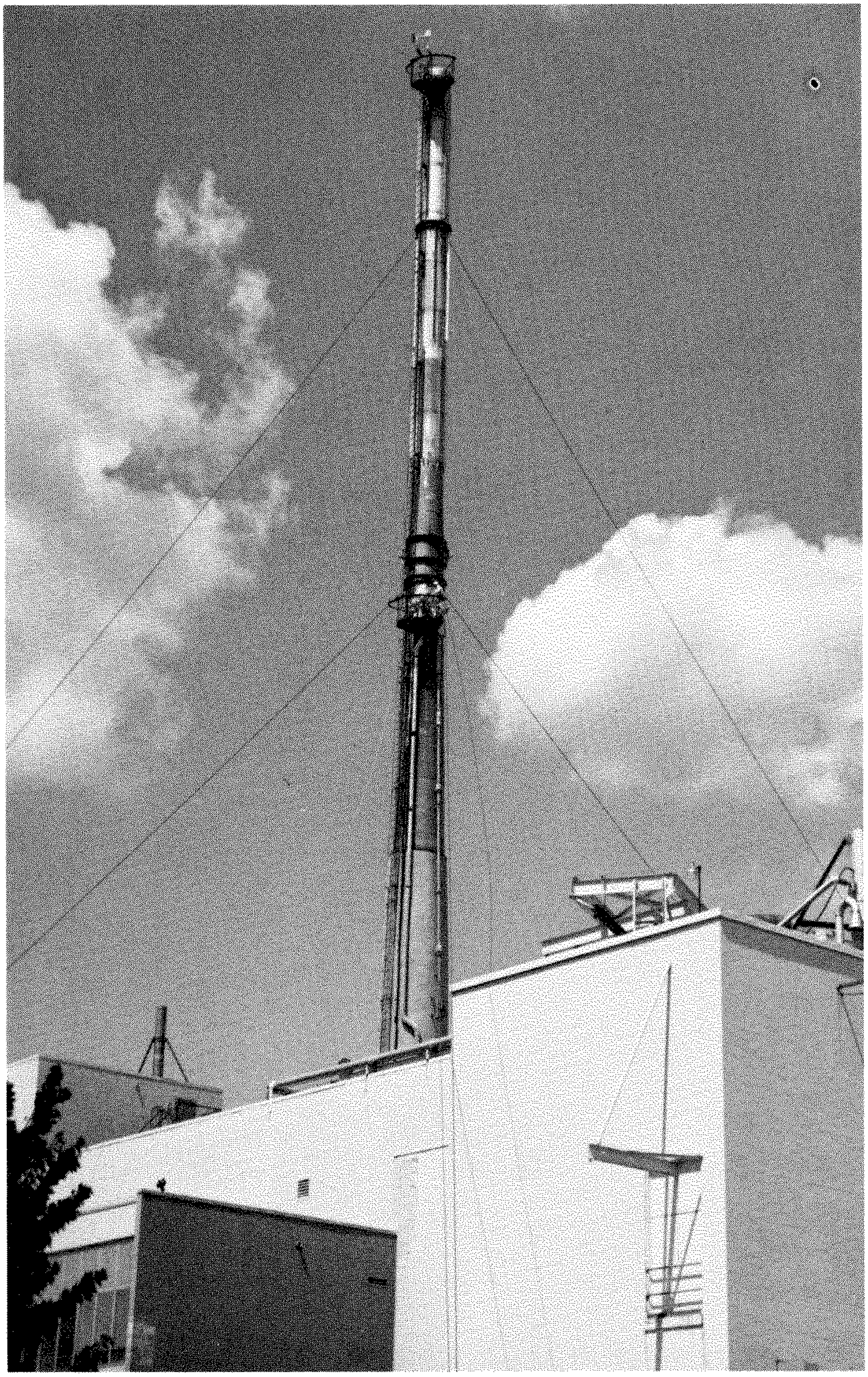


The West Valley Demonstration Project Main Plant Ventilation Stack

4.0 Radiological Dose Assessment

4.1 Introduction

Each year the potential radiological dose to the public from the West Valley site is assessed in order to ensure that no 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" (ALARA) philosophy of radiation protection.

Dose Estimates

This chapter describes the methods used to estimate the dose to the public from radionuclides emitted from the West Valley Demonstration Project through air and water discharges during 1990. The dose estimates, based on concentrations of radionuclides measured in air and water collected from monitored on-site effluent points throughout 1990, are compared to the radiation standards established by the Department of Energy and the Environmental Protection Agency for protection of the public. The radiation doses reported for 1990 are also compared to the doses reported in previous years.

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 models were used to calculate the environmental dispersion of the radionuclides emitted from monitored ventilation stacks and liquid discharge points on-site. These models have been approved by the Department of Energy and the Environmental Protection Agency to demonstrate compliance with radiation standards. Radiological dose is 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 are then summed to obtain the reported dose estimates.

4.1.1 Sources of Radiation Energy and Radiation Exposure

» Radionuclides

Atoms that emit radiation are called radionuclides. Radionuclides are unstable isotopes (variations of an element) 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 – the numbers of protons and neutrons – in the nucleus.

Once a radioactive atom decays by emitting radiation, the resulting daughter atom may itself be 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 24,000–year half-life.

» 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.

While most of the radiation dose affecting the general public is background radiation, manmade sources of radiation may also contribute to the radiation dose to individual members of the public. Such sources include diagnostic and therapeutic x-rays, nuclear medicine, consumer products such as smoke detectors and cigarettes, fallout from atmospheric nuclear weapons tests, and effluents from nuclear fuel cycle facilities.

The West Valley Demonstration Project is part of the nuclear fuel cycle. The radionuclides present at the site are left over from the recycling 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.

4.1.2 Health Effects of Low Levels of Radiation

The concept of dose equivalent (DE) was developed by the radiation protection community to allow a rough comparison of doses from different types of radiation.

The primary effect of low levels of radiation in an exposed individual appears to be an increased risk of cancer. Radionuclides entering the body through air, water, or food are usually distributed unevenly in different organs of the body. For example, isotopes of iodine concentrate in the thyroid gland. Strontium, plutonium, and americium isotopes concentrate in the skeleton. Uranium and plutonium isotopes, when inhaled, remain in the lungs for a long time. Some radionuclides such as tritium, carbon-14, or cesium-137 will be distributed uniformly throughout the body. 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).

4.1.3 Dose Estimation Methodology

The International Commission on Radiological Protection (ICRP) found a way to account for this difference in radionuclide distribution and organ sensitivity. In Publications 26 (1977) and 30 (1979), the Commission developed an organ-weighted average dose methodology to limit permissible worker exposures following intakes of radionuclides. This weighting factor — a ratio of the risk from a dose to a specific organ or tissue to the total risk when the whole body is uniformly irradiated — represents the relative sensitivity of a particular organ to develop a fatal effect. For example, to determine the weighting factor following a uniform irradiation, the risk factor of death from cancer of a specific organ is divided by the total risk of dying from cancer of any organ. Organ-weighted dose equivalents are then summed to obtain an effective dose equivalent (EDE).

- **Units of Measurement**

The U.S. unit of dose equivalent measurement (DE) is the rem. The international unit of measurement of DE is the sievert (Sv), which is equal to 100 rem. The millirem (mrem) and millisievert (mSv) are used more frequently to report the low DEs encountered in environmental exposures.

The National Council on Radiation Protection and Measurements (NCRP) Report 93 (1987) estimates that the average annual EDE received by a person living in the U.S. is about 360 mrem (3.6 mSv) from both natural and manmade sources of radiation (Fig. 4-1). This number is based on the collective EDE, defined as the total EDE received by a population (expressed in units of person-Sv or person-rem). The average individual EDE is obtained by dividing the collective EDE by the population number.

- **Risk Estimate**

The Committee on Biological Effects of Ionizing Radiations (BEIR) has estimated that the increased risk of dying from cancer from a single acute dose of 10 rem (0.1 Sv) is about 0.8% of the background risk of cancer. According to the BEIR Committee, chronic ex-

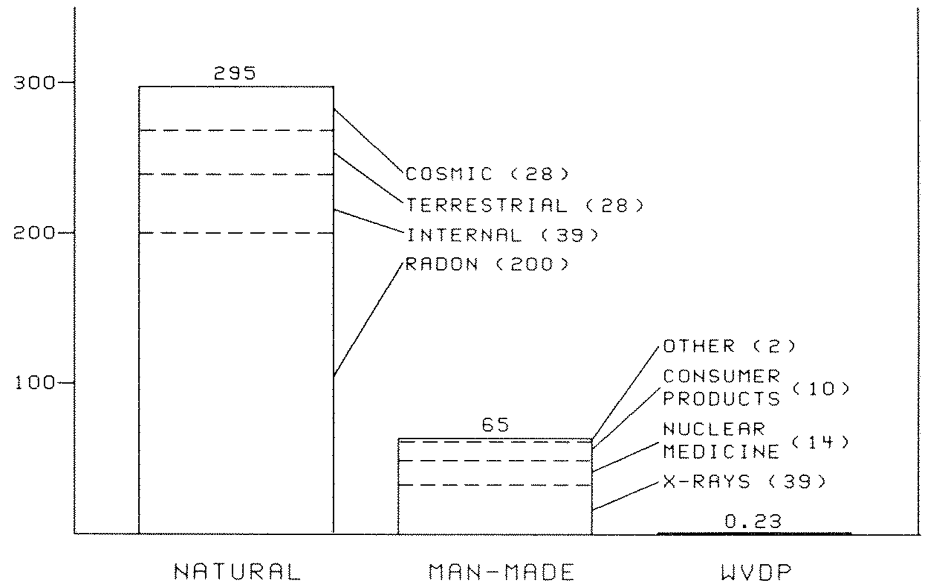


Figure 4-1

Comparison of annual radiation dose (in millirem) to an average member of the United States population (NCRP 1987) with the maximum dose to an off-site resident from 1990 WVDP effluents.

posure, i.e., accumulation of the same dose over long periods of time, might, compared to acute exposure, reduce the risk by a factor of two or more. The background risk of fatal cancers in the United States is currently about one in every eight fatalities.

The BEIR Committee has stressed that the health effects of very low levels of radiation are not clear, and any use of risk estimates at these levels is subject to great uncertainty (BEIR 1990). As will be shown in the following sections, the estimated maximum EDE received by a member of the public from Project activities during 1990 is many orders of magnitude lower than the exposures considered in the BEIR report.

4.2 Estimated Radiological Dose from Airborne Effluents

Sources of Radioactivity from the WVDP

As reported in Chapter 2, "Effluent and Environmental Monitoring," five stacks and vents were monitored for radioactive air emissions during 1990. The activity that was released to the atmosphere from these stacks and vents is listed in Tables C-2.1 through C-2.11 in Appendix C-2.

Because of a delay in receiving some specific quarterly isotopic sample analysis results from the contract laboratory, annual emissions for certain radionuclides had to be estimated to fill in gaps in the data. The estimate was made by applying scaling factors based on past plant emissions (1989 and available 1990 analysis results). As plant processes during 1990 did not vary significantly from the previous year's activities, it is expected that such an estimation will result in off-site doses within 20% of the doses that would have been obtained had the missing sample results been available.

The main plant stack, which vents to the atmosphere at a height of 60 meters (197 ft), is considered an elevated release; all other releases are considered ground level (10 m) releases.

Meteorological Data

Wind data collected from the on-site meteorological tower during 1990 were used as input to the dose assessment codes. Data collected at the 60-meter and 10-meter heights were used in combination with elevated and ground level effluent release data, respectively. A more detailed description of the WVDP meteorological monitoring program is given in section 2.1.5 .

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 (NESHAP) - Radionuclides." The applicable standard for radionuclides released during 1990 is 10 mrem (0.10 mSv) EDE for any member of the public.

Dose Assessment Methodology

AIRDOS-PC (version 3.0) and CAP-88 are the approved versions of the AIRDOS-EPA computer code used to demonstrate compliance with the standard for the 1990 assessment period. Using site-specific meteorological data, AIRDOS-EPA (Moore et al. 1979) calculates the dispersion of radionuclides into the environment following airborne releases and then estimates the external dose to individuals from radionuclides both in the air and deposited on the ground. It also estimates the doses to individuals from inhalation of contaminated air and ingestion of contaminated water and foods produced near the site. The mainframe computer version of AIRDOS-EPA (CAP-88) was also used to estimate the collective dose to the population residing within 80 kilometers of the site.

4.2.1 Maximum Dose to an Off-Site Resident

Based on the airborne radioactivity released from the site during 1990 and using AIRDOS-PC, a person living in the vicinity of the WVDP was estimated to receive an EDE of 7×10^{-4} mrem (7×10^{-6} mSv). This hypothetical maximally exposed individual was assumed to reside continuously about 1.9 kilometers north-northwest of the site and to eat only locally produced foods. As in 1989, approximately 75% of the dose from airborne emission in 1990 was contributed by iodine-129. Cesium-137 and strontium-90 made up much of the remainder, with less than 10% contributed by americium-241 and isotopes of plutonium.

The dose reported above is 0.007% of the 10 mrem (0.10 mSv) standard and can be compared to about one minute of the annual background radiation received by an average member of the U.S. population.

4.2.2 Collective Dose to the Population

The CAP-88 version of AIRDOS-EPA was used to estimate the collective dose to the population. According to census projections for 1990, an estimated 1.7 million people reside within 80 kilometers (50 mi) of the WVDP. This population received an estimated 8×10^{-3} person-rem (8×10^{-5} person-Sv) collective EDE from radioactive airborne effluents released from the WVDP during 1990. The resulting average EDE per individual is 5×10^{-6} mrem (5×10^{-8} mSv).

There are no standards limiting the collective EDE to the population. However, the calculated average individual EDE is 60 million 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 (equivalent to an exposure of less than one second of background radiation).

4.3 Estimated Radiological Dose from Liquid Effluents

Sources of Radioactivity from the WVDP

As reported in Chapter 2, four batch releases of liquid radioactive effluents were monitored during 1990. The radioactivity that was discharged in these effluents is listed in Appendix C-1, Table C-1.1.

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 (USEPA 1984b,c). The potable water wells sampled for radionuclides are upgradient of the West Valley Demonstration Project and are not considered a realistic pathway in the dose assessment. Since Cattaraugus Creek is not designated as a drinking water supply, the estimated radiation dose was compared with the limits stated in DOE Order 5400.5.

Dose Assessment Methodology

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 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 pathway calculated by the code is from the consumption of 21 kilograms (46 lb) of fish caught in the creek. Population dose estimates assume that the radionuclides are further diluted in Lake Erie before reaching municipal drinking water supplies. A detailed description of LADTAP II is given in "Radiological Parameters for Assessment of WVDP Activities " (WVDP-065).

4.3.1 Maximum Dose to an Off-Site Individual

Based on the radioactivity in liquid effluents released from the WVDP during 1990, an off-site individual was estimated to receive a maximum EDE of 0.23 mrem (2.3×10^{-3} mSv). Approximately 95% of this dose is from cesium-137; the remainder comes from carbon-14. This dose is about 1,300 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 (equivalent to an exposure of seven hours).

4.3.2 Collective Dose to the Population

As a result of radioactivity released in liquid effluents from the WVDP during 1990, the population living within 80 kilometers (50 mi) of the site received a collective EDE of 4.8×10^{-2} person-rem (4.8×10^{-4} 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 2.8×10^{-5} mrem (2.8×10^{-7} mSv), or approximately ten million times lower than the 300 mrem (3 mSv) that an average person receives in one year from natural background radiation (equivalent to an exposure of less than three seconds).

4.4 Estimated Radiological Dose from All Pathways

The potential dose to the public from both airborne and liquid effluents released from the Project during 1990 is the sum of the individual dose contributions. The maximum EDE from all pathways to a nearby resident was 0.23 mrem (2.3×10^{-3} mSv). This dose is 0.23% 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 5.6×10^{-2} person-rem (5.6×10^{-4} person-Sv), with an average EDE of 3.3×10^{-5} mrem (3.3×10^{-7} mSv) per individual.

Table 4-1 on the following page summarizes the dose contributions from all pathways and compares the individual doses to the applicable standards.

Figure 4-2 shows the trend in dose to the maximally exposed individual over the last five years. The estimated dose for 1990 is higher than the dose reported in 1989 but is within the range of variation observed in previous years. The increase in the dose during 1990 can be attributed mostly to increased cesium-137 releases in liquid effluents and changes in the dose factors applied to these releases.

Figure 4-3 shows the trend in collective dose to the population. The estimated collective dose for 1990 is slightly lower than the dose reported in 1989 but is within the range of variation observed in previous years.

4.5 Estimated Radiological Dose from Local Food Consumption

In addition to dose estimates based on dispersion modeling, the maximum EDE to a nearby resident from consumption of locally produced food can also be estimated. Because the estimated doses using the computer models al-

TABLE 4 - 1

Summary of Dose Assessment from 1990 West Valley Demonstration Project Effluents

	Maximum Dose to an Individual [1]	*Maximum Dose to the Population* [2]
Effective Dose Equivalent from Airborne Emissions [3]	7×10^{-4}mrem (7×10^{-6}mSv)	8×10^{-3}person-rem(8×10^{-5}mSv)
EPA Radiation Protection Standard [4] **(percent of standard)**	10 mrem (7×10^{-3}%)	-0-
Effective Dose Equivalent from Liquid Effluents [5]	2.3×10^{-1}mrem (2.3×10^{-3}mSv)	4.8×10^{-2}person-rem(4.8×10^{-4}personSv)
Effective Dose Equivalent from all Releases	2.3×10^{-1}	5.6×10^{-2} person-rem(5.6×10^{-4}person-Sv)
DOE Radiation Protection Standard [6] **(percent of standard)**	100 mrem (0.23%)	-0-
Background Effective Dose Equivalent [7] **(percent of background)**	300 mrem (3 mSv) (7.8×10^{-2}%)	510,000 person-rem(5100 person-Sv) 1.1×10^{-5}%

1 Maximally exposed individual at a residence 1.9 km NNW from the main plant.

2 Population of 1.7 million within 80 km of the site.

3 Calculated using AIRDOS-EPA (AIRDOS-PC for individual; CAP-88 for population).

4 Airborne emissions only.

5 Calculated using LADTAP II (effective dose equivalent).

6 Applies to doses from both airborne and liquid effluents.

7 U.S. average (Source: NCRP 1987).

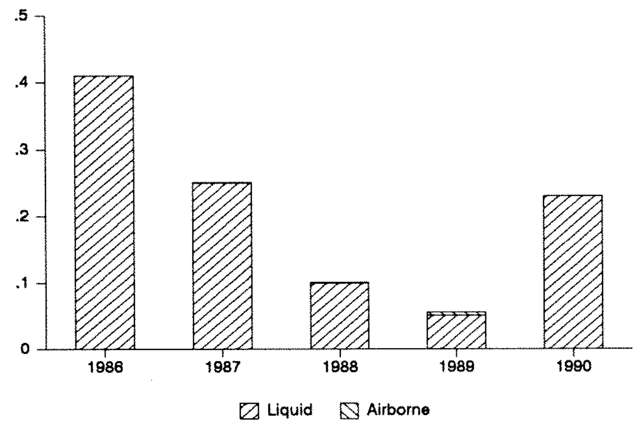


Figure 4-2

Maximum dose equivalent (in millirem) from liquid and airborne effluents to an individual residing near the West Valley Demonstration Project.

ready incorporate the food pathway, the doses from food consumption should not be added to doses reported in previous sections but should serve as an additional means of measuring the effect of Project operations.

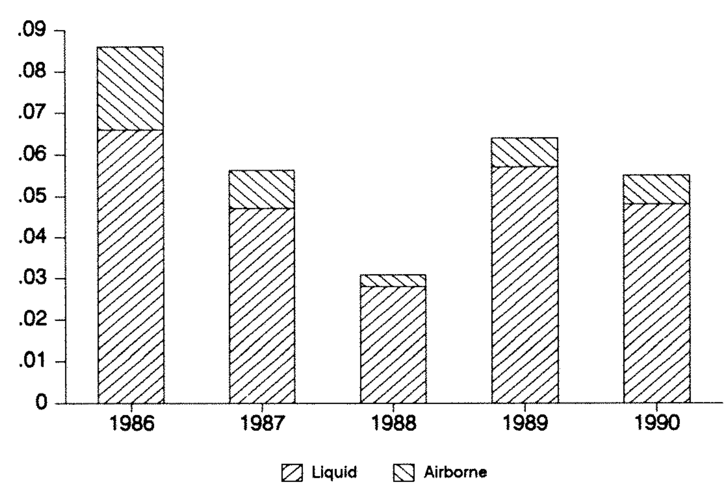
Near-site and control samples of fish, milk, beef, venison, fruit, and vegetables were collected and the samples analyzed for various radionuclides, including tritium, potassium-40, cobalt-60, strontium-90, iodine-129, cesium-134, and cesium-137. The measured radionuclide concentrations are reported in Appendix C-3, Tables C-3.1 through C-3.4.

While the biological samples were collected as scheduled throughout 1990, a number of analyses had not been completed by the contract laboratory in time to be included in the dose assessment calculated for this year's report. It was not possible, therefore, to make reliable dose assessments regarding the consumption of locally produced foods, except for fish. (See following paragraph). Doses reported in previous sections of this chapter (using computer models) do not differ significantly from the doses reported in previous years' reports. This provides some assurance that dose estimates from food consumption in 1990 will not differ significantly relative to doses reported in previous years.

Based on the net strontium-90 concentration in fish caught below the Springville dam during the first half of 1990, the CEDE to an individual consuming 21 kilograms of fish per year (10.5 kg in the first half of 1990) was estimated to be 1.1E-02 mrem (1.1E-04 mSv).

Figure 4-3

Collective dose equivalent (in person-rem) from liquid and airborne effluents to the population residing within 80 kilometers of the West Valley Demonstration Project.



This is lower than the CEDE calculated for liquid releases (section 4.3.1) by a factor of approximately twenty.

4.6 Conclusions

Based on dose assessment, the West Valley Demonstration Project during 1990 was in compliance with all applicable EPA standards and DOE Orders. The EDE to members of the public estimated from effluent dispersion models and radionuclide concentrations in food samples was below the dose limits, indicating no measurable effects on the public's health.