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Poison in the Vadose Zone: Threats to the Snake River Plain Aquifer from Migrating Nuclear Waste

SOURCE: DOE

Boxes and barrels containing low-level radioactive waste floated freely when INEEL's infamous Pit 9 flooded in the spring of 1969 due to heavy snowmelt and spring rains. Floods in this area also occurred in 1962 and 1982. Dikes and diversion drainage ditches have since been built, but ponding occasionally still occurs.

BY MICHELE BOYD AND ARJUN MAKHIJANI[1]

The Snake River Plain aquifer is the most important underground water resource in the northwestern United States. The US Environmental Protection Agency (EPA) has designated this aquifer as a sole source aquifer, because it is the only source of drinking water for 200,000 people in southern Idaho. It is also a major source of irrigation water for regional crops, notably potatoes. The produce grown in Idaho is eaten throughout the United States and in many other countries, including Japan, Canada, and Mexico. Idaho's trout farms, which also rely on the groundwater, produce 75 percent of the commercial rainbow trout eaten in the United States. The Snake River Plain Aquifer contains roughly 2,500 trillion liters (more than 600 trillion gallons) of water.

The Idaho National Engineering and Environmental Laboratory (INEEL) sits directly above 2,300 square kilometers (890 square miles) of this aquifer. For the second half of the twentieth century, large quantities of radioactive and hazardous chemical wastes were directly injected into the aquifer, discharged into surface ponds, or dumped into shallow pits and trenches at INEEL from nuclear weapons production operations there and from other sites around the United States. This waste included more than a metric ton of plutonium – enough for more than 200 nuclear bombs – as well as large amounts of other radionuclides like strontium-90 and americium-241 and non-radioactive hazardous materials such as carbon tetrachloride and trichloroethylene (TCE).

Wastes highly contaminated with plutonium (now called "transuranic wastes") were dumped into shallow pits on the assumption that transuranic radionuclides would migrate very slowly, if at all, takings tens of thousands of years to reach the aquifer. The water table is about 600 feet below the surface at the location of the disposal area, known as the Subsurface Disposal Area. Measurements of plutonium and americium at the site, laboratory work, as well as theoretical work over the last twenty-five years, have shown that this assumption was wrong. Plutonium and americium can migrate to the aquifer in decades instead of millennia. Figure 1 (page 2), taken from a report by the National Research Council of the National Academy of Sciences, shows the estimated travel time of plutonium to the aquifer as the estimate evolved from the mid-1960s to the late 1990s.

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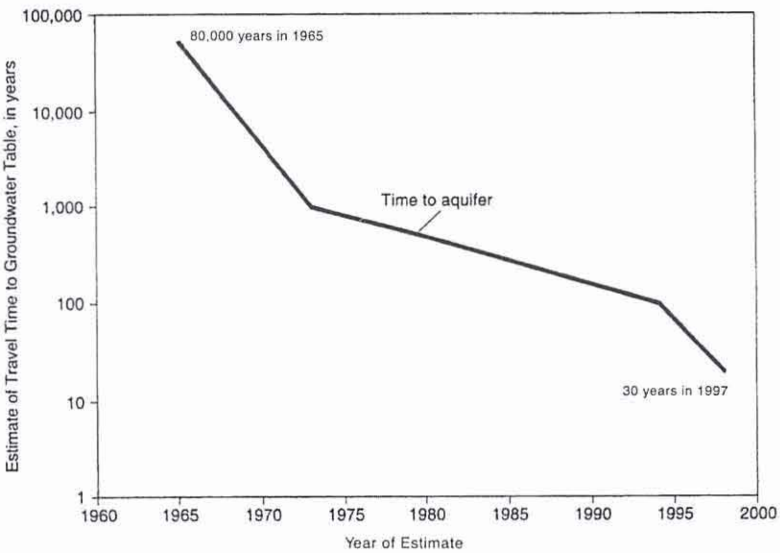
As a result of these waste management practices, water on site, including much of INEEL's drinking water and many parts of the aquifer, is already polluted, in some cases at levels greater than the maximum contaminant level (MCL) set by the US Environmental Protection Agency under the Safe Drinking Water Act. This water is not currently being used for drinking, so the drinking water standards do not apply as a legal matter. But the contamination above drinking water levels is worrisome both because it indicates the potential for offsite contamination and because it compromises the future usability of the water on site. Offsite Snake River Plain aquifer water is well within compliance of the drinking water limits today.

Despite the fact that historical practices have resulted in contamination of the Snake River Plain aquifer and pose a threat to the health of the aquifer, shallow land burial of low-level radioactive wastes, as well as discharge of waste into percolation ponds, continue at INEEL. Percolation ponds delay water from reaching the aquifer only on the order of days to months. As contaminated water moves through the vadose zone, it can carry dissolved chemicals to the aquifer from the pond or by remobilizing vadose zone contamination from prior releases. (The vadose zone is the unsaturated region of soil and rock between the land surface and the water table.) Figure 2, on page 4, shows a conceptual model of groundwater and perched water body recharge, contaminant sources, and exposure pathways at INEEL.

Groundwater contamination

Groundwater contamination may occur in plumes or in a more scattered and unpredictable fashion, depending on the pollutants in question, the methods of their discharge, and their interaction with the environment. Contaminants like strontium-90, tritium, and TCE, which move rapidly through the vadose zone, tend to form plumes. Plutonium, whose migration depends greatly on local

FIGURE 1: Changing Estimates of Travel Time of Plutonium Through the Vadose Zone to the Snake River Aquifer



Source: NAS-NRC, 2000

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Editor: Lisa Ledwidge

Table 1: Highest plume concentrations in the Snake River Plain aquifer in 1995

Contaminant	Highest concentration in plume (picocuries per liter; TCE in micrograms per liter)	Drinking Water Standard (picocuries per liter; TCE in micrograms per liter)	As % of Drinking Water Standard	Area with concentration greater than Drinking Water Standard (square miles)
Iodine-129*	3.82	1	382	1.5
Technetium-99	448	900	49.8	0
Tritium	30,700	20,000	153.5	1.3
Strontium-90	84	8	1,050	0.6
Trichloroethylene (TCE)	32,000	5	640,000	2,700 meters long; maximum width of 900 meters

* Data for iodine-129 is from 1991.

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geologic conditions, has not formed a plume at INEEL, indicating widely different rates of migration in different places at the site.

There are currently several contaminant plumes in the Snake River Plain aquifer, including tritium, strontium-90, iodine-129, and several volatile organic compounds (primarily TCE). Of these, large areas have tested at greater than the maximum contaminant levels.

Table 1 shows the highest plume concentrations in the aquifer, both as picocuries per liter and as a percent of the drinking water standard, and the area with concentrations greater than the drinking water standard. The highest concentrations in the tritium, strontium-90, and iodine-129 plumes are all much higher than the drinking water standards. The highest concentration of the TCE plume is 640,000% greater than the drinking water standard.

Plutonium-238, plutonium-239, and americium-241 have also been found in the Snake River Plain aquifer, but no pattern or plume has been detected or established. Table 2, on page 8, shows the americium and plutonium detections in groundwater between the years 1972 and 2000 beneath the Radioactive Waste Management Complex (RWMC), where the transuranic waste was dumped into unlined pits and trenches. Measurements of plutonium and americium ranges from tiny fractions of a picocurie per liter to 24 picocuries per liter for plutonium-239/240. Table 2 also shows that the results of the measurements have been highly variable.

There has been and continues to be some controversy about the validity and interpretation of the positive detections for plutonium. It must be noted that there are only a few samples, taken at one time, and they are not necessarily representative of a longer pattern of plutonium detections and plutonium migration throughout the vadose zone.

It has been suggested that the positive detections of plutonium may be due to measurement problems. However, it seems unlikely that all of the positive detections, which were taken at intervals decades apart and in which no systematic measurement errors have been identified, would be attributable to measurement or sampling protocol errors. The highly variable results may be a result of the fact that plutonium transport in the vadose zone is highly complex and can be greatly affected by very localized factors. One of these factors relates to colloidal transport – that is, transport of plutonium that is not dissolved but moves as tiny colloidal particles in suspension. Even single sub-micron size colloidal particles of plutonium-238 and micron size particles of plutonium-239 carry significant amounts of radioactivity, so that high variability between different subsamples of the same sample may be expected. As a result, plutonium migration is quite unpredictable. The findings of plutonium in the groundwater are also supported by findings of plutonium in the vadose zone. Overall, the evidence indicates rapid migration of plutonium and americium through the vadose zone, which constitutes one of the principal threats to the Snake River Plain aquifer.

Many contaminants are not regularly monitored. For example, despite the fact that there is a known plume of iodine-129, neither Department of Energy (DOE) contractors nor the US Geological Survey (USGS) have published any measurements of this radionuclide in the groundwater since 1992. The most contaminated well with iodine-129 had a concentration of 3.82 picocuries per liter in 1991 (its maximum contaminant level is 1 picocurie per liter). This radionuclide is among those of special concern due to its rapid migration through the vadose zone and its very long half-life (17 million years). Radioactive iodine affects the thyroid, especially in children.

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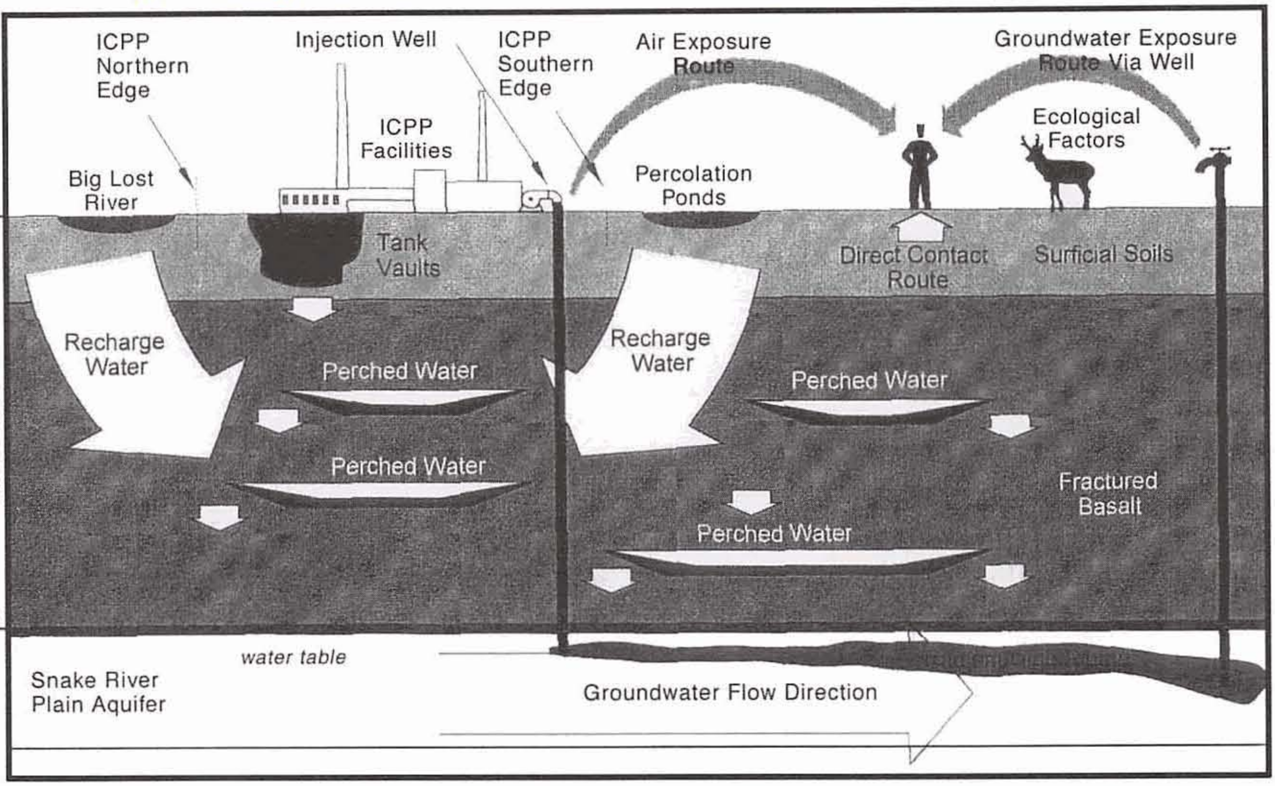
FIGURE 2: Conceptual Model of Groundwater and Perched Water Body Recharge, Contaminant Sources and Exposure Pathways at INEEL



Source: DOE, July 1999

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Compliance with drinking water standards

Several sets of wells drawn from the Snake River Plain aquifer provide drinking water to workers on the INEEL site. Much of the drinking water on the site is significantly contaminated with both radioactive and hazardous chemicals, notably TCE and carbon tetrachloride.

- The drinking well at the RWMC is contaminated with carbon tetrachloride. A purging system, known as a sparger, is used to reduce the contamination levels.
- The Technical Support Facility (TSF) system historically got drinking water from TSF well #1, which was found to be contaminated with TCE. TCE levels in this well have exceeded or been very near the allowable drinking water limit since at least 1987. The facility was supplied with bottled water between 1987 and 1988. From 1988 to 1997, the water was purged before entering the distribution system (well water goes through a distribution system before it is consumed) and the content of TCE in the drinking water was reportedly less than the drinking water standard. Post-1997 TSF well #1 data is not available.
- Drinking water from Technical Support Facility well #2 has tested at less than the drinking water standard for TCE contamination, but it is significantly contaminated with it. About 100 people use this water daily.
- Tritium levels in the Central Facilities Area (CFA) wells are significant, though less than the current drinking water standard. Over 1,000 people use the CFA system daily.

Table 3 (page 8) shows data on three water supply systems at INEEL. Compliance with drinking water standards can be expressed by calculating the ratio of the measured contamination to allowable contamination for each pollutant. While this calculation is used to evaluate radionuclide contamination, it is not mandated for hazardous chemicals, even though it provides a reasonable estimate of the quality of the water. It is not the most conservative way to estimate the impact of the pollutants in the water, since simple addition ignores synergistic effects between various hazardous chemicals and between hazardous chemicals and radionuclides. In addition to the percentages for individual pollutants, the sum (% burden) is calculated, not as a measure of regulatory compliance, but as a public health measure to indicate the suitability of the water for drinking. While no distribution system exceeds 100 percent of the cumulative contaminant limits, the RWMC system

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is close and carbon tetrachloride levels in the RWMC drinking water have been gradually increasing. Note that several contaminants are not being monitored (so far as we can determine), so that the official conclusion of compliance assumes that the contamination due to these pollutants is low.

Future threats: radioactive, mixed, and hazardous buried waste

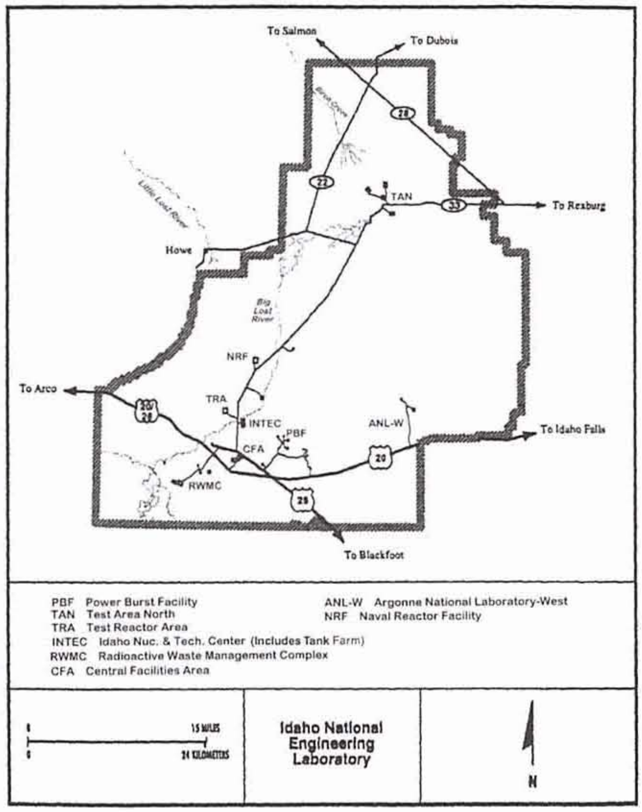
Table 4 (next page) shows the main long-lived radionuclides, defined here as radionuclides with half-lives of more than ten years, that were buried at the RWMC.[2] The radioactivity content of the wastes was estimated as of the time of disposal and are not corrected for decay. The total radioactivity of the radionuclides listed at the time of burial was almost 4 million curies. The total radioactivity of the very long-lived radionuclides, with half-lives greater than 100 years, is about 1 million curies.

With a half-life of 432 years, americium-241 is one of the most important of the alpha-emitting radionuclides in terms of its threat to the environment. Groundwater travels from under INEEL to the Magic Valley, the heart of southern Idaho's agricultural region, in roughly half that time. There would be some attenuation of radionuclides such as americium-241 as they travel downstream in the aquifer due to dilution as well as sorption in the geological medium.

Some americium-241 has already migrated through the vadose zone into the aquifer. The highest concentration of americium-241 found in the groundwater was 1.97 picocuries per liter in 1997. The levels of americium-241 are still below allowable drinking water limits (15 picocuries per liter), and no plume has as yet been identified. However, it should be noted that the allowed levels of americium and plutonium in drinking water are far higher than for most other radionuclides (in terms of allowed radiation dose) due to an irregularity in the way the Safe Drinking Water regulations are written. Were the radiation dose limit of 4 millirem to the critical organ, which is the criterion for most radionuclides, applied to plutonium-239 or americium-241, the maximum pollutant limit would have to be reduced by more than hundred fold.

Plutonium-239 presents yet another set of problems. First, the amount of plutonium-239 in the buried wastes at INEEL – more than a metric ton[3] – presents a security concern, should control of the site be lost. It is enough to make more than 200 nuclear bombs. The plutonium in some of the wastes was in relatively concentrated form when the dumping took place, which heightens the security problem. The pits and trenches therefore represent a potential plutonium mine in the case of loss of site control.

INEEL Site Map



Adapted from DOE, June 1996.

Second, migration of plutonium represents a serious environmental problem. The evidence from groundwater sampling so far indicates that plutonium migrates far more slowly than americium. However, it is much faster than originally anticipated and, moreover, the half-life of plutonium-239 – more than 24,000 years – is far longer than americium. How the migration of plutonium will occur over such long periods is unknown.

Finally, security and environmental risks are increased by the lack of information about the contents of the containers at the RWMC. It is not well established whether any of the containers have enough plutonium to go critical (a spontaneous uncontrolled nuclear reaction) if they fill up with water. Also, plutonium that has leaked from the buried wastes could accumulate in a small volume of soil, which could lead to an accidental criticality in times of heavy rainfall or flooding. Water also increases the potential that a container will lose its integrity and thus increases the risks to workers. There were floods at the Subsurface Disposal Area (SDA), which is located in a topographic depression, in 1962, 1969, and 1982. (See cover photograph) At the time of the 1962 flood, two pits and two trenches were open and filled with water. Boxes and barrels containing low-level radioactive waste floated freely. Dikes and diversion drainage ditches have since

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been built, but ponding still occasionally occurs in small depressions on the SDA.

One criterion by which the threats of radionuclides present in buried INEEL wastes might be addressed is to ask the following question: Were all the long-lived or very long-lived radionuclides in the buried waste to end up uniformly distributed in the Snake River Plain aquifer, would the contamination in the aquifer exceed allowable limits, and if so, by how much?

This is calculated by first dividing the total concentration of a contaminant in the buried waste by the drinking water standard for that contaminant. The result, called the dilution volume, is the volume of water that would be required to keep the concentration of the contaminant within allowable drinking water limits. The dilution volume can then be compared to the total amount of water in the aquifer. This approach gives us a rough indication of the potential magnitude of the threat posed by buried wastes.[4]

The dilution volumes for buried long-lived radionuclides at INEEL are shown in Table 4. According to the dilution volumes, the most important long-lived radionuclides in the buried wastes are strontium-90, cesium-137, plutonium-239/240, and americium-241. The total

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TABLE 4: DILUTION VOLUMES OF LONG-LIVED RADIONUCLIDES* BURIED AT INEEL BETWEEN 1952 AND 1983

Radionuclide	Half-life (years)	Main Decay mode	Total radioactivity of buried waste (curies)	Drinking Water Standards (picocuries per liter)	Dilution Volume (total radioactivity/ drinking water standard) (liters)	Ratio of dilution volume to volume of Snake River Plain aquifer
Tritium	12.3	beta	1,200,000	20,000	6.0×10^{13}	0.02
Carbon-14	5,730	beta	16,000	2,130	7.5×10^{12}	0.00
Nickel-59	76,000	EC	5,100	533	9.6×10^{12}	0.00
Nickel-63	100	beta	750,000	80	9.4×10^{15}	3.8
Strontium-90	29.1	beta	450,000	8	5.6×10^{16}	23
Technetium-99	213,000	beta	260	800	3.3×10^{11}	0.00
Iodine-129	17,000,000	beta	0.099	0.533	1.9×10^{11}	0.00
Cesium-137	30.2	beta	700,000	160	4.4×10^{15}	1.8
Plutonium-238	87	alpha	2,500	15	1.7×10^{14}	0.07
Plutonium-239	24,110	alpha	66,000	15	4.4×10^{15}	1.8
Plutonium-240	6,537	alpha	15,000	15	1.0×10^{15}	0.41
Plutonium-241	14.4	beta	400,000	533	7.5×10^{14}	0.31
Americium-241	432	alpha	150,000	15	1.0×10^{16}	4.1
Total			**3,700,000**		**8.6×10^{16}**	**35**
Radionuclides >100 year half-life			**1,000,000**		**2.5×10^{16}**	**10**
Strontium-90 and cesium-137			**1,120,000**		**6.0×10^{16}**	**25**

Notes:

* Long-lived radionuclides are defined here as those with half lives of more than ten years
EC = electron capture
Snake River Plain aquifer volume = 2.44×10^{15} liters
Numbers are rounded to two significant digits.
Decay is not calculated.
The transuranic isotopes all have radioactive decay products that build-up over time. In particular, plutonium-241 decays into americium-241.

IEER RECOMMENDATIONS FOR PROTECTING THE SNAKE RIVER PLAIN AQUIFER

- *Recover and stabilize buried wastes.* The buried wastes that were dumped into pits and trenches at the Subsurface Disposal Area at the Radioactive Waste Management Complex at the Idaho National Engineering and Environmental Laboratory present the greatest long-term threat to the Snake River Plain aquifer, because they not only contain dangerous radionuclides but also hazardous, flammable and explosive chemicals. The wastes are very heterogeneous. It will not be possible to get thorough knowledge of the waste characteristics through a sampling program prior to removal of the wastes.
- *Discontinue the use of percolation ponds and shallow land burial of low-level radioactive wastes.* As contaminated pond water moves through the vadose zone, it can carry dissolved chemicals to the aquifer. Releases of uncontaminated water can also facilitate the transport of contaminants to the aquifer by remobilizing vadose zone contamination from prior releases, or driving contaminated groundwater in the perched water bodies into the aquifer. Radionuclides can also be mobilized from shallow land burial of low-level waste.
- *Solidify liquid high-level waste and store the resultant solid products.*
- *Remediate the vadose zone.* A more vigorous research and development program for vadose zone remediation and a better technology selection process are needed.
- *Create a thorough and comprehensive program of groundwater monitoring and contaminant transport research.* While there is a substantial amount of groundwater monitoring already conducted, it is inadequate for the purpose of analyzing the migration of transuranic radionuclides, notably plutonium, which have not formed plumes. A more focused and open effort needs to be carried out to ensure that a thorough, rigorous, and effective program of measurements and analysis is conducted. Such a program can probably be conducted within existing resources by rethinking goals of the program and hiring contractors according to their ability to meet the goals of the program.
- *Implement new institutional arrangements for carrying out clean-up.* Despite the availability of much sound science and a growing understanding of the nature of the threats posed by the environmental legacy of the Cold War, the DOE and its contractors have proved unable to carry out a sound clean-up program. Contractors for clean-up should be selected according to the task at hand, with strict criteria for expertise and experience relevant to the specific job, as well as for accountability and openness.

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radioactivity of radionuclides with half-lives greater than 100 years would require ten times the volume of the Snake River Plain aquifer to achieve allowable drinking water levels. Note that the dilution volume required would be even greater if the drinking water standard for plutonium and americium were set in the same way as for most other radionuclides.

A variety of hazardous wastes have also been buried at INEEL along with the radionuclides. These include highly toxic organic compounds, such as carbon tetrachloride and trichloroethylene, and toxic metals, such as lead and chromium. Table 5, on page 9, shows some of these hazardous materials in the Subsurface Disposal Area, according to where the waste was generated. Most of the toxic organic chemicals were sent to INEEL from the Rocky Flats Plant in Colorado as part of that site's transuranic waste shipments.

The principal difficulty with evaluating the potential effect of dumped non-radioactive hazardous materials is that the records are so inadequate that the total waste inventory is essentially unknown. Besides the major uncertainties with respect to those chemicals for which some data are available, there are chemicals for which there are essentially no data, including highly toxic chemicals such as beryllium, cyanides, mercury, and polychlorinated biphenyls (PCBs).

Calculating the dilution volume for the known non-radioactive hazardous chemicals in the buried waste yields a total dilution volume less than the volume of the Snake River Plain aquifer, about 4 percent of the volume of the aquifer. However, the limitations of the waste data are even greater with hazardous chemicals than with radionuclides. No estimates of the amount of hazardous chemicals that were dumped exist for many areas. Further, unlike radionuclides, many hazardous materials have no set maximum contaminant level under the Safe Drinking Water Act. The uncertainties created by some hazardous chemicals are increased by the fact that they can alter properties of the soil and change (increase or decrease) mobility of other contaminants, including radionuclides.

Since 1954, liquid wastes from reprocessing operations have been stored in eighteen stainless steel underground tanks in an area called the Tank Farm. These are primarily high-level wastes from reprocessing of naval reactor spent fuel. In addition, some solidified ("calcined") high level waste is stored there. Contaminants in the soil from leaks and accidental spills are known to be moving through the Tank Farm soil to the perched water body. The major radionuclide contaminants in the Tank Farm soils are americium-241,

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TABLE 2: SOME AMERICIUM-241 AND PLUTONIUM ISOTOPE DETECTIONS IN THE SNAKE RIVER PLAIN AQUIFER (IN PICOCURIES PER LITER)

Date	USGS detections						Contractor detections						INEEL OP detections					
Year	Americium-241		Plutonium-238		Plutonium-239/240		Americium-241		Plutonium-238		Plutonium-239/240		Americium-241		Plutonium-238		Plutonium-239/240	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
1972–1976	0.01	0.3; 1.5; 5	0.02	0.96; 9	0.02	0.29	–	–	–	–	–	–	–	–	–	–	–	–
1981	–	0.14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1993–2000	–	0.14	–	0.39	–	–	0.008	1.97	0.012	0.3	0.006	4.3	–	0.039	0.36	0.9	0.42	24

USGS = United States Geological Survey | INEEL OP = Idaho National Engineering and Environmental Laboratory Oversight Program | - = No detection above background

TABLE 3: DRINKING WATER AT INEEL, 1998

	Percent of maximum contaminant levels (MCL) for drinking water standard for some contaminants at various locations at INEEL (reported mean values)								Drinking Water standard
	CFA Well #1	CFA Well #2	CFA Distribution	TSF Well #1	TSF Well #2	TSF Distribution	RWMC Well	RWMC Distribution	
Tritium	65%	54%	59%	Low	Low	Low	7%	7%	20,000 picocuries per liter
Strontium-90	?	?	?	?	?	?	?	?	8 picocuries per liter
Technetium-99	?	?	?	?	?	?	?	?	900 picocuries per liter
Iodine-129	?	?	?	?	?	?	?	?	1 picocurie per liter
Carbon tetrachloride	?	?	2%	?	?	?	95%	56%	5 micrograms/liter
TCE (Trichloroethylene)	?	?	6%	92%	52%	28%	44%	29%	5 micrograms/liter
Total burden, %	**65%**	**54%**	**67%**	**92%**	**52%**	**28%**	**146%**	**92%**	

Notes: CFA = Central Facilities Area • TSF = Technical Support Facility • RWMC = Radioactive Waste Management Complex • ? = not reported in the sources cited [see report for sources]
Total burden = sum of percent of MCL • Alpha emitter measurements not reported • Regulations do not require the addition of chemical burdens to one another or to radionuclides

TABLE 5: MAIN BURIED NON-RADIOACTIVE MATERIALS IN THE SUBSURFACE DISPOSAL AREA, 1952-1983

Chemical	Total Amount (grams)	Origin of Waste (in grams)								
		Test Area North	Test Reactor Area	INTEC (Chem Plant)	Naval Reactors Facility	Argonne West	Central Facilities Area	Rocky Flats Waste	Other Offsite Generators	Power Excursion Reactor
Organic Chemicals										
1,1,1-trichloroethane	110,000,000			1,700,000				110,000,000		220,000
Carbon tetrachloride	120,000,000			26,000		16		120,000,000	Unknown	
Tetrachloroethylene	27,000,000							27,000,000		
Trichloroethylene (TCE)	100,000,000							100,000,000		410,000
Inorganic chemicals										
Asbestos	1,200,000		1,100,000	110,000	Unknown	Unknown			Unknown	11,000
Sodium cyanide	940						940			
Metals (various chemical forms)										
Chromium	1,000	550		20		Unknown				450
Lead	580,000,000	Unknown	140,000,000	26,000,000	Unknown	14,000,000	180,000,000	190,000,000	19,000,000	2,100,000
Uranyl nitrate (also radioactive)	220,000			220,000						
Uranium-238 (also radioactive)	320,000,000	17,000	3,500,000	1,900,000		3,500,000		240,000,000		

Note: Figures rounded to two significant digits.

Perspective of a Former Idaho Trout Farmer

The following exchange is based on a transcript of a videotaped interview with Bob Erkins, formerly a trout farmer in Idaho, conducted on May 18, 2001 by Gary Richardson, Executive Director of the Snake River Alliance. The version published here was modified from the original transcript for length, grammatical, and clarification purposes.

GARY RICHARDSON: How did you first become aware that there might be a problem with the aquifer because of the Idaho National Engineering and Environmental Laboratory (INEEL)?

BOB ERKINS: We were in the process of working with the W.R. Grace Co. in New York to sell them our trout farms which range from one of the largest, the Snake River Trout Co. north of Buhl, all the way across the state of Idaho, from Hagerman through Buhl and Pocatello, Blackfoot, and our feed manufacturing company in Wendell.

One of Grace's senior vice presidents sent me a clipping out of a New York paper and said the government was moving atomic waste from the Denver area, Rocky Flats I think it was, up to Idaho to store. The representatives from Grace said, "We're really not too excited about buying a fish farm that [gets its water from a source above which nuclear waste is buried]." I could understand that because why would you put your outhouse over your main source of water, which is what the spring system is for this entire Hagerman Valley and all the way down the Columbia.

Adapted from USGS, 1999, page 2.

So they came out and looked and I went with them to INEEL. And it was amazing! Here, workers at the site were dumping atomic waste in cardboard boxes into the ground and then covering it over with back-

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strontium-90, cesium-137, europium-154, plutonium-238, plutonium-239/240, plutonium-241, and uranium-235, and the primary non-radioactive contaminants include mercury and nitrate. No decision has been made yet on a remediation plan for the Tank Farm soils because current information regarding the nature and extent of Tank Farm contamination is considered inadequate.

Conclusion

There is sufficient evidence to conclude that the buried wastes at INEEL present an urgent threat to the Snake River Plain aquifer and all the people who depend on it. Overall, the theoretical, experimental, and field evidence for rapid plutonium and americium migration though the vadose zone is very strong and more than sufficient basis for urgent action to clean up the buried wastes. Removing buried wastes, stopping current and future dumping, and remediating the vadose zone to the extent possible should be the central technical and policy approaches to water resource protection. IEER's main recommendations are shown on page 7.

1 This article is based on the IEER report, *Poison in the Vadose Zone: An examination of threats to the Snake River Plain aquifer from the Idaho National Engineering and Environmental Laboratory*. All references can be found in this report, unless otherwise mentioned.

2 Tritium, despite its large inventory in the buried wastes, poses a lower risk for offsite pollution of the Snake River Plain aquifer because tritium decays relatively quickly compared to its travel time to the INEEL boundary.

3 There are also an estimated 65 kilograms of plutonium-240. The lower and upper limits for the plutonium-239/240 totals are estimated to be 0.8 metric tons and 1.5 metric tons respectively.

4 For limitations of this approach see page 83 of the report.

hoes, not too deep. What they hadn't covered up (it was wintertime) was filled with water, snow and rainwater that collected.

I said, "This is asinine to do this. Somebody should have some control over this." So I complained and the next thing I know I had CBS, NBC and ABC camera crews all out. The head of the site's atomic waste division, whose name I no longer remember and I don't care if I remember, said, "What's this little fish farmer down in southern Idaho doing talking about atomic energy. He doesn't know anything about atomic energy."

Workers at the site were dumping atomic waste in cardboard boxes into the ground.

No, I didn't. *But I know what atomic energy can do.* I was at Hiroshima right after the bomb went off, so I had a better feel than the average Joe does for what atomic waste and atomic power can do.

I'm not against atomic power if properly controlled. But I think it's tragic when you have a government agency as you had it then, and I still think to a great extent, covering up for waste disposal and literally covering up the waste disposal over our aquifer.

G.R.: What do you think would be the effect if these materials showed up in the aquifer of the Magic Valley?

B.E.: Well, it would be disastrous for the economy of the whole Magic Valley [and all down the Columbia River] because the word will spread: "They've got atomic waste in their water." And it will drive property prices down; it will be a mess. Will it happen today or tomorrow? No. But somewhere down the line as that material creeps through that aquifer, as it flows down – remember that's one of the largest aquifers in North America, in the world – it will pop out somewhere along the line, probably all along the line, and be very devastating.

Why would you put your outhouse over your main source of water?

G.R.: How important is the purity of the aquifer to the economy?

B.E.: I think pure water is beneficial completely to any area. If you don't have pure water and you have to put in systems to purify it, you have a great expense. But if you can't get that water pure, and you have other elements in it – mercury, for instance, when we know the terrible disaster in Japan from mercury in the water when babies were born crippled or born dead and mothers were just devastated.

Water is the main ingredient of our life. What are we, 85% water? But you take that and you contaminate it in some way and you drink it and you're contaminating yourself. That's why bottled water sales have gone up so much in recent years, because people are beginning to realize that even city water can be contaminated in one way or another and they don't realize it. I think pure water is essential to a growing economy and water as we know in the west is essential, period.

G.R.: Did the potential threat of radionuclides in the aquifer have anything to do with you getting out of the trout business?

B.E.: Not really. I just thought it was an opportune time to sell out. I realized that anything that would happen is going to happen way down the line, not tomorrow or a year from now but way down the line.

I just said to my wife, you know, this is another problem and if anybody builds on it, as a food industry we could be ruined, but that could be a long time away. Not only if the water became contaminated with atomic waste at the spring source but the publicity is enough to kill the food industry. No person wants to put into their mouth anything that's going to injure them if they know it.

G.R.: Is this an issue in the aquaculture industry?

B.E.: I don't think this is a major issue that they talk about because most people don't think there is anything they can do about it themselves. But the issue is there…

News spreads in various sources and by various ways, and certainly the people who are producing any aquaculture products are not going to bring up this subject, or potato producers or anybody else using water from the springs to irrigate. I don't think they have a concern at the moment or need a concern at the moment, but somewhere down the line they will.

G.R.: Don't you think they should get politically involved in a solution?

B.E.: Do you find a lot of people getting politically involved? Not when you really come down to it. They should, but no, they don't, and yes, I think they should. I think they should go after this thing in every way they can to get these waste materials put someplace else. I fully appreciate that no one else wants it in their backyard – we've got it in our backyard, over our aquifer, our biggest source of water. And as I said at the beginning, it's just like putting your outhouse over your spring and then drinking the water and then saying 'Aaa! What's the matter with me?'

It pays to increase your jargon power with Dr. Egghead

MCL

a. The highest number to which Julius Caesar could count.

b. Newest Ben and Jerry's ice cream flavor: Mint Chocolate Licorice.

c. Acronym for Maximum Contaminant Level, the maximum permissible level of a chemical or radionuclide contaminant in water that is delivered to any user of a public water system. MCLs are set as close to MCLGs [maximum contaminant level goals, the level of a contaminant in drinking water below which there is no known or expected risk to health] as feasible using the best available technology and taking cost into consideration. MCLs are enforceable standards set by the US Environmental Protection Agency or the US Nuclear Regulatory Commission.

Perched water table

a. Art-deco furniture piece characterized by a raised, flat surface with built-in depressions to hold beverages.

b. Feeder designed for classy but thirsty birds.

c. The water table of a relatively small groundwater body in the vadose zone, above the general groundwater body. (A water table is the upper boundary of a free groundwater body at atmospheric pressure.)

Percolation ponds

a. Small bodies of water preferred as habitat by particularly perky animals, like leaping frogs and darting fish.

b. Puddles of coffee that form underneath leaky coffeemakers.

c. Ponds (usually man-made) designed to allow wastewater to percolate slowly into the ground. The ponds act as holding facilities while gravity allows the water to percolate or seep through the soil or other unconsolidated medium into the local water table and lower aquifers. Also called infiltration pond.

Sole-source aquifer

a. A body of water formed in the depression created by a dinosaur footprint.

b. A water cooler manufactured at a shoe factory.

c. An aquifer is underground porous geologic medium that is saturated with water and is sufficiently permeable to conduct groundwater so as to enable its extraction. A sole-source aquifier provides a minimum of 50% of the water for its users in a situation where no other source of water could reasonably replace it. Under the Safe Drinking Water Act, the U.S. EPA can determine that an area has an aquifer that is the sole or principal drinking water source for the area and, if contaminated, would create a significant hazard to public health; thereafter, no federal financial assistance can be used for any project that would contaminate the aquifer through a recharge zone so as to create a significant hazard to public health.

vadose zone

a. Point in time halfway between wakefulness and slumber, often characterized by talking in one's sleep about environmental cleanup technologies. Mainly afflicts civil engineers and environmental activists.

b. A tourist spot in Virginia where people go to get cured of insomnia.

c. Unsaturated region of rock and soil located beneath the land surface and above the water table.

(For definitions of additional terms, see the glossary contained in the IEER report *Poison in the Vadose Zone.*)

Answers: c, c, c, c, c

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DEAR ARJUN

Dear Arjun:

What are the risks of protesting at the Nevada Test Site? What about protests by pregnant women and children?

Nonplussed in Nevada[1]

Dear Nonplussed:

Before the atomic age, the Test Site was a risqué place. But when the nuclear boys took over, it transmuted into a risky place. How so and how risky? Well it was very risky during the days of atmospheric testing, which stopped in the early sixties and it's not very risky now and it may be more risky again in the future. But I run ahead of myself. Let me consider the scientific issues first and then the ethical-social-political issues.

Scientific Issues

Natural background radiation amounts to about 80 or 90 millirem (mrem) per year at sea level and more at higher altitudes. This includes external radiation from cosmic rays, natural radionuclides on the earth, and internal radiation from, for instance, naturally-occurring potassium-40.[2] Potassium-40 gets into the body mixed up naturally with the non-radioactive potassium which we consume with our food. This is the source of the often-cited comment by pro-nuclear industry people that one can get more radiation from sleeping next to someone (on the order of a few millirem per year, depending on how close one gets) than from living next to a nuclear power plant or radioactive dump (also depending on how close one gets).

A major source of radiation exposure is indoor radon – averaging 100 to 300 millirem – which is a decay product of uranium-238. The nuclear establishment counts this as "natural background" but it is mainly an artifact of house construction, and so IEER does not consider it as natural.

Other sources of exposure are medical X-rays and tobacco smoking (active or passive). These are highly variable also, as you can readily imagine. A chest X-ray with modern devices might expose a person to an equivalent of 5 or 10 millirem of whole body radiation.

Nuclear Weapons Testing

Historical doses during the time of atmospheric testing were large for many people.[3] Atmospheric testing continues to be by far the largest contribution to current radiation doses from nuclear testing even though the last atmospheric weapons test, a surface burst, at the Nevada Test Site was in 1962 and the last atmospheric test by any country was in 1980 (China). The current annual dose commitment in the northern hemisphere from global fallout is on the order of a few millirem per year. This decreases as time goes on due to the decay of some of the principal sources of the dose, notably cesium-137 and strontium-90, which have half-lives of about 30 years and 28 years, respectively.

The releases of radioactivity to the atmosphere from underground testing have been far lower than from atmospheric testing, which amounted to 12 billion curies. Even so, there were, in the United States, many large releases from underground testing, totaling 25.3 million curies.[4] The last very large release was during the Baneberry underground test in 1970 (6.7 million curies). Since that time, the largest single release has been a "controlled" purging from the Mighty Oak test in 1986 amounting to 36,000 curies. The two next largest releases since the Baneberry test have been accidental ventings of 6,800 curies (1971) and 3,100 curies (1980), according to a study by the now-defunct Congressional Office of Technology Assessment (OTA).

The current annual dose commitment in the northern hemisphere from global fallout is on the order of a few millirem per year.

These release estimates do not include the residues of radioactivity which have been left underground. According to that same study, the total (lifetime) dose from all U.S. tests since the Baneberry test for a "person...standing at the boundary of the Nevada Test Site in the area of maximum concentration of radioactivity [for the duration of the specified period of testing]...would be equivalent to 32 minutes of normal background exposure (or the equivalent of 1/1000 of a single chest X-ray)." [5] No one at IEER has verified the OTA calculations, but there does not appear to be anything wrong or suspicious about these figures and I presume them to be okay.

The dose for a typical single test would be far lower. The dose from the test with the largest accidental venting since Baneberry would be lower than 6 microrem (μrem). Of course, past accident magnitudes

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are no guarantee that future accidents will not be larger should underground nuclear testing resume. They are only a guide.

As you know, radiation is not the only environmental agent producing cancer, mutations, depression of immunity or other health problems. These same problems are also produced by other things, both natural and human-made. A large part of the problem of dealing with estimates of cancer and other health problems caused by radiation at the kinds of levels we have been discussing is that it is very difficult to sort out the effects of incremental amounts of radiation doses to people from the large of number of other factors which affect health outcomes, including cancer.

In sum, the doses per test from underground tests of the type done at Nevada after the Baneberry test in 1970 have been on the order of a few microrem or smaller. These doses are small compared to other commonly encountered doses, including the current doses from the residues of past atmospheric tests. There has been a test moratorium since 1992, though the United States maintains readiness to resume testing at the Nevada Test Site and has rejected ratification of the Comprehensive Test Ban Treaty.

Onsite Doses

Various portions of the test site are contaminated from past testing. Radiation levels at the Sedan crater range up to 30 to 40 microrem per hour, so that about ten or twelve minutes in this area on a test site tour may give as much radiation dose as that which would have been received at the site boundary from all underground tests since Baneberry in 1970 (about six microrem total).

There are probably areas where there are unmapped "hot particles." This would include the general areas where "safety tests" were conducted, scattering plutonium on the site. I understand that the test site tour excludes these areas which may be a greater danger in the dry, desertic environment of the Nevada Test Site. Activities on the test site near contaminated locations are likely to be more risky than activities on the site boundary.

Social, Political and Ethical Issues

Whether to protest at the test site or to take a tour of it to learn more is a personal political and ethical choice that should be made in the context of the kind of scientific information I have given you. So, let me describe my own framework for making a choice. This discussion is about some social and ethical principles as I see them, with some illustrations of how they might be applied. It is not meant to address detailed technical issues arising from various kinds of site visits or protests, past, present, or future, or to tell anyone what they should or should not do.

First the issue of natural and human-made radiation. I accept natural radiation in the same way I accept other facts about being born. Dying of something or other is part of the order of nature and of one generation replacing the next. However, the fact that the natural order inexorably links life to death does not give any human being the right to accelerate my end without my consent. For someone to say that natural background radiation is 100 millirem, so it is okay for that person or institution to impose another few millirem is like saying "you're going to die anyway so why don't you let me punch you in the nose? It won't hurt much."

It is completely unacceptable for any human being to appeal to naturally-imposed risks (or risks imposed by God, if you're religiously inclined) in order to assume for themselves the right to impose risks upon another human being.

Now, as to the various human-created risks. It is true that we do make a choice of increased radiation exposure when we sleep next to someone. However, it is the cost-benefit ratio that is important. I can't think of any benefits of sleeping next to a dump, and certainly the benefits don't get any bigger the closer you get to the dump!

> I am willing to take some risks in order to protect people from the menace of nuclear weapons and nuclear warfare.

Moreover, there is the matter of choice. If one does not want a dump in one's neighborhood to accommodate wastes generated by a process in which one did not have a say, then it is the fact of the imposition of any risk at all which is in question, and not only the magnitude of risk. Further, if it is an imposition of risk from a process whose goals people do not share, then the institution or person imposing the risk has no right to impose it. This is where issues such as democracy, secrecy and informed consent come into play. Who benefits? Who bears the risk?

In that same perspective I am willing to take some risks in order to protect people, including myself and my children, but also future generations, from the menace of nuclear weapons and nuclear warfare. I recognize that there are risks associated with my profession. I try to keep these to a minimum but I don't let it prevent me from doing my job, a large part of which is to keep track of what the nuclear establishment is doing to the environment.

In this larger perspective of peace and of the protection of the Earth, a dose of a few millirem is a small risk that I am willing to take. In the same

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perspective, I am not willing to consent to the nuclear weapons testers to impose even a microrem of radiation on me, much less on my children, though today we are all unwilling victims of their past activities.

As for the question of whether to alert people to dangers of onsite activities. Generally speaking, dangers of activities near contaminated areas onsite are far greater than those for activities off the site or at the site boundary, but are still comparable to or smaller than many other routine exposures.

How does one think about exposures to children or pregnant women in protest activity? It is here that we can make comparisons of the risk from protest with voluntary exposures of other kinds. Many of us have taken trips that involve airplane trips. Many of us have taken children on such trips. Pregnant women decide to go on such trips, and if they refrain, it is usually not from fear of the added radiation dose.

> Considering whether to protest involves a personal judgment about the effectiveness of the protest in stopping nuclear tests versus the risk one is willing to take to contribute to that goal.

A round trip in an airplane from New York to Las Vegas would result in a dose of a few millirem due to added cosmic rays and neutrons.[6] The cumulative total average dose to an individual from routine releases from underground tests since Baneberry in 1970 has been on the order of a thousand of times smaller than this, when measured at the test site boundary. (But there is of course a small chance that a future venting might result in a far higher dose, should testing resume.) Hence, routine releases from underground tests after 1970 resulted in doses far smaller than those from airplane trips. Onsite doses near the Sedan test crater would be higher than doses at the test site boundary (depending on the length of time spent near the crater).

Considering whether to protest therefore involves a personal judgment about the effectiveness of the protest in stopping tests versus the risk one is willing to take to contribute to that goal. By contrast, the same dose would be unacceptable if nuclear tests involuntarily expose people who believe that nuclear testing is immoral. That increases risk to people while harming their goals and violating their principles.

A huge amount of plutonium has been left underground by past testing. More is being put there by "sub-critical" testing. So if one does not support nuclear testing then one should reject even minute doses involuntarily imposed by testing and also should work to stop more testing and plutonium contamination underground because that may exposure future generations. But I would add a caveat. I believe that if there is protest, it should be peaceful, for as Mahatma Gandhi said: "We must become the change we want to see in the world."

The risk that one is willing to take in the form of radiation doses to accomplish that is a personal choice that I hope can be better made in light of the discussion and information I have given you here.

Yrs. etc.

Arjun, a.k.a. Dr. Egghead

1 This column is largely drawn from an unpublished 1991 communication in response to an inquiry received in that year.

2 See centerfold 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.

3 See "Let Them Drink Milk: Iodine-131 Doses from Nuclear Weapons Testing," in SDA vol. 6 no. 2, November 1997, online at http://www.ieer.org/sdafiles/vol_6/6-2/iodine.html.

4 The United States conducted atmospheric nuclear tests from 1945 to 1962. U.S. underground testing began in 1962; the last underground test was conducted in 1992. The United States is now conducting "sub-critical" nuclear weapons tests at the Nevada Test Site.

5 Office of Technology Assessment of the U.S. Congress, entitled "the Containment of Underground Nuclear Explosions", OTA-ITC-414, October 1989. The quote is from pp. 4-5.

6 Airline crews who are repeatedly exposed should be informed about their exposure and their doses should be monitored.

Reflections on September 11th

Through violence you may murder a murderer, but you can't murder murder.
Through violence you may murder a liar, but you can't establish truth.
Through violence you may murder a hater, but you can't murder hate.
Darkness cannot put out darkness. Only light can do that....
— Martin Luther King, Jr.

An eye for an eye only ends up making the whole world blind.
Satyagraha is a process of educating public opinion, such that it covers all the elements of the society and makes itself irresistible.
Satyagraha is a relentless search for truth and a determination to search truth.
Satyagraha is an attribute of the spirit within.
Satyagraha has been designed as an effective substitute for violence.
— Mahatma Gandhi

The destruction of the World Trade Center towers and a part of the Pentagon on September 11, 2001, was more than an attack on the symbols of financial and military power of the United States. It was more than what the media have called an "Attack on America." It was mass murder of people from around the world. People from about eighty countries were among those who perished along with thousands of Americans. No goal, however lofty, can justify the murder of innocent people.

People from around the world are grieving and share the immense sadness of the families and friends of the victims of the tragedies. The staff of IEER grieves with them.

IEER has posted several materials on its web site which reflect on September 11th. They include:

- Reflections on September 11, 2001, by Arjun Makhijani: http://www.ieer.org/comments/sept11.html
- Pursuing justice for the crimes of September 11, 2001 and reducing the risks of terrorism, by Arjun Makhijani: http://www.ieer.org/comments/justice.html
- Selected Quotes of Mahatma Gandhi: http://www.ieer.org/latest/oct2quot.html
- A brief history of air warfare doctrine, by Jack Colhoun: http://www.ieer.org/comments/bombing.html

More will be posted in the near future. Visit http://www.ieer.org.

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