RADIOLOGICAL DOSE ASSESSMENT

Each year the potential radiological dose to the public from the West Valley Demonstration Project is assessed to determine if an individual could possibly have received an exposure exceeding the limits established by the regulatory agencies. The results of these conservative dose calculations demonstrate that the hypothetical maximum dose to an off-site resident is well below permissible standards and is consistent with the "as low as reasonably achievable" philosophy of radiation protection.

Introduction

This chapter describes the methods used to estimate dose to the general public resulting from exposure to radionuclides released by the Project to the surrounding environment during 1992.

Estimated doses are compared directly with current radiation standards established by the Department of Energy (DOE) and the Environmental Protection Agency (EPA) for protection of the public. Doses are also compared to the dose the public receives from natural background radiation and to doses reported in previous years for the Project.

Radioactivity

Atoms that emit radiation are called radionuclides. Radionuclides are unstable isotopes that have the same number of protons and electrons as any other isotope of the element but different numbers of neutrons, resulting in different atomic masses. For example, the element hydrogen has two stable isotopes, H-1 and H-2 (deuterium), and one radioactive isotope, H-3 (tritium). The numbers following the element's symbol identify the atomic mass, which is the number of protons plus neutrons in the nucleus.

Once a radioactive atom decays by emitting radiation, the resulting daughter atom also may be either radioactive or stable. Each radioactive isotope has a unique half-life that represents the time it takes for 50% of the atoms to decay. Strontium-90 and cesium-137 have half-lives of about thirty years, while plutonium-239 has a half-life of 24,000 years. Emitted radiation may consist of electromagnetic rays such as x-rays and gamma rays or alpha or beta particles. Each radionuclide may emit one or more of these radiations at characteristic energies that can be used to identify them.

Radiation Dose

The energy released from a radionuclide is eventually deposited in matter encountered along the path of radiation, resulting in a radiation dose to the absorbing material. The absorbing material can be either inanimate matter or living tissue. Alpha particles leave a dense track of ionization as they travel through tissue and thus deliver the most dose per unit mass. However, alpha particles are not penetrating and must be taken into the body by inhalation or ingestion to cause harm. Beta and gamma radiation can penetrate the protective skin layer of the body from the outside to deliver a whole body dose or expose internal organs. However, beta and gamma radiation deposit much less energy in tissue per unit mass relative to alpha radiation.

Units of Measurement

The U.S. unit of measurement for dose equivalent is the rem. The international unit of measurement of dose equivalent is the sievert (Sv), which is equal to 100 rem. The millirem (mrem) and millisievert (mSv), used more frequently to report the low dose equivalents encountered in environmental exposures, are the equivalent of one-thousandth of a rem or sievert. The dose equivalent concept was developed by the radiation community to allow comparison of dose from different types of radiation.

The effective dose equivalent (EDE) was developed to account for the relative risk of radiation exposure to a particular organ or tissue. The EDE is calculated by multiplying the organ dose equivalent by the organ-weighting factors developed by the International Commission on Radiological Protection (ICRP) in Publications 26 (1977) and 30 (1979). The weighting factor is a ratio of the risk from a specific organ or tissue dose to the total risk resulting from whole body irradiation. All organ-weighted dose equivalents are then summed to obtain the EDE.

The dose from internally deposited radionuclides usually is calculated for a fifty-year period following one year of intake and is called the fifty-year committed effective dose equivalent (CEDE). The CEDE sums the dose to an individual over fifty years to account for the biological retention of radionuclides in the body. The total EDE is calculated by adding the dose equivalent from external, penetrating radiation to the CEDE. Unless otherwise specified, all doses discussed here are EDE values, which include the CEDE for internal emitters.

A collective population dose is expressed in units of person-rem or person-sievert because the individual doses are summed over the entire potentially exposed population. Average individual dose can therefore be obtained by dividing the collective dose by the number in the population.

Sources of Radiation

Members of the public are routinely exposed to different sources of ionizing radiation from both natural and manmade sources. Figure 4-1 shows the relative importance of the annual dose in millirem (mrem) from these sources in comparison to the estimated annual dose from the WVDP. The National Council on Radiation Protection and Measurements (NCRP) Report 93 (1987) estimates that the average annual effective dose equivalent (EDE) received by an individual living in the U.S. is about 360 mrem (3.6 mSv) from both natural and manmade sources of radiation.

As can be seen in Figure 4-1, natural sources of radiation contribute 295 mrem of the total annual dose of 360 mrem. The WVDP contributes a very small amount (0.046 mrem per year) to the total annual manmade radiation dose of about 65 mrem and is less than the average dose received from using consumer products.

While most of the radiation dose affecting the general public is background radiation, manmade sources of radiation also contribute to the average radiation dose to individual members of the public.

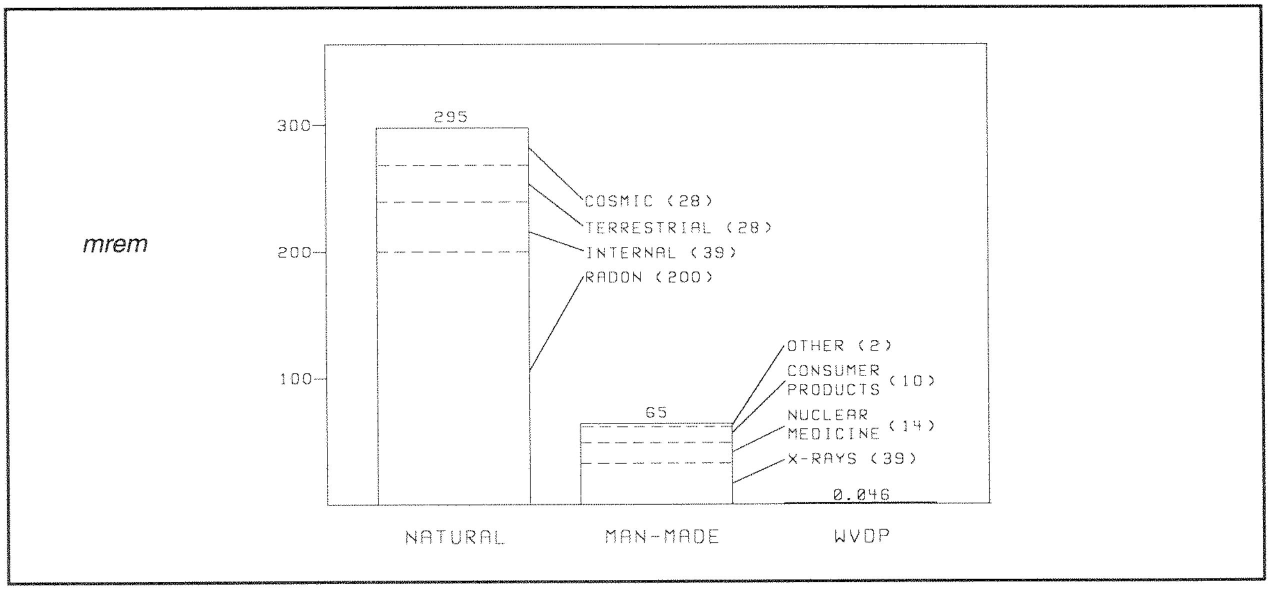


Figure 4-1. Comparison of Annual Background Radiation Dose to the Dose from 1992 WVDP Effluents

Such sources include diagnostic and therapeutic x-rays, nuclear medicine, fallout from atmospheric nuclear weapons tests, effluents from nuclear fuel cycle facilities, and consumer products such as smoke detectors and cigarettes.

Health Effects of Low-Level Radiation

The primary effect of low levels of chronic radiation in an exposed individual is generally assumed to be an increased risk of cancer. Radionuclides entering the body through air, water, or food are usually distributed in different organs of the body. For example, isotopes of iodine concentrate in the thyroid. Strontium, plutonium, and americium isotopes concentrate in the skeleton. When inhaled, uranium and plutonium isotopes remain in the lungs for a long period of time. Some radionuclides such as tritium, carbon-14, or cesium-137 are distributed uniformly throughout the body. Therefore, depending on the radionuclide, some organs may receive quite different doses. Moreover, at the same dose levels, certain organs (such as the breast) are more prone to developing a fatal cancer than other organs (such as the thyroid).

Because of the uncertainty and difficulty in measuring increased cancer resulting from exposure to ionizing radiation, a linear model is used to predict health effects from low levels of radiation. This model assumes that there is an effect on the exposed person at all dose levels even though the body may effectively repair damage incurred from low levels of beta and gamma radiations.

Exposure Pathways

The radionuclides present at the West Valley Demonstration Project site are left over from the reprocessing of commercial nuclear fuel during the 1960s and early 1970s. A very small fraction of these radionuclides is released off-site annually through ventilation systems and liquid discharges. An even smaller fraction actually contributes to the radiation dose to the surrounding population through exposure pathways. An exposure pathway consists of a source of contamination or radiation that is transported by environmental media to a receptor location where exposure to contaminants may occur. For example, a member of the public could potentially be exposed to low levels of radioactive particulates carried by prevailing winds.

The potential pathways of exposure to Project emissions are inhalation of gases and particulates, ingestion of local food products, ingestion of fish, beef, and deer tissues, and exposure to external penetrating radiations emanating from contaminated materials. The drinking water pathway was excluded based on usage surveys of the local population surrounding the WVDP site. Table 4-1 summarizes the potential exposure pathways for the general off-site population.

Dose Assessment Methodology

The general dose assessment methodology was to first assess radionuclide concentrations measured in environmental media to ascertain if any detectable effects from WVDP activities and releases have occurred. Even if the assessment of environmental media concentrations determined that there were no effects, airborne and waterborne releases from the WVDP were modeled to estimate annual doses to individuals and the local population. This two-tiered approach to assessing potential effects and doses resulting from WVDP emissions ensures that a complete evaluation is conducted. This general methodology also allows the collective annual dose to the local population to be calculated.

Environmental Media Concentrations

Near-site and control samples of fish, milk, beef, venison, and local produce were collected and analyzed for various radionuclides, including tritium, cobalt-60, strontium-90, iodine-129, cesium-134, and cesium-137. The measured radionuclide concentrations reported in *Appendix C-3*, Tables C-3.1 through C-3.4 are the basis for comparing near-site and background concentrations.

If statistically significant differences were found between near-site and background sample concentrations, the excess near-site sample concentration was used to conduct further dose assessment. If no significant difference in concentrations was found, then it was concluded that there was no impact from site operations and further dose assessment was not conducted.

The dose to nearby residents from the consumption of foods with radionuclide concentrations above background concentrations was calculated by multiplying the excess concentrations by the maximum adult annual consumption rate for each type of food and the unit dose conversion factor for ingestion of the measured radionuclide. The consumption rates are based on site-specific data and recommendations in *NRC Regulatory Guide* 1.109 for terrestrial food chain dose assessments (U.S. Nuclear Regulatory Commission 1977). The internal dose conversion factors were obtained from *Internal Dose Conversion Factors for Calculation of Dose to the Public* (U.S. Department of Energy 1988).

Predictive Computer Modeling

Because of the difficulty of measuring the small amounts of radionuclides emitted from the site beyond those that occur naturally in the environment, computer codes were used to model the environmental dispersion of radionuclides emitted from on-site monitored ventilation stacks and liquid discharge points. The EDE to the maximally exposed off-site individual and the collective EDE to the population were calculated. These models have been approved by the Department of Energy and the Environmental Protection Agency to demonstrate compliance with radiation standards.

Radiological dose was evaluated for the three major exposure pathways: external irradiation, inhalation, and ingestion of local food products. The dose contributions from each radionuclide and pathway combination were then summed to obtain the reported total dose estimates.

Table 4 - 1

Potential Exposure Pathways under Existing WVDP Conditions

Potentially Exposed Populations	Exposure Pathway and Transporting Medium	Reason for Inclusion/Exclusion
Current off-site residents	*Inhalation: gases and particulates from air*	*Off-site transport of contaminants from WVDP stacks or resuspended particulates from soils*
	Ingestion: cultivated crops	*Local agricultural products irrigated with contaminated ground- or surface water; foliar deposition and uptake of airborne contaminants*
	Ingestion: surface and groundwater	*No documented use of local surface water and downgradient groundwater wells by local residents*
	Ingestion: fish, beef, venison, and milk	*Fish exposed to contaminants in water or sediments may be consumed; beef, venison, and milk consumption following deposition of transported airborne contaminants and surface waters*
	External exposure: radiation emanating from particulates and gases from air or surface water	*Transport of air particulates and gases to off-site receptors; transport of contaminants in surface water during stream use and swimming*

Airborne Releases

Releases of airborne radioactive materials from nominal 10-meter stacks and from the main 60-meter stack were modeled using the EPA-approved CAP88-PC computer code. This air dispersion code estimates effective dose equivalents for the ingestion, inhalation, air immersion, and ground surface pathways. Site-specific data for radionuclide release rates in curies per year, wind data, local agricultural information, and the current local population were used as input parameters. Resulting output from the CAP88-PC code was then used to determine the total EDE to a maximally exposed individual and the collective dose to the local population within an 80-kilometer (50-mile) radius of the WVDP.

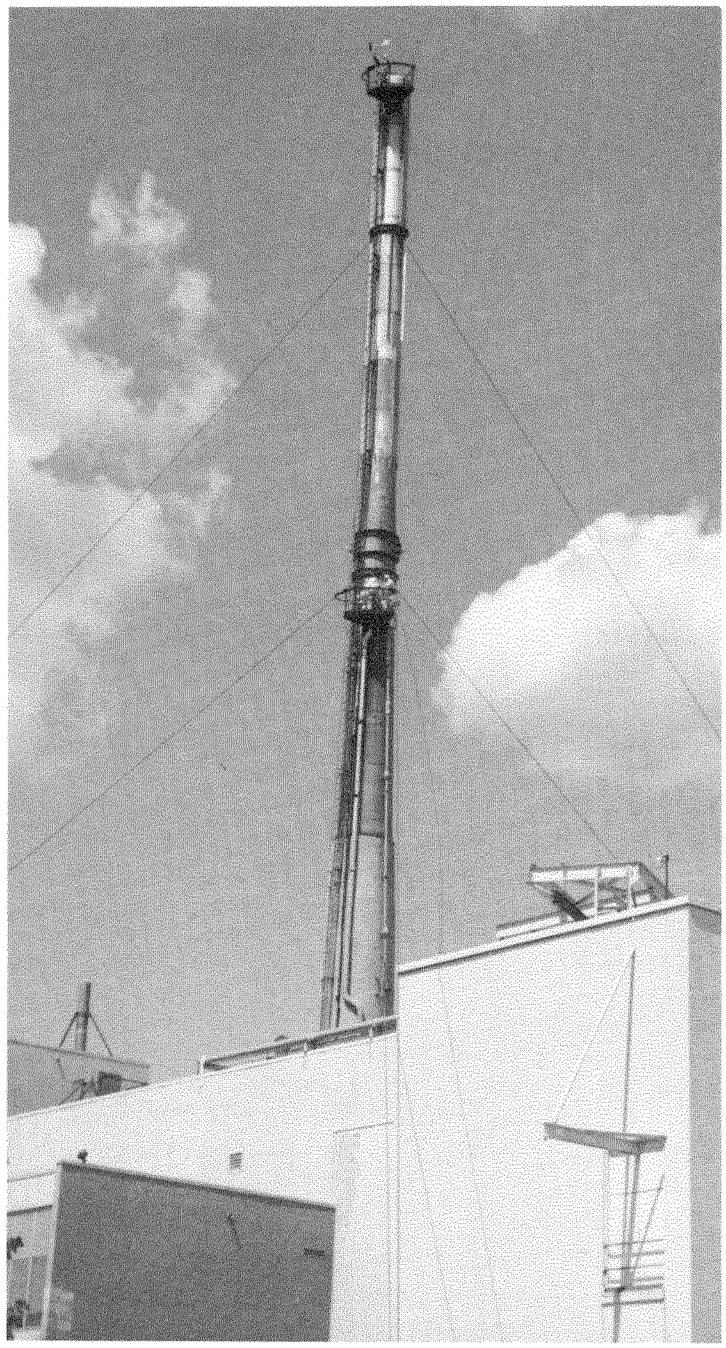
As reported in Chapter 2, *Environmental Monitoring*, five 10-meter stacks were monitored for radioactive air emissions during 1992. The activity that was released to the atmosphere from these stacks is listed in Tables C-2.1 through C-2.11 in *Appendix C-2* and was used as input to the CAP88-PC code.

The main plant stack, which vents to the atmosphere at a height of 63 meters (208 ft), was considered an elevated release; all other releases were considered ground-level releases.

Wind data collected from the on-site meteorological tower during 1992 were used as input to the CAP88-PC code. Data collected at the 60-meter and 10-meter heights were used in combination with elevated and ground-level effluent release data, respectively.

Waterborne Releases

The computer code LADTAP II (Simpson and McGill 1980) was used to calculate the EDE to the maximally exposed off-site individual and the collective EDE to the population from routine waterborne releases and dispersion of these effluents. Since the effluents eventually reach Cattaraugus Creek, which is not used as a source of drinking water, the local exposure pathways calculated by the code are from the consumption of 21 kilograms (46 lb) of fish caught in the creek and exposure to external radiation from shoreline or from water surface contamination.



The Main Plant Ventilation Stack at the West Valley Demonstration Project

Population dose estimates assumed that radionuclides were further diluted in Lake Erie before reaching municipal drinking water supplies and ingested by the local population. A detailed description of LADTAP II is given in *Radiological Parameters for Assessment of WVDP Activities* (Faillace and Prowse 1990).

Seven batch releases of liquid radioactive effluents were monitored during 1992. The radioactivity that was discharged in these effluents is listed in *Appendix C-1*, Table C-1.1, and was used as input data for the LADTAP II computer code. Other input data included site-specific stream flow and dilution, drinking water usage, and stream usage factors. Dose conversion factors for individual and population dose were used for each radionuclide as reported in *Radiological Parameters for Assessment of WVDP Activities.*

Biological Compartment Concentrations

Radionuclide concentrations in samples of fish, milk, beef, venison, and local crops were assessed to determine if near-site concentrations were significantly above concentrations for corresponding background samples.

Fish

Muscle tissue from fish were collected from May through November 1992 in Cattaraugus Creek upstream (background samples) and downstream of the site above and below the Springville dam. Ten tissue samples were collected at each of the three stations and analyzed primarily for strontium-90, cesium-134, and cesium-137. Other gamma-emitting radionuclides were not detected in any sample. Average radionuclide concentrations from samples downstream of the site were found to be statistically indistinguishable from average background concentrations at the 95% confidence levels. Strontium-90 and cesium-134 averages were also numerically below background averages. Individual concentrations for cesium-134 and cesium-137 were all below detection limits except for one cesium-137 value for a downstream sample.

Milk

Milk samples were collected from various nearby dairy farms throughout 1992. Control samples were collected from farms 25-30 kilometers (15-20 mi) to the south and north of the WVDP. Milk samples were measured primarily for tritium, strontium-90, iodine-129, cesium-134, cesium-137, and any other detectable gamma-emitting radionuclides. Ten near-site milk samples were collected and compared with eight background samples. All average radionuclide concentrations from near-site locations were statistically identical to average background concentrations. Individual iodine-129 concentrations in near-site milk were all at or below detection limits. The highest iodine-129 concentration reported was from a background sample.

Beef

Near-site and control samples of locally raised beef were collected in 1992. These samples were measured for tritium, strontium-90, cesium-134, cesium-137, and detectable gamma-emitting radionuclides. Two samples of beef muscle tissue were collected from background locations and two from near-site locations. All individual concentrations of tritium, strontium-90, and cesium-134 were below detection limits in background and near-site samples. The average strontium-90 concentration from near-site samples was below the average for background samples. Cesium-137 concentrations were above detection limits in background and near-site samples but were statistically identical, using 95% confidence intervals.

Venison

Meat samples from three near-site and three control deer were collected in 1992. These samples were measured for tritium, strontium-90, cesium-134, cesium-137, and other gamma-emitting radionuclides. Strontium-90 and cesium-134 concentrations were below detection limits in background and near-site samples. Tritium and cesium-137 were detectable, but average concentrations for background and near-site samples were statistically identical.

Produce (hay, corn, beans, and apples)

Near-site and background samples of hay, corn, beans, and apples were collected during 1992 and analyzed for tritium, strontium-90, cesium-134, cesium-137, and any other detectable gamma-emitting radionuclides. Single samples of each type of produce were collected and compared with single background sample results. Tritium, cesium-134, and cesium-137 were all below detection limits or within the 95% counting error interval of background concentrations. Strontium-90 concentrations were found to be higher in the near-site samples of hay and beans than in background samples.

To further assess strontium-90 concentrations in hay and beans, individual concentrations for near-site and background samples from 1987 through 1992 were statistically compared using conventional one-way analysis of variance. In addition, since the distributional nature of the data was not known, a Mann-Whitney rank sum nonparametric test was performed. The analysis of variance showed average strontium-90 from near-site and controls to be identical at the 95% level of confidence. The rank sum nonparametric test showed similar results, indicating no significant difference between average strontium-90 concentrations for hay or beans collected from background and near-site locations.

Predicted Dose from Airborne Emissions

Applicable Standards

Airborne emissions of radionuclides are regulated by the EPA under the Clean Air Act. Department of Energy facilities are subject to 40 CFR 61, subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAPs). The applicable standard for radionuclides released during 1992 is 10 mrem (0.10 mSv) EDE for any member of the public.

Maximum Dose to an Off-Site Resident

Based on the airborne radioactivity released from the site during 1992, a person living in the vicinity of the WVDP was estimated to receive a total EDE of 1.1×10^{-4} mrem (1.1×10^{-6} mSv). This hypothetical maximally exposed individual was assumed to reside continuously 1.9 kilometers north-northwest of the site and to eat only locally produced foods. Approximately 63% and 70% of the total dose from 1992 airborne emissions were due to iodine-129 from the 60-meter and 10-meter stacks, respectively. Cesium-137 and its daughter product, barium-137m, contributed another 20% to the total dose from the 60-meter stack emissions, followed by americium-241 (7%), tritium (3%), strontium-90 (3%), and plutonium-239 (2%). The shorter 10-meter stack radionuclide contributions were uranium-238 (9%), tritium (6%), uranium-234 (5%), americium-241 (4%), and plutonium-239 (4%).

Total dose to the hypothetical off-site resident was also assessed by individual exposure pathways. Ingestion accounted for 70% and 72%, inhalation for 10% and 23%, and external exposures for 20% and 5% from tne 60-meter and 10-meter stacks, respectively.

The total EDE of 1.1×10^{-4} mrem is far below measurable levels. This dose could be compared to less than one minute of natural background radiation received by an average member of the U.S. population.

This dose is also well below the 10 mrem NESHAPs standard promulgated by the EPA. A more conservative NESHAPs assessment was also conducted using upper detection release rates for airborne radionuclides. The resulting EDE of 2.9×10^{-4} mrem (2.9×10^{-6} mSv) was a factor of 2.6 higher than this analysis, which used actual reported release rates. Both assessments amply demonstrate compliance with EPA standards.

Collective Population Dose

The CAP88-PC version of AIRDOS-EPA was used to estimate the collective total EDE to the population. According to census projections for 1992, an estimated 1.7 million people resided within 80 kilometers (50 mi) of the WVDP. This population received an estimated 1.6×10^{-3} person-rem (1.6×10^{-5} person-Sv) total EDE from radioactive airborne effluents released from the WVDP during 1992. The resulting average EDE per individual was 9.4×10^{-7} mrem (9.4×10^{-9} mSv).

There are no standards limiting the collective EDE to the population. However, the calculated average individual EDE is orders of magnitude lower than the 300 mrem (3 mSv) that an average member of the U.S. population receives in one year from natural background radiation. Using the more conservative values, a collective EDE of 2.4×10^{-3} person-rem (2.4×10^{-5} mSv) was calculated, with a resulting average EDE per individual of 1.4×10^{-6} mrem (1.4×10^{-8} mSv).

Predicted Dose from Waterborne Releases

Applicable Standards

Currently there are no EPA standards establishing limits on the radiation dose to members of the public from liquid effluents except as applied in 40 CFR 141 and 40 CFR 143, *Drinking Water Guidelines* (U.S. Environmental Protection Agency 1984 a,b). The potable water wells sampled for radionuclides are upgradient of the West Valley Demonstration Project and are not considered a pathway in the dose assessment. Since Cattaraugus Creek is not designated as a drinking water supply, the estimated radiation dose was compared with the guidelines provided in DOE Order 5400.5.

Maximum Dose to an Off-Site Individual

Based on the radioactivity in effluents released from the WVDP during 1992, an off-site individual was estimated to receive a maximum total EDE of 4.6×10^{-2} mrem (4.6×10^{-4} mSv). Approximately 97% of this dose is from cesium-137. This dose is about 6,500 times lower than the 300 mrem (3 mSv) that an average member of the U.S. population receives in one year from natural background radiation. The majority of this dose was from the hypothetical ingestion of fish. The external radiation pathway was comparatively insignificant.

Collective Dose to the Population

As a result of radioactivity released in liquid effluents from the WVDP during 1992, the population living within 80 kilometers (50 mi) of the site received a collective EDE of 9.2×10^{-3} person-rem (9.2×10^{-5} person-Sv). This estimate is based on a population of 1.7 million living within the 80-kilometer radius. The resulting average EDE per individual is 5.4×10^{-6} mrem (5.4×10^{-8} mSv), or approximately 55 million times lower than the 300 mrem (3 mSv) that an average person receives in one year from natural background radiation.

Predicted Dose from all Pathways

The potential dose to the public from both airborne and liquid effluents released from the Project during 1992 is the sum of the individual dose contributions. The maximum EDE from all pathways to a nearby resident was 4.6×10^{-2} mrem (4.6×10^{-4} mSv).

This dose is 0.05% of the 100 mrem (1 mSv) annual limit in DOE Order 5400.5. The total collective EDE to the population within 80 kilometers (50 mi) of the site was 1.1×10^{-2} person-rem (1.1×10^{-4} person-Sv), with an average EDE of 6.5×10^{-6} mrem (6.5×10^{-8} mSv) per individual.

Table 4-2 summarizes the dose contributions from all pathways and compares the individual doses to the applicable standards.

Risk Assessment

Estimates of cancer risk from ionizing radiation have recently been presented by the International Commission on Radiological Protection (1990), the National Council on Radiation Protection and Measurement (1987), and the National Research Council Committee on Biological Effects of Ionizing Radiation (1990). These reports estimate that the probability of fatal cancer induction to the public of all ages ranges from 100 to 500×10^{-6} cancer fatalities/rem. The most recent risk coefficient by the International Commission on Radiological Protection of 500×10^{-6} was used to estimate risk to a maximally exposed off-site individual. The resulting risk to this hypothetical individual from airborne and waterborne releases was 2.3×10^{-8} cancer fatalities. This risk is well below the range of 1×10^{-6} to 1×10^{-5} per year considered acceptable by the International Commission on Radiological Protection Report 26 (1977) for any individual member of the public.

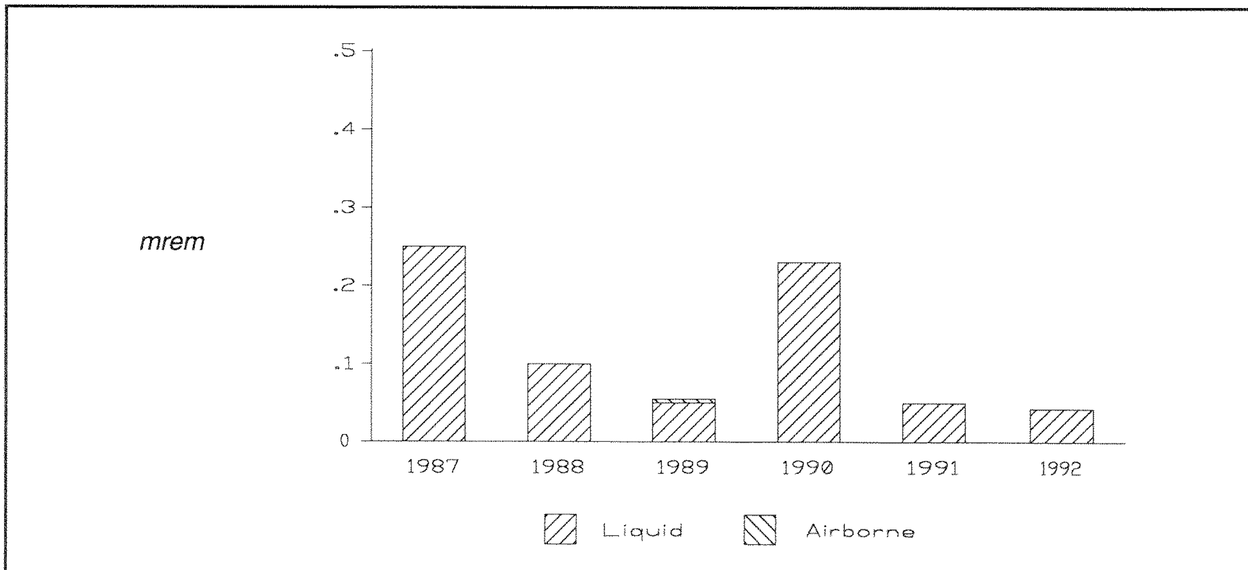


Figure 4-2. Effective Dose Equivalent from Liquid and Airborne Effluents to a Maximally Exposed Individual Residing near the WVDP

Figure 4-2 shows the dose to the maximally exposed individual over the last six years. The estimated dose for 1992 is lower than the dose reported in previous years.

Figure 4-3 shows the collective dose to the population over the last six years. The estimated collective dose for 1992 is also lower than doses reported in previous years.

Table 4 - 2

Summary of Annual Effective Dose Equivalents to an Individual and Population from WVDP Effluents

Exposure Pathway	*Annual Effective Dose Equivalent*	
	Maximum Individual [1] *mrem/y (mSv/y)*	*Collective* [2] *person-rem (person-Sv)*
Airborne Releases [3]	*1.1E-04 (1.1E-06)*	*1.6E-03 (1.6E-05)*
% EPA Standard (10 mrem)	*1.1E-03*	*NA*
Waterborne Releases [4]	*4.6E-02 (4.6E-04)*	*9.2E-03 (9.2E-05)*
Total Releases	*4.6E-02 (4.6E-04)*	*1.1E-02 (1.1E-04)*
% DOE Standard (100 mrem)	*0.05*	*NA*
% Natural Background (300 mrem; 510,000 person-rem)	*0.02*	*2.2E-06*

[1] *Maximally exposed individual at a residence 1.9 kilometers NNW from the main plant.*

[2] *Population of 1.7 million within 80 kilometers of the site.*

[3] *Calculated using AIRDOS-EPA (CAP88-PC for individual and population).*

[4] *Calculated using methodology described in Radiological Parameters for Assessment of WVDP Activities (Faillace and Prowse 1990).*

Exponents, expressed as "E" in the table, are expressed as "10" in the text. Thus, $1.1x10^{-2}$ in the text is the same as 1.1E-02 in the table.

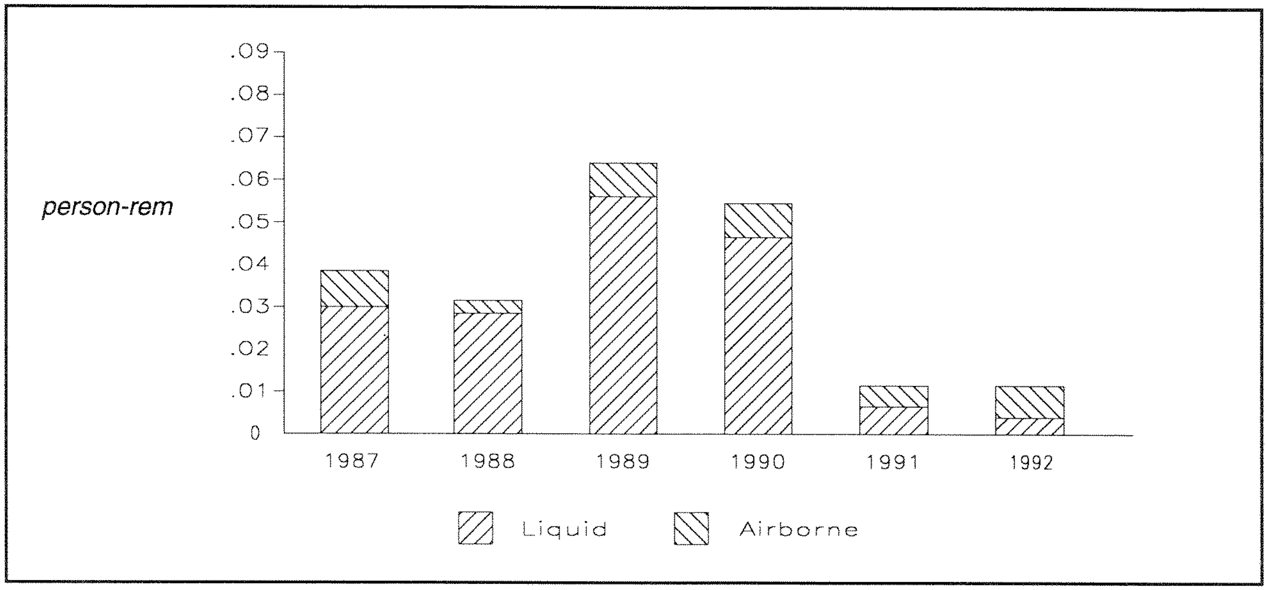


Figure 4-3. Collective Effective Dose Equivalent from Liquid and Airborne Effluents to the Population Residing within 80 Kilometers of the WVDP

Summary

Radionuclide concentrations in biological samples (fish, milk, beef, venison, and local produce) were determined to be below detectable levels or statistically identical to background concentrations. Thus, no specific dose assessment was performed using environmental media concentrations. Predictive computer modeling was performed for airborne and waterborne releases. This analysis resulted in doses to the hypothetical maximally exposed individual that were orders of magnitude below all applicable EPA standards and DOE Orders, which limit the release of radioactive materials and dose to individual members of the public. The collective population dose was also assessed and found to be orders of magnitude below natural background radiation doses. Based on the dose assessment, the West Valley Demonstration Project was found to be in compliance with all applicable radiological guidelines and standards during 1992.