial nuclear power plant, Plant Vogtle, is also a contributor.

The concentration near the mouth of the river at Savannah, Georgia in 2000 was 950 picocuries per liter; it was somewhat lower in 2002 at 774 picocuries per liter. This means that the entire length of the Savannah River, from the SRS discharge points to the Atlantic Ocean, is affected by SRS tritium discharges. In the past few years, the concentrations of tritium in the Savannah River south of the site have been at about 5 percent of the present safe drinking water standard (20,000 picocuries per liter); that is, it is well within the regulatory limit. The cancer risk to adults from Savannah River water is well below regulatory

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limits, but this does not put all the essential health-risk-related questions to rest.

Leaving aside any future dumping and discharges from new processing, there is a considerable source of tritium at SRS due to past dumping. While the half-life of tritium is shorter than other radionuclides of concern, like strontium-90 or cesium-137 or plutonium-238 or neptunium-237, at 12.3 years it is still long enough that tritium will continue to be the major radioactive contaminant of the Savannah River from SRS for decades. Given the nature of the health risks and the lack of adequate standards for protecting pregnant women (see below), remediation to reduce tritium leakage and discharges should be among the topmost priorities for SRS cleanup.

**TABLE 4: MEAN CONCENTRATION OF TRITIUM IN THE SAVANNAH RIVER, 2000 TO 2002, PICOCURIES PER LITER**

| RIVER MILE (DESCRIPTION) | Tritium concentration 2000 | Tritium concentration 2001 | Tritium concentration 2002 |
|---|---|---|---|
| 160.0 (upstream of SRS) | 110 | 82.3 | 171 |
| 150.4 (at Four Mile Creek) | 2,220 | 2,280 | 2,530 |
| 150.0 (south of Four Mile Creek mouth) | 2,130 | 1,230 | 1,080 |
| 141.5 (south of Steel Creek mouth) | 1,420 | 1,220 | 1,120 |
| 118.8 (south of the swamp and SRS) | 1,180 | 1,020 | 1,010 |

Sources: *Savannah River Site Environmental Data for 2000,* Westinghouse Savannah River Company, WSRC-TR-2000-00328, page 69; *Savannah River Site Environmental Data for 2001,* Westinghouse Savannah River Company, WSRC-TR-2001-00475, Compact Disk; Savannah River Site Environmental Report for 2002, Westinghouse Savannah River Company, WSRC-TR-2003-00026, Compact Disk.

### *SRS tritium in Georgia*

Tritium from SRS affects Georgia in several ways:

- SRS discharges pollutants, including tritium, into the Savannah River, and river water is polluted with tritium.
- Rainwater around SRS, including on the Georgia side of the Savannah River, contains levels of tritium that are attributable to evaporation of contaminated water from SRS.
- Groundwater in the Upper Three Runs Aquifer in Georgia is contaminated with tritium attributable to SRS.
- The fish in Savannah River are contaminated with tritium and other radionuclides from SRS.

All this contamination is well below present regulatory limits, including safe drinking water limits.

In 1991, tritium was discovered in drinking water wells in Burke County, Georgia, which borders the Savannah River along SRS. A subsequent study found tritium contamination in 15 wells ranging from 500 to 3,500 picocuries per liter. The latter figure is almost 18 percent of the regulatory limit for drinking water.

Rainwater contaminated by evaporation from SRS

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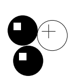
## ABOUT TRITIUM

Tritium is a radioactive form of hydrogen with two neutrons, resulting in a total atomic weight of 3 (1 proton and 2 neutrons). Most tritium is man-made. Some tritium occurs naturally due to interactions between the atmosphere and cosmic radiation. With its relatively short half-life (12.3 years), tritium decays at about 5.5 percent annually.

Tritium 

*The tritium molecule has one proton and two neutrons.*

As a gas, tritium is a light and small atom. Hence, it diffuses readily through all but the most highly engineered containment vessels and mixes freely with the other forms of hydrogen in water and water vapor. Tritium forms tritiated water by replacing one or both atoms of non-radioactive hydrogen in water. Tritiated water is often designated as HTO or $T_2O$, depending on whether it has one or two atoms of tritium in the water molecule, respectively. (Water is designated as $H_2O$.) When tritiated water is generated by neutron absorption in one of the deuterium (D) nuclei in heavy water ($D_2O$), it is DTO. While all the forms of water containing tritium are radioactive, they behave in a manner that is chemically the same as ordinary water ($H_2O$). The pervasiveness of tritium is due to the mobility of tritiated water in the environment along with non-radioactive water and to the great difficulty of separating trace quantities of it from ordinary water.

Tritium's primary function in a nuclear weapon is to boost the yield of the fissile material used in both pure fission weapons and in the primary of thermonuclear weapons. Contained in removable and refillable reservoirs in the warhead, it increases the efficiency with which the nuclear explosive materials are used. Although no official data are publicly available, each warhead is estimated to require an average of approximately four grams of tritium. However, neutron bombs, designed to release more radiation, have been estimated to require more tritium (10-30 grams).[1]

1. Reproduced from Hisham Zerriffi, *Tritium: The environmental, health, budgetary, and strategic effects of the Department of Energy's decision to produce tritium* (Takoma Park, Maryland: Institute for Energy and Environmental Research), January 1996, page 1. On the Web at http://www.ieer.org/reports/tritium.html.

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has been established as a source of pollution in Georgia. A crucial issue that remains unresolved is whether tritium migrates into Georgia directly from contaminated aquifers at SRS beneath the Savannah River (called transriver flow). Resolving this question is of immense importance because evidence of migration of contaminants into the deeper aquifers would be a very serious issue for the health of the groundwater resources in Georgia and South Carolina.

### *Tritium in drinking water*

Municipal drinking water systems near SRS, in South Carolina, use both groundwater and surface water, with 25 of 28 systems depending on groundwater. However, about 57 percent of the customers depend on the 3 surface water systems.

Table 5 shows the mean concentration of tritium in drinking water systems offsite in 2000. The highest concentration represents about 5 percent of the safe drinking water limit of 20,000 picocuries per liter. These data make it clear that drinking water is contaminated with tritium from SRS; the pollution is well within allowable safe drinking water limits.

### *The significance of tritium contamination*

The U.S. Department of Energy (DOE), which is responsible for SRS, argues that present levels of tritium contamination do not pose a problem, because the concentration of tritium is generally ten to twenty times less than the maximum tritium contamination limit allowed for drinking water under present U.S. Environmental Protection Agency (EPA) rules. But DOE must also adhere to keeping releases "as low as reasonably achievable" (the ALARA principle), so the fact that the level is below the maximum limit does not mean that all regulations or public safety requirements have been met.

For reference, it is important to compare contamination not only to the safe drinking water limit but also to background levels. The natural concentration of tritium in lakes, rivers, and potable waters was 5 to 25 picocuries per liter prior to nuclear weapons testing. Nuclear weapons testing greatly increased the amount of tritium in the atmosphere. Though most of this has decayed away, there is still sufficient tritium from bomb testing to elevate global tritium levels. Rainwater over Atlanta in the early 1990s contained about 39 picocuries per liter of tritium, and for purposes of analysis, this might be considered as "background" (natural plus bomb-testing) — that is, a level that would be there even if there were no emissions from SRS. The tritium concentration of 1,000 picocuries per liter is one-twentieth of the safe drinking water limit, but it is also about 25 times the tritium content of rainwater in Atlanta.

The EPA safe drinking water standard for tritium is somewhat more stringent than it is for other beta emitters in terms of radiation dose to adults. However, there are questions that need to be addressed regarding the health risks from tritium that go well beyond cancer risks to adults. These include non-cancer risks, risks to children and developing fetuses regarding cancer as well as non-cancer health effects, and synergistic effects of toxic non-radioactive materials with tritium. Adequate consideration of the variety and character of cancer and non-cancer risks posed by tritium may require a considerable tightening of the current safe drinking water standard. This makes the implementation of an ALARA policy in regard to tritium all the more important.

Due to its chemical properties, tritiated water can replace ordinary water in human cells (water constitutes approximately 70% of the soft tissue in the human body). In addition, tritiated water in the body can become organically-bound tritium by being incorporated into biomolecules, such as amino acids, proteins, and DNA.

The current tritium safe drinking water standard does not protect children and developing fetuses to the same standard as adults. Current radiation protection standards assume that exposure to beta radiation (such as that from tritium) causes the same biological damage as whole-body exposure to gamma and x-rays. But the cancer risk from tritium per unit of radiation energy can be far higher. A 2002 study concluded that the dose conversion factors for tritium may be 2 to 5 times larger for adults than used in current U.S. regulatory guidance, depending on the form of tritium (with considerable uncertainties around these best estimates), and 4 to 10 times larger for fetuses when pregnant women ingest tritium, also with considerable uncertainties.[5]

These conclusions indicate that the maximum contaminant level for tritium in drinking water should be re-

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**TABLE 5: MEAN CONCENTRATION OF TRITIUM IN DRINKING WATER SYSTEMS OFF-SITE, FINISHED WATER, IN 2000 AND 2002**

| Treatment plants | Tritium, finished water, pCi/liter, 2000 | Tritium, finished water, pCi/liter, 2002 |
|---|---|---|
| North Augusta Public Water Works (upstream of SRS) | 41.2 | 132 |
| Beaufort Public Water Works | 1,030 | 824 |
| City of Savannah Industrial and Domestic Water Supply Plant | 950 | 774 |

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evaluated in light of the significantly higher cancer risk of fetal exposure, especially in regard to organically-bound tritium. Since rivers can be and are used by large numbers of people, as is the case with the Savannah River, it is crucial that the higher health risk created by organically-bound tritium be factored into drinking water standards.

## Other Contamination

In addition to tritium, other radionuclides also migrate from the burial grounds and seepage basins to the groundwater. Concentrations of some radionuclides are above drinking water standards in the groundwater under many of the site areas. Currently, concentrations of these radionuclides are low both in the onsite streams and in the Savannah River. However, large source terms — that is, sources from which radioactivity could migrate into water — remain in the buried wastes and contaminated soils onsite.

For instance, in the F- and H-Areas, migration from the burial grounds and seepage basins has led to highly contaminated groundwater, especially with strontium-90 and iodine-129, which have half-lives of 28.1 years and 16 million years, respectively. Radium-226, uranium isotopes, iodine-129, and strontium-90 are significantly above drinking water standards in the groundwater. Some of these radionuclides have migrated from the groundwater under the seepage basins to Four Mile Creek. Iodine-129 concentrations at point of discharge into the Savannah River averaged 40 percent of the drinking water standard in 1998.

Volatile organic compounds, particularly trichloroethylene (TCE) and tetrachloroethylene, were used as degreasers throughout SRS. TCE is one of the primary groundwater contaminants throughout the site. The highest concentrations of volatile organic compounds are generally found under the seepage basins.

## Contaminant levels in fish

Fish bioaccumulate certain elements, especially cesium-137 and mercury. By the mid-1950s, it was evident that fish in the Savannah River were impacted by SRS activities, including bass, bream, and catfish.

Fish in the Savannah River have concentrated about 3,000 times more cesium than levels found in the water. According to Georgia's Department of Natural Resources, the mercury guidelines are sufficient to be protective for cesium-137. Given the present mix of contaminants, limiting fish consumption based on the mercury guidelines would keep doses from cesium-137 far below 1 millirem and therefore well under any applicable standards. However, DOE is leaving an enormous amount of residual cesium-137 and other radionuclides in the tanks, which may create a greater threat in the future. The problem of cesium-137 in the river and the fish should be evaluated together with that of I-129, tritium, and mercury. Further, the issue of subsistence fishing needs to be addressed. Current standards and guidelines may not be sufficient to protect some populations.

Social research indicates that some people use the Savannah River for subsistence fishing, usually defined to include those individuals who consume approximately 50 kilograms (110 pounds) of fish per year (about 2 pounds per week). A 1996 survey by Morris, Samuel, and students of Benedict College indicated that people fish near the SRS outfalls that are contaminated.[6] A 1999 survey of people fishing along the Savannah River found that some individuals eat more than 50 kilograms of fish from the Savannah River per year. There are people from various segments of the population who practice subsistence fishing, including Whites, but both surveys found that the practice is more common among African-Americans, who, on average, also eat more fish from the river than Whites. The average daily consumption among African-Americans indicated by the 1999 survey was about four ounces, or four times the maximum limit recommended by the South Carolina Department of Health and Environmental Control. *Reducing pollution in the Savannah River along SRS is therefore an essential aspect of environmental justice as well as of protecting the health of all people who depend on the river for their subsistence and as an important source of protein.*

## So-called remediation

More than 99 percent of the radioactivity in the waste at SRS is contained in the high-level waste. Of this, only about one percent (about 4.2 million curies[7]) has been extracted from the tanks, mixed with molten glass and cast in to glass logs at the Defense Waste Processing Facility, a vitrification plant for high-level waste that was opened onsite in 1996. The 1,221 glass logs that have been cast are in steel-alloy canisters, and are stored onsite pending disposal in a high-level waste repository. In the short and medium term, this waste poses the least risk of contaminating the environment at the site. In the long term, it must be disposed of in a deep geologic repository.[8]

DOE has not yet determined how the bulk of the waste from the tanks will be disposed. The original waste management plan, adopted in the 1980s, was to treat the salt and supernate wastes (about 90 percent of the volume), remove key radionuclides (especially cesium-137), and vitrify almost all the radioactivity. The bulk liquid that would remain was to be mixed with cement and disposed of onsite as low-level waste called saltstone.

DOE's original plan to separate the cesium-137 from the salt wastes ran into severe technical difficulties. The method originally chosen, large-scale in-tank precipitation, was abandoned in 1998. The main problem was that the residual waste generated benzene, a flammable

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and toxic gas whose presence in the tanks gave rise to risks of fire in the radioactive wastes.

In July 2001, DOE announced that it had decided to extract cesium-137 from the salt solution with specific organic solvents with a technology called Caustic Side Solvent Extraction.[9] Currently, DOE is researching this technology, as well as back-up technologies. The extracted cesium-137 waste is to be vitrified.

In its August 2002 Record of Decision, DOE decided to follow the same procedure to close the remaining 49 tanks as it has with the two tanks it has "closed" so far — filling the tanks with grout after the bulk of the waste has been removed. The "heels" of radioactive materials left in these tanks contain substantial amounts of radioactivity. According plans for "closure" of Tank 19, the cesium-137 activity of the residual waste in Tank 19 is estimated to be over 48,000 curies. This is greater than the total estimated cesium-137 activity for the residual waste in for *all* tanks in the F- and H-Area tank farms estimated by DOE in the High-Level Waste Tank Closure Final Environmental Impact Statement (9,990 curies). Hence, specific tank-by-tank planning shows that the estimates in the F- and H-area Tank Closure EIS were unreliable and should therefore be discarded.

In fact, the closure plan for Tank 19 is a blatant, illegal, and dangerous example of "dilution is the solution to pollution." The residual waste in the tank is estimated to have a concentration of radioactivity over 14 times the Class C low-level waste limit, which defines the most radioactive waste allowed to be put into shallow land burial. The Class C limit is exceeded for each one of four radionuclides by itself: plutonium-238, plutonium-239, plutonium-240, and americium-241. The tank residuals are therefore "Greater than Class C" waste, or equivalently, transuranic waste, of the type that is generally required to be disposed of in a deep geologic repository. But once the tank residual wastes are diluted with a huge amount of grout, the Tank 19 closure document estimates that the resultant waste will be 0.997 times the Class C limit — that is, it would squeak under the wire of present "low-level" waste rules. Allowing such dilution and dumping could open the door to diluting even more radioactive wastes and leaving them by the riverside to threaten people far into the future.

The tanks that remain to be emptied contain far more radioactivity than those that have been emptied so far. Given the escalation in estimates of residual radioactivity that is occurring, grouting the residual waste in the more than four dozen high-level tanks may result in several hundred thousand or even millions of curies remaining in the tanks. This represents an enormous amount of radioactivity. Over the long term, that will pose a serious threat to the groundwater and surface water resources, including the Savannah River.

Plutonium is a concern. The "emptied" Tank 19 is estimated to contain 30 curies of plutonium-239, and almost 11 curies of plutonium-240. The Pu-239/240 inventory in this single tank amounts to about half a kilogram. Given that only about one percent of the radioactivity in all the tanks' sludge has been vitrified (4.2 million curies out of 320 million curies), and that almost all the plutonium is in the sludge, the eventual residual plutonium-239/240 in the tank farm may be very substantial. In addition, the Tank Farms contain well over a million curies of plutonium-238,[10] which has a half life of about 87 years. Residual radioactivity of even one or two percent of the total in these tanks would leave behind a vast amount of total alpha-emitting plutonium radioactivity, in addition to other radionuclides. This is unsafe and will pose a serious risk to future generations. In effect, DOE's policy of high-level waste tank closure would turn the Savannah River Site into a vast, shallow high-level nuclear waste dump in the watershed of the Savannah River.

## High-level waste

DOE has even considered the possibility of abandoning most high-level waste (HLW) at SRS. This possibility was broached by the DOE in November 2001:

> HLW processing is the single largest cost element in the EM [Environmental Management] program today. Eliminate the need to vitrify at least 75% of the waste scheduled for vitrification today. Develop at least two (2) proven, cost effective solutions to every high-level waste stream in the complex.[11]

This would effectively turn SRS, Hanford, and the Idaho National Engineering and Environmental Laboratory into shallow high-level nuclear waste dumps, near some of the most important water resources in the United States.

As a method of going around the Nuclear Waste Policy Act of 1982, which requires deep geologic disposal of high-level waste, the DOE tried to redefine the waste from "high-level waste" to "incidental waste." This end-run was rejected by a federal court in 2003; DOE is appealing. As a result, it would appear that closure of the two high-level waste tanks at SRS by grouting the residual waste is contrary to present nuclear waste law. After the rejection of its reclassification attempt in court, the DOE has attempted to get Congress to give it the authority to redefine waste, but as of this writing (early February 2004) has not succeeded.

Even if the practice is deemed legal by the courts or legalized by new legislation, it will not be safe. Disposal of such vast quantities of long-lived radionuclides in proximity to water resources is unsafe and will pose severe, and in some ways incalculable, risks, far greater than DOE's tank closure policy is already creating.

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There is insufficient understanding of the long-term risks to groundwater and surface water from simply grouting high-level waste in tanks. Given past experience with grouting of wastes, these contaminants may leach out into the groundwater much faster than anticipated and add to the existing contamination in the groundwater, and eventually to the surface water. Moreover, grouting the tank waste in place would put the residual wastes in a form that would be very difficult to retrieve were they to leak. Grouting would also make remediation of the vadose zone even more difficult. DOE admits that:

> [T]ank closure is, for all practical purposes, irreversible. DOE would have great difficulty undoing a closure [with grout] if it were later discovered that an estimate [of residual radionuclide inventory] had been improperly developed, or that the performance had been improperly evaluated.[12]

### Buried waste

SRS buried transuranic waste into the 1970s and continues to dispose of low-level waste by shallow land disposal. There is a huge area of 195 acres (78 hectares) called the Burial Ground Complex where radioactive and mixed radioactive and non-radioactive hazardous wastes were dumped. A part of this, including 58 acres involving mixed wastes, has been closed and capped. Another 25 acres are also capped. Because of the hazardous materials, it is required to be, and is, regulated under the Resource Conservation and Recovery Act.

The purpose of surface caps is to reduce water infiltration and hence the leaching of contaminants from the buried waste and the contaminated vadose zone to the groundwater. They are not a remediation method for already contaminated groundwater. Vegetation planted on the caps increases evapotranspiration and hence can reduce water infiltration. But vegetation also reduces runoff and may therefore sometimes increase water infiltration. In any case, caps are a short-term palliative, not a long term remedy. Physical and biological processes can also decrease the long-term performance of compacted soil caps. They include wetting and drying cycles, soil erosion, root intrusion, worms, and burrowing animals.

The way in which physical, chemical, and biological processes interact to disperse radionuclides in the environment over the long-term is not very well understood. For instance, using clay as a retardant for radionuclides assumes that ion-exchange will bind metal cations in the waste in the soil. This assumption has been shown to be dubious under a variety of real-life circumstances, as for instance when organic material from decaying leaves accelerates the movement of radionuclides. As for biological processes and radioactivity dispersal, there is research on how bacteria might be used to concentrate radioactivity for the purpose of remediation. But if bacteria can, under controlled circumstances, be used for remediation, they may equally well disperse radioactivity under natural circumstances where there is no means to prevent the microorganisms from spreading in the environment. Similarly, using trees as a means for taking up tritium-contaminated water, a technique being used at SRS (see cover photograph), poses threats to the long-term genetic integrity of tree species that are not well-understood.

DOE's ongoing disposal of low-level waste using shallow unlined and unregulated trenches could result in two potentially significant groundwater contamination problems. First, this disposal of low-level waste increases the inventory of waste in the ground that could later migrate to groundwater and surface water. Second, continuing to have open trenches causes existing contamination to be driven further towards the aquifers. As rainwater collects in trenches and percolates downward, it can dissolve chemicals in the waste and carry them to the aquifer, as well as remobilize vadose zone contamination. As a self-regulated government entity regarding radioactive materials, DOE has not been required to provide a technical justification for continued radioactive waste dumping in trenches.

### Long-term issues

DOE has abused its ownership of the land. Lack of regulation for radioactive waste dumping has created risks for time periods that are far beyond any imaginable maintenance of site control. There are abundant examples of loss of site control within decades and loss of institutional memory of serious risks within the same time frame. For example, chemical weapons-related toxic materials (including arsenic) were dumped by the U.S. Army near American University right in the capital city of the United States, and within a few decades, homes were built on or near the dumps.

DOE plans for SRS are dependent on the use of institutional controls for protection of human health and the environment. The general cleanup strategy at SRS is to leave large amounts of waste and contamination in place, grout it and/or put a cap over it, declare the site cleaned up, and assume that institutional controls will be effective in preventing inadvertent exhumation of the site.

DOE acknowledges that current plans for sites like SRS leave contamination in place that will pose risks in perpetuity (or for centuries or millennia). The word "perpetuity" means for an eternal or unlimited duration — which is surely far, far longer than recorded history. There is simply no factual or analytical basis for DOE's assumption that it is possible to have continuing federal control of SRS for national security (or any other) purposes with the current boundaries and institutional controls in perpetuity.

According to a 2000 study on long-term stewardship by the National Research Council:

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> The Committee on Remediation of Buried and Tank Wastes finds that much regarding DOE's intended reliance on long-term stewardship is at this point problematic….
>
> […]
>
> Other things being equal, contaminant reduction is preferred to contaminant isolation and imposition of stewardship measures whose risk of failure is high.
>
> […]
>
> *The committee believes that the working assumption of DOE planners must be that many contamination isolation barriers and stewardship measures at sites where wastes are left in place will eventually fail, and that much of our current knowledge of the long-term behavior of wastes in environmental media may eventually be proven wrong. Planning and implementation at these sites must proceed in ways that are cognizant of this potential fallibility and uncertainty.*[13] [Original emphasis.]

The DOE is systematically spurning this advice at SRS (and elsewhere). The result is that some of the most precious water resources in the country are being put at risk for the long term. It is a course that must be reversed.

1 This article is based on the IEER report of the same title by Arjun Makhijani and Michele Boyd (Takoma Park, Maryland: Institute for Energy and Environmental Research, March 2004). We are grateful to Jim Werner for the many contributions he made to the report, including writing portions of an early draft, as a consultant to IEER before he began working for the State of Missouri, and for his very helpful detailed reviews and suggestions after that. Michele Boyd, former IEER global outreach coordinator and staff scientist, is now

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### MOST IMPORTANT FINDINGS

1. *Water contamination at SRS:* Waste disposal practices have led to severe contamination of portions of the surface and groundwater at SRS, especially with tritium and trichloroethylene (TCE). Ground and surface water is polluted at SRS often to levels far greater than safe drinking water limits with both radioactive and non-radioactive toxic materials. This water is not now being used for drinking.
2. *Threats to regional water resources:* The main threats to the Savannah River and possibly other water resources in the region due to SRS come from radioactive and non-radioactive toxic wastes that were dumped in shallow trenches and pits, contaminated soil onsite, and contaminated water from SRS groundwater into streams, wetlands, and the Savannah River. Capping or grouting the wastes in place compounds the risks.
3. *Pollution of the Savannah River:* The Savannah River is contaminated as a result of highly contaminated surface water flowing into it from SRS, though the large flow of the river dilutes the contamination to well within present safe drinking water limits.
4. *Tritium contamination:* Tritium, which is a radioactive isotope of hydrogen, is the most common radioactive groundwater and surface water pollutant. It is present at levels of about 5 percent of the drinking water limit in the Savannah River in the environs of SRS. Though there is some further reduction of this by dilution, elevated tritium levels due to SRS are present all the way to the mouth of the Savannah River at Savannah, Georgia.
5. *Tritium contamination in Georgia:* Rainfall and groundwater in parts of Georgia across the river from the Savannah River Site are contaminated with tritium from SRS, though well below safe drinking water limits. Evaporation of contaminated water from SRS contaminates rain, some of which then falls on the Georgia side of the river. There may or may not be pathways under the Savannah River that carry tritium to groundwater in Georgia. Investigations have been inconclusive. As of this writing (early February 2004), DOE funding to the State of Georgia for environmental monitoring related to SRS is set to expire April 30, 2004.
6. *Tritium standards:* Tritiated water is far more dangerous to children and developing fetuses than to adults. Recent research indicates that current safe drinking water standards for tritium may not be adequate to protect pregnant women and developing fetuses.
7. *Subsistence fishing:* Many people use the Savannah River for subsistence fishing — that is, as a primary source of food; the practice is more common among African-Americans. Studies have shown that African-American fishermen consume about four times more fish than the maximum limit set by the South Carolina Department of Health and Environmental Control. This environmental injustice is unlikely to be rectified unless a sound and stringent clean-up plan — far more stringent than any present plans — is implemented at Savannah River Site.
8. *Inadequate clean-up plans:* The DOE practice of capping shallow dumps and seepage basins is not suited to long-term protection of the water resources of the region.
9. *Unsafe and illegal high-level waste management:* DOE is leaving large amounts of residual radioactivity from high-level waste in tanks that are being "closed" by pouring grout into them. The total amount of residue left in the ground from such practice, if extended to all 51 high-level waste tanks, may eventually amount to a million or more curies and include significant amounts of plutonium-238 and plutonium-239. The concentration of alpha-emitting plutonium isotopes in the two closed tanks (17 and 20) is well above the maximum allowed for shallow land disposal of radioactive waste; such waste is generally required by regulations to be disposed of in a deep geologic repository. This means that grouting is being used to create *de facto* shallow high-level waste dumps at SRS; in other words, DOE is treating high-level waste as if it were low-level waste. This practice violates the 1982 Nuclear Waste Policy Act. Even if the practice were to be declared legal, it would pose a significant threat to the Savannah River over the long term. The closure plan for Tank 19 is another example of this dangerous DOE policy. It would create one more *de facto* high-level waste dump — the residual waste would be more than 14 times greater than the highest limit allows for radioactive waste allowed in shallow land burial. DOE plans to dilute the waste with grout so that the net result would squeak in under the low-level waste limit. Allowing such dilution and dumping could open the door to diluting even more radioactive wastes and leaving them by the riverside to threaten people far into the future.

## MOST IMPORTANT RECOMMENDATIONS

1. The DOE should urgently develop plans to recover buried wastes and highly contaminated soil, so that the main sources of water pollution over the long term are minimized.
2. The DOE should stop grouting residual radioactivity in high-level waste tanks so as not to leave vast amounts of radioactivity near the Savannah River. It should make a commitment to removing the radioactivity from the tanks and to decommissioning the tanks by removing them from the ground for safer, retrievable storage. The argument is not that every last curie can be retrieved, but retrieval can be more complete with appropriate effort and time. Decommissioning the tanks by removal is worth doing, even if it takes decades, because of the reduction of risk to the water resources of the region.
3. DOE should restore funding for environmental monitoring to the State of Georgia and expand such funding.
4. The States of Georgia and South Carolina as well as the federal government should initiate efforts to inform those who rely on subsistence fishing of the risks of large-scale fish consumption and of efforts being made to reduce those risks. More complete studies of diets of the people living along the Savannah River, especially African-Americans, are needed. These should be done with the involvement of local people, historically Black colleges, and the States of Georgia and South Carolina, with technical assistance as needed from the U.S. Centers for Disease Control and Prevention, which is headquartered in Atlanta, and with adequate funding from the federal government.
5. The U.S. government should provide sufficient funds for a geological investigation that would be thorough enough to conclusively settle the question of whether radioactivity is migrating into Georgia groundwater by pathway(s) under the Savannah River. It should also provide funds for an independent investigation of long-term threats to the Tuscaloosa aquifer if large amounts of residual radioactivity are left at SRS. This is crucial to understanding the risks to deep aquifers in the region from SRS wastes.
6. The National Academy of Sciences panel on the effects of low-level radiation (called the BEIR VII panel) should fully address the non-cancer risks of tritium, and the risks of tritium to pregnant women and developing fetuses, as well as risks from combined exposure to tritium and non-radioactive toxic materials.
7. Current standards for tritium contamination of water should be re-examined and tightened so as to protect pregnant women and developing fetuses, with due regard for the fact that the nourishment of the fetuses comes via the woman, so that protecting both is essential.
8. More extensive monitoring of Iodine-129 in Savannah River water and fish should be conducted. The health implications of I-129 contamination of the Savannah River should be studied, including its effect on pregnant women, and communicated to the public.

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the legislative representative and manager of the nuclear program at Public Citizen's Critical Mass Energy and Environment program. The named authors of this article alone are responsible for its contents. Proposed plutonium fuel processing, tritium processing, and possibly a huge new plant to make plutonium bomb cores, known as plutonium pits, pose additional risks that are not covered in this study of SRS. References can be found in the report.

2 DOE has closed the F-canyon, but H-canyon is to continue operating until 2008.

3 The vadose zone is the soil between the ground surface and the water table.

4 "Institutional controls" are, generally, legally enforceable measures, like water use restrictions, zoning ordinances, or well-drilling prohibitions, meant to affect human behavior in order to prevent or reduce exposure to radioactive or toxic contamination. Institutional controls are distinct from physical controls like engineered barriers or containment systems.

5 Calculated by IEER from Harrison et al., "Uncertainties In Dose Coefficients For Intakes Of Tritiated Water And Organically-Bound Forms Of Tritium By Members Of The Public," *Radiation Protection Dosimetry,* 98:299-311 (2002).

6 Milton Morris and May Linda Samuel, *A Study of Factors Relating to Fish Subsistence/Consumption Within Communities Near the Savannah River Site* (Benedict College, Columbia, South Carolina), November 26, 1996, pages 29, 89, and 91. See answers to questions 10 and 21. Benedict College is an historically Black college in Columbia, South Carolina. IEER thanks Dr. May Linda Samuel for providing us with the research data and making a presentation on the subject at an IEER workshop.

7 Caldwell et al., *High Level Waste System Plan Revision 13 (U),* (Cover title: Savannah River Site High Level Waste System Plan: Waste Immobilization), HLW-2002-00025, March 2002, page 80.

8 The DOE is hurtling ahead with plans to make Yucca Mountain the country's nuclear waste repository, but the plan is opposed by most Nevadans, under review by the U.S. Nuclear Regulatory Commission, and plagued with technical problems. IEER has concluded that it is a poor site, and that a new geologic disposal program should be developed. (See *Science for Democratic Action*, vol. 7 no. 3, May 1999. On the Web at http://www.ieer.org/sdafiles/vol_7/7-3/index.html.)

9 U.S. Department of Energy, Savannah River Operations Office, "DOE Announces Availability of Final Supplemental EIS and Identifies Preferred Salt Processing Alternative," SR-01-09, July 20, 2001.

10 DOE's then-contractor for SRS, Dupont, listed the Pu-238 content of the Tank Farm in 1986 as being 1.5 million curies. This would have decayed to about 1.3 million curies by 2003. See Makhijani, Alvarez, and Blackwelder, *Evading the Deadly Issues: Corporate Mismanagement of America's Nuclear Weapons Production* (Washington, DC: Environmental Policy Institute), September 1987, Table 1, and associated discussion.

11 Jessie Roberson, Department of Energy Assistant Secretary for Environmental Management, *Environmental Management Priorities,* Memorandum For Director, Office Of Management, Budget And Evaluation, Chief Financial Officer, November 19, 2001.

12 U.S. Department of Energy, Savannah River Operations Office, *Technology to Mitigate Effects of Technetium under Tank Closure Conditions*. SR00-2051, [Aiken, SC]. On the Web at www.srs.gov/general/scitech/stcg/Needs/00-2051.htm. Date of Latest Revision: November 2001.

13 National Research Council, Board on Radioactive Waste Management, Commission on Geosciences, Environment, and Resources. *Long-Term Institutional Management of U.S. Department of Energy Legacy Waste Sites*. Washington, DC: National Academy Press. 2000, pages 3-5.

## TARGETING

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a military, political, social, moral, and legal monstrosity, whose nature is only now coming into fuller view. Rather than establishing long-term peace monitored and maintained by a single bomb-wielding overseer, the bomb made tangible the illusion of absolute power, spurring greater violence, human rights abuses, and near global annihilation in the quest to obtain and manage it. Yet the nuclear-bomb-equals-total-control formula survives today, and with recent moves away from arms controls, the threat from such an attitude is growing.

The global political fallout has been more than anyone considered at the outset of the Manhattan Project. Harold Urey, a leading project scientist, believed if Hitler got the bomb, "the war will be over in two weeks." In that time, in the deafening roar of the dictator's blitzkrieg across Europe, Hitler simply could not be allowed a monopoly on the weapon—other questions related to its development were secondary. What would happen if the United States gained a monopoly on the bomb? What would such absolute power do to those who wielded it? What would those leaders do to their societies and to the world?

It wasn't until May 5, 1943 that the answers to these secondary questions began taking shape in secret. The nuclear bomb began to create its very own strategic universe centered on nuclear materials and capabilities. At that meeting, five members of the Military Policy Committee—Vannevar Bush, director of the Office of Scientific Research and Development; James B. Conant, chairman of the National Defense Research Committee; Adm. W. R. Purnell; Gen. Wilhelm Styer; and Manhattan Project leader Gen. Leslie Groves—ruled out Germany as the first target, reasoning that if the bomb turned out to be a dud, that country, with its advanced scientific capabilities, could use the unexploded fissile material to make one of its own. They decided instead to target the Japanese fleet stationed at the Pacific island of Truk, so if the bomb did not explode, it would sink to the bottom of the ocean.[2]

Only Manhattan Project officials attended the historic meeting. No World War II commanders were present. None served on the Military Policy Committee, nor is there any evidence that one was consulted. In fact, neither Gen. Dwight Eisenhower nor Gen. Douglas MacArthur even knew about the Manhattan Project at the time of the first targeting decision. Furthermore, Manhattan Project scientists, including émigrés like Hans Bethe and Leo Szilard, had no clue about this secret decision and continued to be driven by the threat of a nuclear-armed Hitler.

During 1944, U.S. atomic intelligence missions to Germany gathered increasing evidence that Germany had no effective bomb project. By early December 1944, when U.S. troops were already in parts of Germany, that became a certainty. Joseph Rotblat, a Polish émigré scientist at Los Alamos, quit then, but his was a lonely walk away from the project.

By January 1945 it was clear inside the Manhattan Project that Hitler would be defeated before the bomb was ready. Only then did the scientists realize that Japan would be the target. Some of them tried to stop the use of the bomb on cities; most did not.

> The nuclear bomb program had become its own justification.

The nuclear bomb program had become its own justification. The bomb had to be used because it was made. The immense expenditure had to be justified by something more than the fact that a project of deterrence had been undertaken as a precaution. The proof of the scientific and engineering work had to be carried through to a nuclear test. The technical questions about the destructive power of nuclear bombs had to be answered by their use on cities. The power of the bomb had to be demonstrated to the world, especially to the Soviet Union.

The idea that the United States might use the monopoly of the bomb to rearrange the world to its liking was formally raised by Henry L. Stimson, who was Secretary of War during World War II. After President Franklin D. Roosevelt's death, Stimson had the job of briefing President Harry Truman about the Manhattan Project. On April 25, 1945, Stimson told Truman, "If the problem of the proper use of this weapon can be solved, we will have the opportunity to bring the world into a pattern in which the peace of the world and our civilization can be saved."

The first experiments in "proper use" were the bombings of Hiroshima and Nagasaki. The swift end to the war after those bombings created an aura of complete military success for the United States. It obscured the role that the Soviet declaration of war on Japan (on August 8, 1945) also played in the Japanese surrender decision and the fact that the Japanese had been close to surrender in July. Post-war official proclamations about the huge numbers of American lives that were saved were exaggerated and had no relation to the official estimates of fatalities made by the military during the conflict. But in their relief at the end of a brutal war, Americans believed them. And so, along with the horror of the bombings, an attraction to the power of the bomb was born.

Sixty years after the fateful day when the Manhattan Project's anti-Nazi purpose was bent to other destructive aims, the idea that the nuclear bomb is still a useful means of exercising power is spreading. A dozen years after the end of the Cold War, North Korea is threatening nuclear war. Osama bin Laden has publicly

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announced his nuclear ambitions and rationalized his determination to kill innocents by making reference to Hiroshima. India and Pakistan are hurling nuclear threats at one another as their troops face off across a frozen mountainous line, inflamed with religious and nationalistic passions.

Russia and the United States between them have 4,000 warheads on hair-trigger alert, ready to be fired within minutes, thereby keeping the world at the edge of utter annihilation. They insist it is necessary, even though the Cold War is long since over and despite the fact that in January 1995, when a scientific rocket launched from Norway was thought by the Soviets to be a U.S. nuclear launch, that policy brought the world within minutes of all-out nuclear war by miscalculation.

The world is now faced with a stark question: Will the determination of some to wield the power of annihilation triumph over the rule of law, over justice, over human rights and democracy, over the laws of war, over the protection of the environment, and even over common sense about not aggravating risks of nuclear terrorism and accidental nuclear war?

### Casualties

In early December 1944, when it was clear that Germany had no bomb program worth the name, large-scale separation of plutonium had not yet begun in the United States. The U.S. program to make highly enriched uranium was nowhere near its goal of having enough to make at least one bomb.

But instead of declaring the Manhattan Project a success and shutting it down, General Groves sped it up. He was determined that the bomb should be ready in time for use against Japan, which, he declared in April 1945, was "always" the target. The vast airborne armadas that were incinerating Japanese cities in early 1945 with firebombs would be replaced by the decisive terror of a single atom bomb dropped from a lone plane. It was also to be a message to the Soviets. Stalin got it; he ordered the Soviet bomb program accelerated to breakneck speed after Hiroshima.

Nuclear establishments have subverted the rule of law and democracy, where they existed, in the name of national security. In 1989, as the Cold War was ending, U.S. Deputy Secretary of Energy W. Henson Moore criticized prior administrations as operating the nuclear weapons establishment as "a secret operation not subject to laws." He said the government and its contractors ran the bomb plants with the idea that "This is our business, it's national security, everybody else butt out."[3] "Everybody else" meant, evidently, the people of the United States.

Nuclear governments have consistently put their own workers, citizens, and soldiers at risk. For instance, in the United States, the Atomic Energy Commission and its contractors covered up highly hazardous working conditions in part to deny workers hazardous duty pay. In the Soviet Union Stalin used slaves. Many workers at Soviet reactors and plutonium separation plants received huge doses of radiation.

Nuclear governments have poisoned people living downwind of testing and production sites. They have covered up their acts and lied to their people. By atmospheric testing in Nevada and Kazakhstan, nuclear weapons powers made their people sick, while insisting that fallout would not hurt them (this was called "reeducation," aimed at correcting the "hysterical and alarmist complex now so prevalent," in the words of U.S. military officers involved with the testing program).

While reassuring the public that nuclear tests posed no radiation danger, the military was contemplating the use of the terror of radioactive contamination after a nuclear explosion as a weapon of war. A Joint Chiefs of Staff evaluation of the 1946 tests at Bikini was graphic:

> We can form no adequate mental picture of the multiple disasters that would befall a modern city, blasted by one or more bombs and enveloped by radioactive mists. Of the survivors in the contaminated areas, some would be doomed by radiation sickness in hours, some in days, some in years. . . . Added to every terror of the moment, thousands would be stricken with a fear of death and the uncertainty of the time of its arrival.[4]

At the peak of U.S. production in the 1950s, about 10 plutonium pits a day were being made at Rocky Flats, 16 miles upwind from Denver. The peak U.S. arsenal reached nearly 32,000 bombs. Yet, in the mid-1950s, one U.S. strategic nuclear war plan called for the use of about 750 nuclear bombs. That was judged to be enough to turn Russia into "a smoking, radiating ruin at the end of two hours."[5] The Soviets did one better; their peak arsenal was more than 40,000 bombs.

A large-scale nuclear power program was initiated in the United States as part of Cold War propaganda.[6] Between the race to build more bombs than were required to level every city on Earth and the race to make the atom look peaceful, the world now has about 2,000 metric tons of plutonium, enough to make about 400,000 nuclear bombs—and many more if high-tech designs are used. About a fourth of this plutonium is separated, readily usable in bombs. The rest can be separated by chemical processing. North Korea is doing it, with its bomb program ill-disguised as a nuclear power program. The United States and Russia are separating plutonium in their waste management programs. Britain, France, Japan, and India are doing it in the name of commercial power, though one leading Japanese politician has remarked that Japan could take its commercial plutonium and make a few thousand bombs with it.

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The determination of the big powers to hold on to nuclear weapons persists well after the end of the Cold War. The United States has named seven countries as potential nuclear targets, including North Korea. The naming of North Korea as a target in the Nuclear Posture Review was a clear violation of a U.S.-North Korean 1994 pact under which the United States agreed to "provide formal assurances to the DPRK [North Korea], against the threat or use of nuclear weapons by the U.S." North Korea has violated its part of the bargain, too.

The five major nuclear powers are also the permanent members of the U.N. Security Council, where they sit to decide the fate of billions of people. They are all violating their commitment under the Nuclear Non-Proliferation Treaty to get rid of nuclear weapons and to take irreversible steps toward that goal. Not satisfied with keeping the world at the edge of the nuclear abyss in violation of their treaty commitments, they also want to sit in judgment of everyone else, though some seem to be doing so with more trepidation than others, perhaps only because of practical competition among the powerful.

Since the May 5, 1943 targeting meeting, history has been riddled with examples of the fallacy that nuclear arms can bring peace and safety through absolute power.

The United States and the Soviet Union nearly destroyed each other and everyone else during the Cuban missile crisis but, after a short period of hope that gave the world the atmospheric test ban treaty, continued to expand their arsenals and entertain theories of winnable nuclear war.

Nuclear weapons have frequently been used to threaten non-nuclear states. Nuclear bombers were put on alert and sent to Nicaragua before the CIA-sponsored coup in Guatemala in 1954, which resulted, over time, in the deaths of more than 200,000 people. Nuclear threats have played a role in oil politics, including the 1958 Iraq-Lebanon crisis. Oil and nuclear bombs are now the deadly mix at the center of the current world crisis.

The Comprehensive Test Ban Treaty has been shelved by the United States, breaking a long-standing promise. The nuclear bureaucracy overcame the end of the Cold War, situated itself in a new generalized indefinite war, and now seems set to test or even use weapons in wartime, notwithstanding the possible catastrophic consequences in a time when there are huge amounts of nuclear materials in the world.

Overlapping nuclear crises — potential India-Pakistan-North Korea-U.S.-China-induced nuclear terrors — appear set to overtake the Nuclear Non-Proliferation Treaty. The Middle East, with its festering Israel-Palestine crisis and a nuclear-armed Israel, may well join the list of nuclear hot spots before long, given the rising injustice, violence, and anger in the region.

We shall never be sure of the status of all bomb materials. For instance, in the United States, the Los Alamos National Laboratory and the Energy Department differ on the plutonium content of radioactive waste at the lab. The Los Alamos account shows 765 kilograms (about 150 bombs worth) more than Energy's account. The discrepancy was recognized in 1996 but has not been resolved. The accuracy of military plutonium accounts in Russia is anyone's guess.

> It is an illusion to believe that instruments of terror can deter terror. Such weapons often inspire the determination to wield them. The policy of deterrence has been a principal engine of proliferation.

Instead of the terror of a lone bomber over a city, we are now faced with the terror that any cargo container might contain a nuclear bomb that could destroy a city.

Even if we eliminate all nuclear weapons verifiably — which is both desirable and technically possible — the technical success of the first test created knowledge and insecurities that will persist.

It is an illusion to believe that instruments of terror can deter terror. Such weapons often inspire the determination to wield them. The policy of deterrence has been a principal engine of proliferation. Fear of a German bomb led to the U.S. bomb, which in turn led to the Soviet bomb and the Chinese bomb. . . . Well over half the world's population now lives in countries that have nuclear weapons or are allied with a nuclear weapon state. In all, 44 countries have the technical capability to make nuclear bombs.

### The judgment of history

When the late Chinese Prime Minister Chou en-Lai was asked his view of the historical significance of the French Revolution, he replied. "It is too early to tell." Mahatma Gandhi was not so shy about the Manhattan Project and its terrible unveiling to the world with the bombings of Hiroshima and Nagasaki. While condemning the "misdeeds" and "unworthy ambitions" of the Japanese imperialists, Gandhi predicted that the United States might find itself confronted by nuclear terror one day: "What has happened to the soul of the destroying nation is yet too early to see. . . . A slave holder cannot hold a slave without putting himself or his deputy in the cage holding the slave."

The giant nuclear abyss of the Cold War remains though that war is over. In addition, vast crevasses are cropping up over the world's nuclear landscape.

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ENDNOTES, PAGE 16

# It pays to increase your jargon power with Dr. Egghead

### Beta emitter

a. A person who produces and distributes test versions of computer software.
b. Nickname for a flatulent member of the Beta Beta fraternity.
c. A radionuclide that gives off electrons or positrons (particles identical to electrons, but with a positive electrical charge) in the process of radioactive decay.

### Dose conversion factor

a. The ritual that a dose goes through upon religious conversion.
b. Inversely proportional to the amount of mathematics a given person can take in one sitting.
c. A value, usually in sieverts per becquerel (Sv/Bq), that allows one to convert an intake of radiation to an equivalent dose. Generally, dose per unit intake. Each radionuclide has its own dose conversion factor. For example, a hypothetical person's annual dose from tritium in drinking water could be calculated like this: [Concentration of tritium in drinking water, in Bq/liter] x [Water consumption rate, in liters/year] x [Dose conversion factor for tritiated water (HTO), in Sv/Bq] = [Effective dose equivalent for tritium in drinking water, in Sv/year].

### Ion exchange

a. A market in which electrons and protons are bought and sold. Basis of the proposed economy in official U.S. plans for colonization of the moon and Mars.
b. A tradition during molecules' holiday season.
c. A process whereby two different molecules swap electrically charged atoms or groups of atoms, which are called ions.

### Natural background radiation

a. Type of movie sets used in the films "Godzilla," "Them!" and "Class of Nuke 'Em High."
b. The newest color in the Crayola crayon box, a yellowish, silvery purple that glows in the dark.
c. External radiation from cosmic rays and natural radionuclides on the earth, and internal radiation from, for instance, naturally-occurring potassium-40. Amounts to about 80 or 90 millirem per year at sea level, more at higher altitudes. (For more information, see the IEER tool kit on natural and man-made radiation in SDA vol. 4 no. 1, Winter 1995, online at http://www.ieer.org/sdafiles/vol_4/4-1/c-fold.html.)

### Outcrop

a. Synonym for backyard garden.
b. Technical name for a severe bout of acne.
c. A place where groundwater is discharged to the surface. At SRS, groundwater outcrops in several places to enter site streams. Also referred to as seepline. (Source: http://www.cdc.gov/nceh/radiation/savannah/Glossary.pdf)

### Seepage basin

a. Proposed name for a ski resort planned for land that is currently occupied by U.S. Department of Energy nuclear weapons production facilities. (Converting radioactively-contaminated land to recreation areas is a key part of DOE's "Accelerated Risk-Based End State Performance Management Long-Term Stewardship Closure Plan.")
b. Wetness containment feature on the most exclusive baby diapers.
c. At the Savannah River Site, unlined excavated bowl-shaped area for receiving liquid wastes from facilities onsite. Designed to allow infiltration of the liquid into the ground, thus decreasing, at least in the short term, the total volume of liquid released to onsite streams. The first seepage basins at SRS were put into operation in 1954. (Source: http://www.cdc.gov/nceh/radiation/savannah/Glossary.pdf)

Answers: c, c, c, c, c

## TARGETING

FROM PAGE 14

Henry Stimson's suggestion that there might be a "proper use" of the bomb was wrong. There are no hands in which its possession can be deemed safe. There continues to be a real risk that much of the world could become radioactive rubble in any 15-minute period due to a miscalculation in the United States or Russia. India and Pakistan might incinerate each other's cities — their decision time is five minutes, maybe less. East Asia may again see nuclear horror as a result of the U.S.-North Korean confrontation. The danger of loose nukes is mounting.

"It may be that we shall by a process of sublime irony have reached a stage in this story where safety will be the sturdy child of terror, and survival the twin brother of annihilation," commented Winston Churchill in March of 1955 when discussing the hydrogen bomb. But this is hardly "safety"; much less is it a "sturdy child" of nuclear terror, globally or regionally.

Millions have been killed in proxy wars. For them, the nuclear age brought death, not safety, partly due to the fact that Europeans were too afraid to fight one another again. And the violence of the proxy wars continues, though the Cold War is over. Indeed, the problem of global terrorism, which threatens to go nuclear, is a direct result of some of those wars. The message that nuclear bombs are all-determining has migrated from the capitals of civilization to the caves of Afghanistan.

Since Hiroshima, the Manhattan Project has become a symbol of brilliant achievement, especially in the United States—a technical triumph that combined human ingenuity, bureaucratic organization, money, and single-minded pursuit of a goal. It is commonplace to hear the phrase "We should organize a Manhattan Project to solve [name your big problem]." Yet, scientific brilliance is not enough. Bereft of moral and political vision or consideration for future generations, it can lead to chaos, violence, and in the case of nuclear weapons, annihilation.

States wielding weapons of terror are not the answer to the problem of terror. Only a global movement for democracy that draws inspiration from leaders like Gandhi and Martin Luther King Jr. can overcome the violent and environmentally destructive underpinnings of the nuclear age. Albert Einstein noted the necessity of a change in human thinking so that society could deal with the implications of the bomb. Gandhi showed the manner of its achievement: "We must become the change we want to see in the world."

1 This article first appeared in the May/June 2003 *Bulletin of the Atomic Scientists,* and can be found at http://www.thebulletin.org/issues/2003/mj03/mj03makhijani.html or at http://www.thebulletin.org/issues/2003/mj03/mj03makhijani.pdf.

2 Arjun Makhijani, "'Always' the Target?" *Bulletin of the Atomic Scientists,* May/June 1995, pp. 23-27.

3 T. R. Reid, "Health, Safety Given Priority at Arms Plants; Energy Department Puts Production 2nd," *Washington Post,* June 17, 1989.

4 U.S. Joint Chiefs of Staff, *The Evaluation of the Atomic Bomb as a Military Weapon: The Final Report of the Joint Chiefs of Staff Evaluation Board for Operation Crossroads* (30 June 1947). Document number JCS/1691/7, Record Group 218, Modern Military Branch, National Archives, Washington, D.C. Operation Crossroads was conducted in July 1946 at Bikini Atoll to carry out the first post-World War II nuclear tests.

5 Strategic Air Command, nuclear war briefing, March 18, 1954. Cited in David Alan Rosenberg, "'A Smoking Radiating Ruin at the End of Two Hours': Documents on American Plans for Nuclear War with the Soviet Union, 1954-55," *International Security* 6, no. 3, (winter 1981/1982), pp. 3-38.

6 Arjun Makhijani and Scott Saleska, *Nuclear Power Deception* (New York: Apex Press, 2000).

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