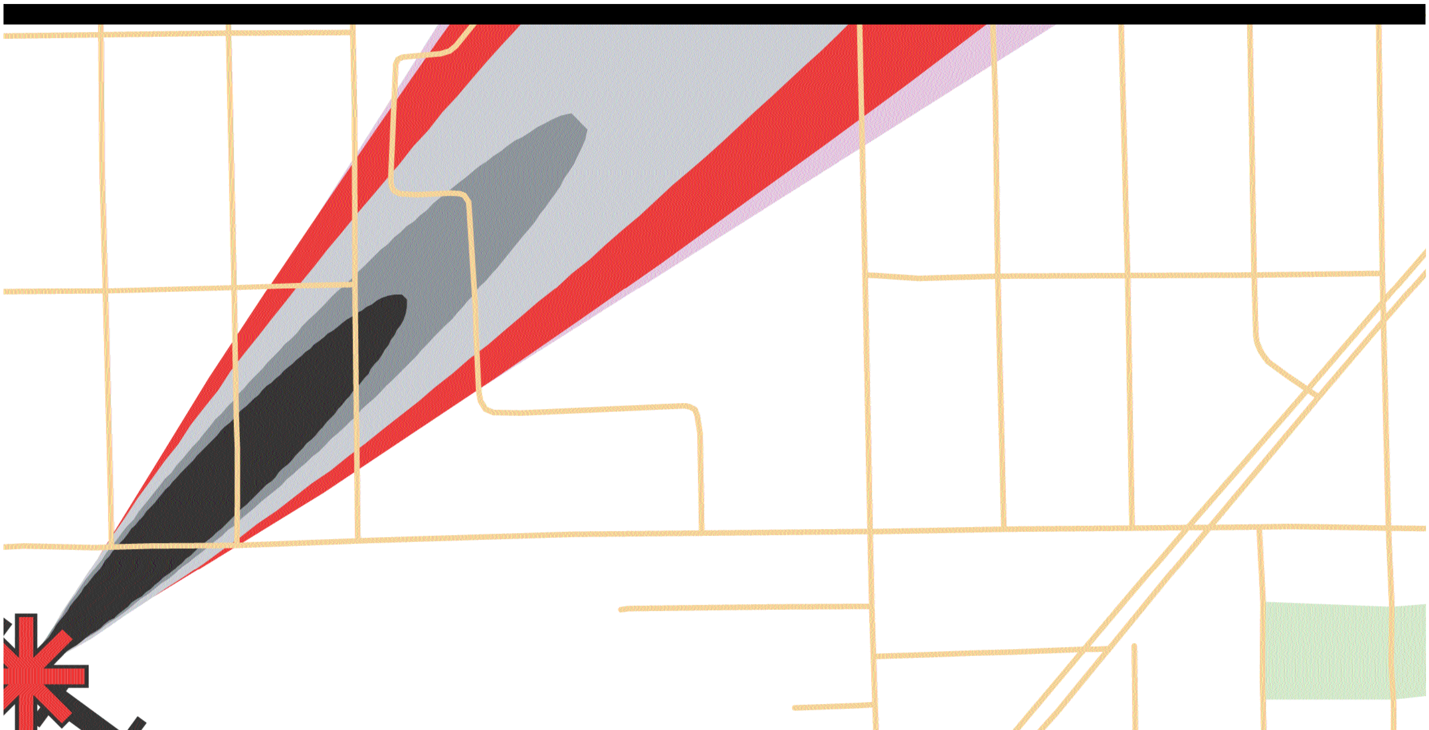
What if...



Nuclear waste accident scenarios in the United States

Environmental Working Group™

Nuclear Waste Route Maps

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Introduction

This report is the first attempt to utilize go vernment data and computer models in order to describe the consequences of a serious, but plausible accident involving the release of high-level radioactive waste in major cities along the DOE-proposed nuclear waste transport routes .

Everyone agrees that there will be accidents if nuclear waste is transported by train and truck through 45 states for 38 years to the repository at Yucca Mountain in Nevada. The Department of Energy (DOE) predicts that there will be about 100 accidents over the life of the project. The State of Nevada predicts about 400 accidents during the same time period. To date, however, the public has not been provided meaningful information about the potential effects of a serious nuclear waste accident in any of the heavily-populated metropolitan areas through which Nevada-bound radioactive waste would travel. This report is the first attempt to utilize government data and computer models in order to describe the consequences of a serious, but plausible accident involving the release of high-level radioactive waste in major cities along the DOE-proposed nuclear waste transport routes.

The DOE has developed a series of computer models at its Lawrence Livermore, Sandia, and Argonne National Laboratories in order to predict the consequences of accidents involving shipments of nuclear materials. These models, known as HOTSPOT, RISKIND, and RADTRAN, among others, are designed to allow anyone to model the radiation plume that would arise from accidents of varying severity, involving different amounts and types of radioactive material, under different weather conditions.

The maps describe the conse - quences of an accident of mod - erate se verity, not a worst case scenario. We did not model the impact of an attack on a nuclear waste shipment that penetrates or explodes the cask.

For people living along the Department of Energy's proposed nuclear waste transport routes, the question is: What if there is a nuclear waste accident in my community that involves the release of radiation?

The maps presented here by Environmental Working Group are the first attempt to provide the public with answers to this question. We use government models and government assumptions as presented in more detail below. The maps describe the consequences of an accident of moderate severity, not a worst case scenario. We did not model the impact of an attack on a nuclear waste shipment that penetrates or explodes the cask, or results in a severe long-term fire, like the Baltimore Tunnel fire, dispersing a far greater amount of radiation into the surrounding community.

The DOE has not published a detailed analysis of the impact of a terrorist attack on a nuclear waste shipment. Instead, the DOE has produced a generic, one-size-fits-all estimate of the number of fatalities from a serious accident, and conducted complex and lengthy probability analyses designed to show that such an accident is very unlikely to occur. The DOE analysis was an abstract exercise. It did not situate the modeled event in any actual community.

Given the unanimous agreement that train or truck accidents are inevitable during the tens of thousands of radioactive waste shipments to Yucca Mountain, we believe people have a right to know what would happen if one of those accidents led to a release of radioactive materials in their town.

Assessing the Risks

If the Senate commits the nation to the Yucca Mountain repository, there will be as many as 2,700 shipments of high-level nuclear waste per year on America's roads and rails, beginning around 2010 and continuing at least for the next 38 years.

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In order to assess what could happen if there were an accident involving a nuclear waste shipment in a major metropolitan area, Environmental Working Group used the following data and computer models:

- The government radiation plume models (HOTSPOT) developed at the Lawrence Livermore National Laboratory;

- Accident scenarios and data on the radioactive composition of nuclear waste shipments developed by the Department of Energy;

- Cancer potency factors for a given radiation exposure level published by the National Academy of Sciences, BEIR V.

The results presented here describe the radiation released from 14 train wrecks and 6 truck crashes with the following characteristics:

- The accident occurs at a speed of between 30 to 60 miles per hour;

- The wreck occurs under average weather conditions (median winds) during the day in each of the metropolitan areas modeled;

- Radiation, primarily in the form of cesium, escapes as a result of a broken seal in the shipping cask and a subsequent modest fire. Again, this is not a "worst case" scenario involving puncture or penetration of the cask, a severe and prolonged fire, or a major explosion that could disperse portions of the spent fuel in a cask.

Cesium will be the primary radionuclide released in a nuclear waste accident. It is a highly reactive metal and e ven a small break in the seal will release significant amounts o f it. Cesium burns spontaneously in air, and will explode when exposed to water .

Cesium will be the primary radionuclide released in a nuclear waste accident because it is present in what is called the fuel-clad gap. This gap is the space between the fuel pellets and the inside wall of the metal tube that contains the fuel. This "gap cesium" can be released in any event where the cladding is breached. Cesium is a highly reactive metal and even a small break in the seal will release significant amounts of it. Cesium burns spontaneously in air, and will explode when exposed to water. In a severe transportation incident, isotopes of cesium would create a plume of radioactive particulates that would be inhaled and ingested by those downwind from the accident site. In the body, cesium compounds collect in the gonads, breast milk and muscle tissue. Following an incident, cesium particulates would also settle to the earth and expose residents and cleanup personnel to external gamma radiation.

Different weather conditions would produce different exposures, some greater, some lesser. A more serious breach of the cask could release more radiation than assumed here.

Extreme Radiation Exposure

The number of people exposed to unsafe doses of radiation is entirely dependent on the timing and location of the accident or attack. If an accident occurs near a city center during the middle of a work day, the number of exposed individuals would be very high. If the accident occurs at night in the city center, the number of people exposed in this scenario could be relatively low. These eventualities are impossible to predict. The numbers presented below assume average residential population densities for the cities analyzed according to the 2000 census and projected to the year 2020. In the 14 cities analyzed with rail accidents, we found that:

Within two minutes of an accident, a cloud of radioactive cesium averaging 5,500 X-rays or 3,667 times the EPA's annual radiation exposure limit would extend about a quarter mile, or two to four blocks from the crash site. EPA's acceptable one-year radiation dose is 15 millirem, or about 1.5 chest X-rays. In about 10 minutes, contamination plumes equal to an average of 750 and 300 X-rays would extend about one half mile and 1 mile respectively from the crash site.

In less than an hour, a zone of radiation exposure equal to about 55 X-rays would extend from 1 to 5 miles form the crash site, and within four to six hours a zone with average exposure of about 5 X-rays would extend from 5 to 25 miles or more down-wind from the accident site.

Based on average residential population densities in each of the cities analyzed, between 20 and 100

TABLE 1:
A serious nuclear waste accident in a major city could expose hundreds o f thousands of people to unsafe le vels of radiation

City	Cask Type	1-Year Latent Fatal Cancers	Population Exposed to radiation	Length of Radiation Plume (mi)
Chicago	Rail	1,228	349,352	25.0
Washington, DC	Rail	1,080	314,250	26.0
Los Angeles	Rail	896	223,942	27.3
Minneapolis	Rail	669	175,884	24.7
Atlanta	Rail	659	207,240	26.5
Denver	Rail	620	188,168	26.5
Pittsburgh	Rail	494	132,591	25.4
Charlotte	Rail	439	131,182	27.8
St Louis	Rail	399	91,120	25.2
Salt Lake City	Rail	350	74,021	26.0
Kansas City	Rail	225	72,930	24.9
New Haven	Rail	222	30,986	23.1
Jacksonville, FL	Rail	210	64,072	27.4
Lansing, MI	Rail	170	17,394	25.4
Miami	Truck	157	47,991	6.8
Phoenix	Truck	84	24,948	7.9
Milwaukee	Truck	60	18,285	6.2
Wilmington, DE	Truck	18	8,874	7.1
Des Moines	Truck	11	5,495	7.2
Portsmouth, NH	Truck	8	725	5.8

people would be exposed to an average of 5,500 X-rays within two or three minutes of the crash. Another 20 to 100 would be exposed to a 750 X-ray dose within another 5 minutes. Five minutes after that, from 150 to 1,150 people wold receive a dose averaging 300 X-rays. In less than one hour after the accident, between 3,500 and 23,000 people would be exposed to a 55 X-ray dose of radiation. By the end of the day, thousands, and in many cases hundreds of thousands of people would be exposed to an average of about 4 times the EPA's annual radiation exposure limit. In this exposure zone, clean-up is very unlikely, with elevated exposures expected to occur for a very long time.

First responders or others approaching the accident site in the minutes after the crash could be exposed to a radiation dose equal to about 30,000 X-rays or perhaps even greater. There is a very high risk of accelerated fatality for these individuals.

In the 6 cities where truck accidents were analyzed, there would be less radiation released, and fewer people harmed (Table 1). The main reason for this is the smaller amount of radioactive waste in a truck cask compared to a rail cask. For example, a truck cask contains six times less cesium-137, the primary radionuclide of concern in these scenarios, than a rail cask. In general, the length of the plume, the number of people exposed to radiation and the number of cancer fatalities resulting from a truck accident is between one-tenth and one-fifth that of a rail accident. For detailed information on the six cities with truck accidents, see our metro area reports.

Future suffering and deaths from cancer caused by radiation exposure would extend far beyond the immediate zone o f highest exposur e.

Latent Cancer Fatalities

The greatest exposure would occur in the immediate aftermath of the crash, when a cloud of radioactive cesium particles would waft over an area downwind from the accident site. The primary health risk is the elevated, long-term risk of cancer from these exposures. Future suffering and deaths from cancer caused by radiation exposure, however, would extend far beyond the immediate zone of highest exposure and would be significantly influenced by longer term radiation exposure called groundshine from contamination of the area. Using cancer potency factors from the National Academy of Sciences' ongoing analyses of cancer rates among World War II atomic bomb survivors, and projected

If a disproportionate number of children were exposed to the radiation, there would be more latent cancers.

average residential population density numbers for 2020 from the U.S. Census, we estimate that:

> In the 14 cities where rail accidents were analyzed, from 170 to 1,225 people would die from a "latent fatal cancer" caused by one year's exposure to radiation from a serious rail accident involving nuclear waste headed for Yucca Mountain (Table 1). In the 6 cities with truck wrecks there are between 8 and 83 latent cancer fatalities from one year's exposure to radiation from the accident. These estimates assume that all people in the 1,000 X-ray zone are evacuated on the day of the wreck and receive no additional exposure. The Department of Energy assumes that all people remain in the zone exposed to radiation for an entire year.

A larger release from a more serious crash or attack on the cask would produce more immediate and latent fatalities. A similar crash closer to large numbers of people would do the same. If a disproportionate number of children were exposed to the radiation, there would be more latent cancers because children have a greater susceptibility to radiation-induced cancer. If a disproportionate number of elderly were exposed, there would be fewer.

The rate of fatal cancers per exposed person declines significantly with distance from the accident. This lower exposure, however, is offset by the greater number of people exposed, producing significant numbers of fatalities at locations miles from the crash. Areas farther from the accident scene are the least likely to be cleaned-up and the most likely to produce longer radiation exposures for the population living there, leading to a high number of latent cancer fatalities miles from the actual crash site.

Hundreds or even thousands of lives are at risk in the event of a serious accident or terrorist attack on a shipment of nuclear waste in a major city.

Recommendations

The accident scenario analyzed here represents a wreck where the cask is cracked, seals are broken and a radioactive cloud of cesium particulates is released downwind from the crash site into the community. This is nowhere near a worst-case analysis where the cask is penetrated by an explosive device, or where weather conditions create a more concentrated dose of radiation for a greater number of people. Even so, it is apparent from this analysis that hundreds or even thousands of lives are at risk in the event of a serious accident or terrorist attack on a shipment of nuclear waste in a major city.

Economic disruption from such a contamination event would be enormous. Estimates run from $10 to $150 billion in clean-up costs. Predicting costs to the local and regional economy is nearly impossible, but costs could be astronomical if primary interstate highways or rail lines were disrupted for weeks or even longer.

A vote in opposition to proceeding with the Nevada repository would allow much needed time to develop a thorough transportation security plan.

Given these risks, we recommend that the U.S. Senate should vote against an override of Nevada Gov. Kenny Guinn's veto of DOE's recommendation to proceed with development of Yucca Mountain as a national nuclear waste repository.

Voting "no" on Yucca Mountain now would not eliminate the possibility of considering Yucca Mountain, or other locations, for use as a repository in the future. Nor would a "no" vote on Yucca Mountain present a waste storage crisis for the nuclear industry or any added risk to the public, according to the Nuclear Regulatory Commission.

A vote in opposition to proceeding with the Nevada repository would allow much needed time to develop a thorough transportation security plan, as well as full public notification and comment on a repository and its transportation implications, before its final selection.

A delay would also provide an opportunity for the public to weigh the implications of a national waste repository in the context of vital state and local concerns about the continued, long-term presence of operating nuclear reactors and the associated long-term, on-site storage of nuclear waste that will be required even if the Yucca Mountain repository is developed.

Shipments of high level nuclear waste present a major transportation security risk.

Nuclear Waste on the Roads and Rails: A Major Security Risk

Every truck or train rumbling through towns and cities on its way to Yucca Mountain will be hauling an extremely radioactive load of spent nuclear fuel from nuclear power plants, the Navy, and government-run nuclear reactors. These shipments of high-level nuclear waste present a major transportation security risk. This was acknowledged by Secretary of Energy Spencer Abraham following the September 11th terrorist attacks on the World Trade Center, when on September 12th he suspended all shipments of high level nuclear waste. The suspension was subsequently lifted, then reinstated, and then lifted again. Currently, small amounts of high level waste are being shipped, but they are a tiny fraction of the mountain of waste that would be on American roads and rails each year if the Senate locks the nation into the Yucca Mountain dump this summer.

Putting nuclear waste on the road to Yucca Mountain through 45 states for 38 years does not get rid of nuclear waste at a single operating nuclear facility in the United States .

Nuclear reactors have been the subject of major security concerns since September 11th in large part because of the significant quantities of highly radioactive spent fuel stored at these reactor sites. The industry and the government have acknowledged these risks and worked to increase security at nuclear power plants. The Nuclear Energy Institute is now running paid advertisements touting nuclear power plants as the most secure industrial facilities in the nation.

If in fact nuclear power plants are the most secure industrial facilities in the United States, one would need a very good reason to move highly hazardous nuclear waste off of these sites onto the nation's highways and rail lines. The rationale typically given is that shipping waste is necessary to consolidate the material in one secure location. If this were true it might justify the obvious risks of such a plan. But it is not.

Putting nuclear waste on the road to Yucca Mountain through 45 states for 38 years does not get rid of nuclear waste at a single operating nuclear facility in the United States. Department of Energy figures show that in the year 2046, after the Yucca Mountain project is completed, all operating nuclear power plants in the United States will have at least 100 tons of waste on site. Thirty (30) of the nation's nuclear power plants will actually have more waste on site in 2046 than they do today. Putting nuclear waste on the road to Yucca Mountain through 45 states for 38 years does not get rid of nuclear waste at a single operating nuclear facility in the United States.

A Ready Made Bomb

Spent fuel coming out of a reactor core is about 1 million times more radioactive than when it was loaded. The spent fuel from the hot core of commercial nuclear power plants accounts for 95 percent of the radioactivity generated in the United States in the last 50 years from all sources, including nuclear weapons production. About 90 percent of the waste travelling to Nevada will be from these commercial nuclear power plants. [DOE EIS Appendix A, figure A-2]

TABLE 2:
Inputs into DOE RISKIND program

Parameter	Value	Source
Burnup	40,000 MWD/MTU	YM EIS
Cooling time	10 y	RWMA
Total uranium in rail cask	10.56 MT	YM FEIS; 24 assemblies of 440 kg
Total uranium in truck cask	1.76 MT	YM FEIS; 4 assemblies of 440 kg
Rainfall	none	Default
Release height	1 m	Default
Release fractions:		
Particulates	0.00002	Lawrence Livermore Modal Study
Ru	0.000027	Lawrence Livermore Modal Study
Cs	0.0066	Gray & Wilson, Pacific Northwest Laboratories (1995)
I	0.0025	Lawrence Livermore Modal Study
Gas	0.33	Lawrence Livermore Modal Study
Heat release	2,000,000 ca/s	Default for accident with heavy fire

Spent fuel coming out of a reactor core is about 1 million times more radioactive than when it was loaded.

Splitting uranium-235 atoms in a nuclear reactor creates intensely radioactive elements known as fission products, such as cesium, strontium, and plutonium. A typical rail cask of high-level nuclear waste contains more than 200 times the long-lived radiation (cesium and strontium) than the atomic bomb dropped on Hiroshima. If unshielded, the average cask of nuclear waste destined for Nevada delivers a lethal dose of radiation in 2 minutes to a person standing 3 feet away.

Both the Department of Energy and the State of Nevada have assessed the consequences of worst-case accidents with these shipments. Estimates of the number of fatalities in these scenarios range from about 100 deaths in the Department of Energy scenario, to as many as 1,800 in the worst case scenario paid for by the state of Nevada.

Methodology and data sources

To provide the public with its first look at the potential impact of an accident involving a nuclear waste shipment, Environmental Working Group used the HOTSPOT computer model developed by the Lawrence Livermore National Laboratory to produce radiation plumes from an accident involving a release of radioactive material from a nuclear waste shipment. We then overlayed these radiation plumes onto maps of some of the major cities through which the Department of Energy has proposed to ship nuclear waste.

TABLE 3:
Inputs into DOE HOTSPOT program (outputs from RISKIND)

Parameter	Value	Source
Dispersion model	General plume	Default
Deposition velocity	1 cm/s	Output from RISKIND
Released radionuclides:		
Rail cask:	Curies:	Output from RISKIND
Co-60	8.88	
Sr-90	1.43	
Ru-106	0.293	
Cs-134	517	
Cs-137	6,850	
Am-241	0.046	
Pu-238	0.089	
Pu-239	0.008	
Pu-240	0.012	
Pu-241	2.02	
Cm-244	0.06	
Truck cask:	Curies :	Output from RISKIND
Co-60	14.9	
Sr-90	0.238	
Ru-106	0.049	
Cs-134	86.2	
Cs-137	1,140	
Am-241	0.008	
Pu-238	0.015	
Pu-239	0.001	
Pu-240	0.002	
Pu-241	0.337	
Cm-244	0.01	

The basic inputs to the models include the variety and quantity of radioactive material present, the age of the material, the fraction of material released, meteorological conditions, exposure times, cask dimensions and seriousness of the crash. The models do not provide an estimate of the amount of material released and dispersed as a result of an attack that penetrates or explodes the cask. The model is used by DOE, the State of Nevada, and others who model radioactive releases.

Radiation inside the casks

The characteristics of the spent fuel in the casks used in the scenario are presented in tables 2 and 3. We assume a 10-year cooling time for the nuclear waste, and radioactive release fractions from the Lawrence Livermore Modal Study, with one modification for cesium as described. DOE models assume 0.3 percent of cesium available is released in an accident. We assume 9.9 percent based on measured values from a 1995 study performed as a part of the Yucca Mountain site assessment (Gray and Wilson 1995). Other studies by the Nuclear Regulatory Commission estimate an even higher cesium gap inventory, from 10 to 27 percent (Parker et al, 1967; Rhyne et al. 1979).

Crash parameters

The scenario modeled here is a category 5 accident which assumes a crash where the cask collides with a hard surface traveling at 30-60 miles per hour, causing a fire that burns for several hours, with leaks in the cask seals (US DOE 2002). The model does not include full penetration of the cask by an explosive device. The fire is not hot enough to melt the cask. The release of radiation is assumed to occur at a height of one meter. This type of accident is reasonable considering the conditions at the postulated accident location.

Rail casks were modeled for all of the cities analyzed with proposed rail routes. In 6 cities, truck accidents were used (Table 1).

Plumes and doses

We used the computer programs RISKIND and HOTSPOT to calculate dose isopleths (“plumes”), which were then superimposed on area maps using the GIS program ArcView.

RISKIND was designed to calculate the dose due to transportation of spent nuclear fuel to the general public, both due to incident-free transport and accidents. RISKIND calculates the average dose to a population evenly distributed around the accident location. To obtain more specific results for a population living within a plume of a radioactive release, we used the release outputs from RISKIND (in Ci for each released radionuclide) as inputs into HOTSPOT.

HOTSPOT was developed at Lawrence Livermore and is used to estimate levels of radioactive contamination following an accident. It uses standard Gaussian plume dispersion equations to estimate airborne concentrations and ground deposition of radionuclides. Relevant inputs for spent fuel characteristics used for RISKIND and HOTSPOT are presented in tables 2 and 3. Parameters for which no values are given are either irrelevant for the calculation that we carried out (such as the incident-free transport parameters), or we used defaults supplied by the programs.

We assumed the average wind speeds for the predominant direction in each metropolitan area and used that direction when placing plumes on the maps. We calculate the dose to the population living within the contamination plume by superimposing acute dose isopleths onto a map of the examined cities and their surroundings. With the average dose (rem) between two isopleths, and the respective population density (persons/km^2) and

TABLE 4:
Weather conditions used in cities analyzed

City	Predominant Wind Direction	Avg. Wind Speed (mph)	Stability Class
Chicago	SW	10.6	D
Salt Lake City	SSE	9.3	D
Milwaukee	SW	11.5	D
St. Louis	S	10.3	D
Des Moines, IA	S	8.7	D
Lansing, MI	SW	10.1	D
Pittsburgh	W	9.2	D
Kansas City	S	10.8	D
Miami	E	9.6	D
Jacksonville	NW	7.9	D
Phoenix	E	6.8	F
Washington, DC	NW	9.5	D
Atlanta	NW	8.9	D
Charlotte	SW	7.4	D
Denver	S	9.0	D
Minneapolis	NW	11.0	D
New Haven, CT	NW	12.8	D
Portsmouth, NH	WNW	13.0	D
Wilmington, DE	WNW	8.6	D
Los Angeles	WSW	8.0	D

area (km^2), we calculated the population dose in person-rem. The size of the areas between plumes, inside and outside of the cities, were estimated using the information from HOTSPOT.

HOTSPOT provides estimates of ground deposition and acute dose only. Estimating the one-year dose was done using RISKIND, which provides estimates of both acute and long-term dose. The one-year dose used was 35 times greater than the corresponding acute dose for that location.

Population parameters

For population densities for each city, we used data from the U.S. Census 2000, available at www.census.gov. All population densities were then projected to the year 2020, using national projection estimates from the U.S. Census.

Meteorological parameters

Surface meteorological data are from the Environmental Protection Agency (EPA), available at http://www.epa.gov/scram001/tt24.htm#surface from June 2002. These data were used to compute Pasquill stability classes and wind roses for each city. In every city analyzed but one, the frequent stability class in D or neutral stability. To use this source, we converted the data with the programs MET144, STAR and WRPLOT, all of which are available at the same website.

Average wind speeds were taken from Weather Underground, Inc., available at www.wunderground.com, accessed in June 2002. For cities where this source provided no data, we used data from the National Climatic Data Center (NCDC), available at http://lwf.ncdc.noaa.gov/oa/climate/online/ccd/avgwind.html, accessed in June 2002.

Calculating fatal cancers

Populations exposed to radiation under the plumes are based on people living under the shaded areas from the 2000 census, projected to the year 2020. People working in or traveling through the exposed area are not counted. We assume that it takes 1,000 person/rem to cause a fatal cancer, in line with the National

Academy of Sciences BEIR V study finding that it takes 1041 person rem to cause a latent fatal cancer in a 20 year old. Gofman estimates a cancer dose for one year old boy at 65 rem, and a dose of 200 rem for a 20 year old (Gofman 1981). Pierce calculates a dose of 556 rem for a 10 year old and 3,780 for a 65 year old (Pierce 1996). Latent fatal cancers are calculated by dividing the total rem in the plume area by the number of exposed individuals. Cancer incidence was calculated based on one day and one year exposure periods.

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