Chapter 19: Prioritization of Chemical Releases from LANL

Operations at LANL have involved many non-radioactive materials, including metals, inorganic chemicals, and organic chemicals including solvents. For the sake of simplicity in this report, we will refer to these materials as "chemicals". Prior to the 1970s, uses of chemicals and their ultimate fate were poorly tracked and documented compared to radionuclides. One particularly challenging portion of the LAHDRA project, for this reason, has been the collection of information concerning historical uses of chemicals, identification of those that were most likely released off site, and determination of which chemicals have been most important in terms of potential off-site health hazards.

Sources of Information Regarding Historical Chemical Usage

The sources of information about chemical usage at LANL that have been most useful to the LAHDRA team include a modern-day chemical inventory, historical chemical inventories, and various types of LANL site documents.

Current Chemical Inventory

LANL maintains an inventory of chemicals present on-site to comply with annual environmental reporting requirements for hazardous chemical emissions. Information on the quantities and types of chemicals used at LANL was collected starting in 1991 and a Microsoft Access® database was completed in 1993 (ESH 1999). The initial tracking system called the Automated Chemical Inventory System (ACIS) had been updated annually since 1994. Recently, the inventory system was changed to the Injury Illness and Chemical Management Online Application by E3. Although the project team was granted access and training for the new system, the initial analysis of chemical inventory data conducted in 2000 was not repeated due to the limited usefulness of recent chemical inventory data for evaluating historical emissions of chemicals from LANL.

Fig. 19-1. Personnel involved in early explosives testing at Los Alamos.

The ACIS database includes the following fields:

- Chemical name, CAS number, and bar code
- Location of chemical (technical area, building)
- Quantity, units of measure, and physical state (solid, liquid, gas)

ACIS is available on the internal LANL Web site using a SecureID card. Access to the database allows the data to be compiled in different ways, and provides details such as the specific locations of chemicals through database search capabilities. A paper copy of the ACIS Microsoft Access® database file was provided to the project team by the ESH-5 group on January 26, 1999. At that time, the database contained approximately 120,000 records. Subsequently, access through a Web interface was granted to allow limited searches to be performed. A request for an official-use-only copy of the database for performing more complex searches was granted. However, the database does not include radionuclides, explosives, beryllium, depleted uranium, or other bulk metals. It contains many trade name products with no information on whether they include any hazardous materials. The database also does not include any information regarding how the chemicals are used or their potential for release to the environment.

Preliminary review of the ACIS database indicates that 37 chemicals were each present onsite at 250 or more individual locations and therefore represented the largest onsite quantities. Twelve of the thirteen chemicals present onsite in the highest quantities do not have USEPA recommended toxicity values for potential cancer and non-cancer systemic health effects, although some can be irritants or corrosives at high concentrations. The 37 high quantity chemicals selected from ACIS are shown in Table 19-1 in order of decreasing estimated on-site quantities.

Of the 37 high quantity chemicals, the 13 with USEPA recommended toxicity values are shown in Table 19-1 ranked in order of generic toxicity, “1” being more toxic than “13”. Generic toxicity includes both cancer and non-cancer chronic health effects with no bias toward any route of potential exposure (e.g., inhalation, ingestion, and dermal contact) or to any potential environmental exposure medium (e.g., air, soil, water, food products) since little is known about how the chemicals were used and the potential for off-site release.

LANL personnel suggested that site files of Material Safety Data Sheets could be reviewed for the trade name products to determine if the trade name products contain any hazardous materials. An analysis of the remaining inventory chemicals not included in Table 19-1 for quantity and location of use information could be conducted in future phases of the dose reconstruction to further prioritize recent chemical use at LANL. For chemicals that could be released to the off-site environment as a result of their use, air

Table 19-1. Selected Data from a Current LANL Chemical Inventory

Chemical	Onsite Quantity	Toxicity Ranking
Nitrogen	4.2×10^7 L	--
Argon	3.8×10^7 L	--
Helium	3.7×10^7 L	--
Hydrogen	1.6×10^6 L	--
Oxygen	1.6×10^6 L	--
Propane	1.3×10^5 L	--
Sulfuric acid	2.2×10^4 L	--
Toluene	2.1×10^4 L	8
Sodium hydroxide	1.5×10^4 kg	--
Sodium chloride	8.6×10^3 kg	--
Ethyl alcohol	7.1×10^3 L	--
Sodium carbonate	6.8×10^3 kg	--
Hydrochloric acid	6.6×10^3 L	--
Acetone	6.2×10^3 L	7
Ethylene glycol	5.1×10^3 L	12
Chlorodifluoromethane	4.8×10^3 L	14
Methyl alcohol	2.8×10^3 L	10
Nitric acid	2.6×10^3 L	--
Isopropanol	2.2×10^3 L	--
Hydrogen peroxide	7.8×10^2 L	--
Buffer solutions	6.3×10^2 L	--
Acetic acid	5.8×10^2 L	--
Hexane	5.4×10^2 L	5
Methylene chloride	4.9×10^2 L	4
Miscellaneous chlorofluorcarbon	4.6×10^2 L	--
1,1,1,2-Tetrafluoroethane	4.4×10^2 L	--
Photographic developer products	3.9×10^2 L	--
Dimethyl sulfoxide	3.8×10^2 L	--
Chloroform	3.4×10^2 L	1
Benzene	2.1×10^2 L	2
Ether	2.0×10^2 L	9
Dichlorodifluoromethane	1.5×10^2 L	6
Photographic fixer products	1.2×10^2 L	--
Tetrahydrofuran	6.0×10^1 L	3
Ethylenediamine tetraacetic acid	3.8×10^1 kg	--
Ethyl acetate	2.1×10^1 L	11
1,1-Difluoroethane	8.5×10^0 L	13

dispersion and other transport models and exposure models can be used to estimate an onsite threshold quantity that would not result in adverse health impacts to off-site populations using site-specific assumptions regarding dispersion, transport and exposure. The threshold quantity approach could be used to focus data gathering efforts on those chemicals for which the on-site inventory quantity exceeds the threshold quantity. However, the chemical inventory database only contains information on selected chemicals present at LANL since 1991.

Historical Chemical Inventories

Harry Schulte, a former Industrial Hygiene group leader, is reported to have conducted a chemical inventory in the early 1970s (ESH 1999). A draft report was prepared, but was never finalized. It was suggested that the draft report and supporting data might be located in the Industrial Hygiene group files in the Central Records Center. Surviving members of Mr. Schulte's group reportedly do not have any copies in their possession. This 1970s chemical inventory information has not been located by the project team.

For years prior to the initiation of the current chemical inventory program, the project team identified several lists of chemicals used at LANL in years prior to 1980s environmental reporting requirements. The lists represent the years 1947-50 (Repos. No. 296), 1971 (Repos. Nos. 756, 883, 997), and 1970s (Repos. Nos. 279, 284, 1380, 2015). Quantities and locations of use are typically not provided in these lists. The project team identified considerable documentation related to chemical use in specific areas for the 1980s and 1990s as LANL began collecting these data in response to regulatory requirements.

Table 19-2 is a list of chemicals documented as having been used at LANL at some point in time. This list was compiled from the LANL documents that have been reviewed to date, entered into the project database, and released to the public. Copies of many of the reviewed documents have not yet been obtained by the project team from LANL as of the preparation of this report. Classification, privacy act, and legal privilege reviews are required prior to public release. Documents used to identify the chemicals in Table 19-2 are included in the reference section and are described below.

Table 19-2. Chemicals Historically Used at LANL

Elements	**Inorganics**
aluminum	asbestos (magnesium silicate)
antimony	bromide
arsenic	cyanide
barium	hydrochloric acid
beryllium	hydrofluoric acid
bromine	nitric acid
cadmium	oxalic acid/ oxalate
chromium	perchloric acid/ perchlorate
copper	phosphoric acid
dioxane	sodium hydroxide
fluoride	sodium thiosulfate
gallium	sulfuric acid
iron	
lanthanum	**Semi-Volatile Organics**
lead	n-butyl acetate
lithium	ethyl acetate
manganese	ethylene glycol
mercury	hexachlorobutadiene
molybdenum	naphthalene
nickel	PCB (polychlorinated biphenyls): Aroclor 1242
niobium	
platinum	**Explosives**
samarium	Baratol (mixture of barium nitrate and TNT)
silver	Comp. B (mixture of 60% RDX and 40% TNT)
tantalum	Cyclotol (mixture of 70-75% RDX and 25-30% TNT)
thallium	Explosive D (ammonium picrate; ammonium-1,3,5-trinitrophenol)
uranium (normal and depleted)	HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)
vanadium	nitrobenzene
zinc	nitrocellulose
zirconium	nitromethane
	NQ (nitroguanidine; Picrite)
Volatile Organic Compounds	Octol (mixture of 70-75% HMX and 25-30% TNT)
acetone	PBX
benzene	Pentolite
carbon tetrachloride	PETN (pentaerythritol tetranitrate)
chloroform	picric acid
chlorodifluoromethane	PTX-2 (2,6-bis-picrylamino-3,5-dinitropyridine)
dichlorodifluoromethane	RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine)
difluoroethane	Saltex
ethanol	TATB (1,3,5-triamino-2,4,6-trinitrobenzene)
ether	Tetryl (1,3,5-trinitrophenyl-methylnitramine)
isopropanol	TNT (2,4,6-trinitrotoluene)
kerosene	Torpex
methanol	
methyl chloride (chloromethane)	
methyl ethyl ketone (2-butanone)	
methylene chloride (dichloromethane)	
tetrachloroethylene	
tetrabromoethane	
tetrahydrofuran	
toluene (toluol)	
trichloroethane	
trichloroethylene	
xylene	

Table 19-3 is a compilation of data located by the project team regarding quantities of chemicals used or released historically from LANL. Five documents report quantities of primarily volatile organic solvents that were used at LANL from 1971 until 1985. Three documents identify chemical quantities as "released or lost to the atmosphere". One of the three documents, Repos. No. 1197, is a third source of the same numbers provided in Repos. Nos. 610 and 1324. It states that the amount of airborne solvents is taken from LASL stock issue records. However, it is often reasoned that all of the volatile solvents will in time become airborne no matter what the disposal method. Therefore, it appears that 100% volatilization was assumed. The chemicals listed in Table 19-3 are in the order of quantity used or released. Selection of the chemicals addressed in these documents was based on State and Federal air pollution requirements at the time of reporting. From Table 19-3, it can be concluded that trichloroethane and trichloroethylene were the most used volatile organic chemicals at LANL in the early 1970s. However, trichlorethylene appears to have been replaced by Freons in the early 1980s. Methyl ethyl ketone was also used in high quantities until 1982.

Site Documents

In the late 1980s, the Senate Committee on Armed Services asked the Office of Technology Assessment to evaluate what was known about the contamination and public health problems at the Nuclear Weapons Complex (U.S. Congress 1991). Contaminated sites and initial cleanup activities at LANL were described in this report. A summary of hazardous substances released to the environment at LANL formed the basis for our initial list.

For each of the over 600 solid waste management units (SWMUs) identified in the 1990 Solid Waste Management Units Report (LANL 1990), the unit, waste and releases information sections were reviewed by the project team to identify additional chemicals that may have been released from LANL.

An additional 480 SWMUs were added by the EPA in 1994, and another 1,000 Potential Release Sites (PRSs) were included in the investigation by the Department of Energy, for a total of 2,120 areas of concern. The 1996 Baseline Environmental Management Report (USDOE 1996) describes historical activities at the potential release sites involving: asbestos, barium, lead, depleted uranium, beryllium, and PCBs. High explosives, organic solvents, and ordnance are also cited but specific chemical names are not provided.

Table 19-3: Reported Quantities of Chemicals Historically Used or Released at LANL

	CHEMICAL	1971 [1] (kg released)	1972-73 (12 mo.) [2] (kg issued)	1972 [3] (kg used)	1973 [3] (kg used)	1974 [3] (kg used)	1975 [3] (kg used)	1976 [3] (kg used)	1977 [3] (kg used)	1978 [3] (kg used)	1978 [4] (kg losses)	1979 [3] (kg used)	1980 [5] (kg used)	1981 [5,6] (kg used)	1982 [6] (kg used)	1983 [6] (kg used)	1984 [6] (kg used)	1985 [6] (kg used)
	ORGANICS																	
	Methyl chloroform (trichloroethane)	26,571	19,138	25,600	18,300	25,800	22,900	34,000	28,300	24,100	13,741	23,800	28,200	39,300	25,600	31,100	27,674	29,665
C	Trichloroethylene	27,719	17,007	20,400	15,500	16,200	9,400	13,200	10,200	7,400	2,041	6,900	3,400	3,200	390	4,200	2,204	3,041
	Acetone	15,610	--	18,800	9,200	12,400	16,100	15,500	12,700	10,600	2,721	8,300	7,900	10,200	10,700	10,900	10,118	6,735
	Freons	16,825	6,531	10,900	13,300	15,000	10,200	12,400	13,800	8,200	3,265	9,200	12,800	12,500	32,200	28,400	22,006	27,097
C	Perchloroethylene	10,540	680	3,400	680	1,000	820	680	1,000	1,400	--	340	1,400	9,100	340	--	2	32
	Kerosene	7,338	--	8,100	5,000	5,900	4,800	4,600	4,400	3,800	--	4,100	5,800	5,300	5,500	2,800	1,315	614
	Methyl ethyl ketone	--	--	--	--	--	2,300	9,400	10,600	14,300	3,537	22,000	11,400	21,000	400	6,200	5,805	4,238
	Ethanol	--	--	--	--	--	--	1,088	9,200	10,900	--	9,900	9,400	11,800	12,800	13,500	7,024	9,420
	Toluene	2,063	--	2,300	2,100	1,200	2,700	3,300	1,600	2,100	--	2,100	650	60	60	190	337	83
	n-Butyl acetate	--	--	--	--	--	3,311	5,170	2,222	10	--	--	--	--	--	--	--	--
	Ethyl acetate	--	--	--	--	--	--	104	2,404	180	1,633	--	--	--	--	--	--	--
	Methanol	1,125	--	590	540	1,500	1,700	6,600	4,300	2,600	--	3,300	2,400	3,400	3,100	730	3,298	1,607
C	Methylene chloride	1,669	--	820	820	310	1,000	820	2,200	250	771	170	180	230	430	100	1,876	2,028
	Isopropanol	--	--	--	--	--	--	218	952	950	--	--	--	--	--	--	--	--
	n-Hexane	--	--	--	--	--	209	304	290	210	--	--	--	--	--	--	--	--
C	Chloroform	3,088	--	360	250	500	380	370	190	160	--	200	310	250	320	500	177	208
C	Carbon tetrachloride	558	--	300	290	250	100	250	230	200	--	280	100	180	190	60	103	238
	Xylene	--	--	--	--	--	--	86	227	290	--	--	--	--	--	70	59	135
C	Benzene	--	--	181	127	110	45	141	32	40	--	--	--	--	--	70	12	78
	Tetrahydrofuran	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	30	79
C	Dioxane	--	--	--	--	--	--	14	32	15	--	--	--	--	--	--	--	--
	INORGANICS																	
C	Cadmium	1.E-02	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
C	Beryllium	3.E-05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	Mercury	--	--	--	--	--	--	500	290	180	--	140	140	200	210	60	24	1
	ACIDS										--							
	Nitric acid	20,200	--	--	--	--	--	--	--	80,000	--	58,100	71,900	99,500	70,500	52,100	55,976	54,212
	GASES																	
	Helium	--	--	--	--	--	--	--	--	--	6800-13,600	--	--	--	--	--	--	--
	Sulfur hexafluoride	6,812	--	17,400	6,700	10,300	11,400	12,200	13,700	9,200	8,209	11,400	6,900	10,600	8,800	14,200	9,507	14,560

-- Not reported.

C known or suspected human carcinogen

[1] 1971 Pollutant Inventory. Releases estimated by group leaders using chemical stock issue records. (Rep. No. 756 / 997).

[2] Response to Sept. 6 TWX Concerning Use of Trichloroethylene. H-5 Division. September 14, 1973. (Rep. No. 2816).

[3] Attachment II to Air Quality Regulation Review #3: NAAQS. Chemical and gas usage. June 9, 1980. (Rep. No. 610);
Volatile and/or dangerous chemicals checked out of the storeroom (Rep. No. 1324);
Airborne effluents 1973: airborne releases, nonradioactive 1972-73 (Rep. No. 1197).

[4] Atmospheric Emissions of Non-Radioactive Materials. Losses estimated by LASL groups using >1500 lb/yr. January 17, 1979. (Rep. No. 610).

[5] Attachment I to Nitric Acid and NOx Emissions. November 30, 1982. (Rep. No. 511).

[6] Table G-12, p. 140, of the HSE-8 Annual Report. Attachment to Chlorinated Hydrocarbon Solvents. December 2, 1986. (Rep. No. 280).

The project team has been following Environmental Restoration (ER) activities at LANL since the project began in early 1999. Numerous press releases and fact sheets regarding environmental investigations and surveillance activities have been provided by the ER Project and have supplied some relevant information. For example, oxalic acid was used to purify uranium and plutonium in early operations at TA-1 and TA-21. Oxalate has been detected in a groundwater monitoring well in Lower Los Alamos Canyon (LANL 1998). Recently, perchlorate was detected in a groundwater monitoring well in Mortandad Canyon, in a water supply well in lower Pueblo Canyon, and in the CMR Building ductwork (LANL 2000). Perchloric acid is used in high-explosive (HE) formulation (Dobratz 1995) and in nuclear chemistry analyses conducted in CMR Building.

Explosives including HMX, RDX, and TNT that have been detected in a groundwater monitoring well at TA-16 (S Site) and at Material Disposal Area-P reflect machining and subsequent disposal activities that occurred at TA-16, the center for research in high explosives since the 1940s. Prior to the construction of the High-Explosives Wastewater Treatment Facility at TA-16 in the 1990s, over 12 million gallons of water per year were used to keep the surface of high explosives cool and wet while machining. Following settling of the solids and heavier materials, the remaining water was discharged to the environment via outfalls. The wet solids were trucked to a burning ground, separated from liquids with a sand filter, then dried and ignited. The filtrate was treated before being discharged. Solvents such as acetone, methanol and ethanol were released to the atmosphere by volatilization from the water discharged at the outfalls (LANL 1998, 1999).

Detonable quantities of explosives have been removed from MDA-P during RCRA clean-closure excavation activities (Santa Fe New Mexican 1999). A document located on microfiche in the Central Records Center at LANL (author and date unknown; Repos. No. 672) states that quantities of explosives burned at TAs-14, 15, 16, 36, and 40 range from 100-300 lb/yr at TAs-14 and 33, to 96,300 lb/yr at TA-16. Normal uranium, HE-contaminated solvents (unidentified) and other combustibles are also disposed of by burning at these locations.

Project team review of X-Division Progress Reports from 1944 through 1945 has yielded reported estimates of quantities of high explosives used during that time period. These data are presented in Table 19-4.

Table 19-4: Reported Quantities of High Explosives Used per Month (lbs)

DATE >	Aug-44	Sep-44	Oct-44	Nov-44	Dec-44	Jan-45	Feb-45	Mar-45	Apr-45	May-45	Jun-45	Jul-45	Aug-45	Sep-45	Oct-45	Nov-45	Dec-45
EXPLOSIVE																	
Barium Nitrate						3,250	3,170	19,850	42,750	35,000	57,500	60,000	-				18,000
Composition B					23,523	27,600	47,150	80,850									17,000
Composition B-1	6,800	5,366	7,510										-				
Composition B-2			3,900						20,600	87,500	90,250	66,850					
TNT		650	131		1,250	2,935	2,475	7,500	9,200	12,800	20,400	20,150	-				6,000
Aluminum-TNT 60/40					937	1,008	1,390	1,750	200								
Torpex [1]	1,100	1,250	6,953														
Saltex		463															
Pentolite						500	0										
Cyclotol 70/30							250										
PTX										150	100	150					
RDX											6						
Sum	7,900	7,729	18,494		25,710	35,293	54,435	109,950	72,750	135,450	168,250	147,150					41,000
Reported TOTAL	8,900	12,434	18,494	--	23,523	34,793	54,185	109,950	72,550	135,300	168,150	147,000	-	--	--	--	41,000
Waste (lbs)	1,200	1,518	2,160														
Rejected Castings																	28%

Source: X-Division Progress Reports 1944-47 (Rep. Nos. 2931, 2915, 2916, 2917, 2918, 2919, 2920, 2921, 2936, 2935, 3128, 3272, 2937).

[1] Torpex is 5:1 Comp B :TNT

-- Quantities of explosives used are not reported in the monthly X-Division Progress Report for November 1944.

A 1981 memorandum from R. W. Ferenbaugh to H. S. Jordan dated January 27, 1981 states that 20,000 – 30,000 kg (91,000 – 136,000 lbs) per year of waste explosives were disposed of at TA-16 by open burning. Explosive burning experiments conducted at LASL several years prior to 1981 estimated annual emissions of 600-800 kg of NO_x, 100-200 kg of carbon monoxide, and 300-500 kg of unidentified particulates from this open burning process (Ferenbaugh 1981; Repos. No. 611).

An effluent material summary for group GMX-7 (Drake 1971; Repos. No. 2114) includes several explosives dispersed at TA-40 as gaseous detonation products during the period July – September 1971 (Table 19-5). Toxic material reports for December 1979 through September 1980 (Dinegar 1980; Repos. No. 2112) report the approximate amounts of HE exploded per month in WX-7 shots at TA-40 and TA-22.

Fig. 19-2. LANL workers watch an explosive test in the distance

Table 19-5. Reported Quantities of Explosives Dispersed

Explosive	July – Sept 1971	Dec 1979 (kg)	Jan 1980 (kg)	Feb 1980 (kg)	Mar 1980 (kg)	Apr 1980 (kg)	May 1980 (kg)	June 1980 (kg)	July 1980 (kg)	Aug 1980 (kg)	Sept 1980 (kg)
Nitromethane	450 kg (990 lb)	--	--	--	--	--	--	--	--	--	--
Comp B	34 kg (75 lb)	0.1	3.1	10.8	22.4	13.2	6.7	19.6	--	52.8	9.6
Baratol	--	0.1	2.9	17.1	63.7	21.1	16.4	25	--	89	3.4
TATB	--	0.4	0.7	0.25	0.1	0.4	0.4	0.03	0.6	0.7	0.7
TNT	--	--	--	2.7	5.4	13.5	2.7	5.4	--	25	2.7
Octol	--	--	12	6	3	--	6	3	--	6	--
PETN	7 kg (15 lb)	0.02	0.09	0.06	0.05	0.1	0.01	0.13	0.03	0.05	1.2
PBX	0.9 kg	0.1	0.4	0.4	0.3	0.4	0.3	0.05	0.4	0.3	0.5
Tetryl	0.05 kg	--	--	--	--	--	--	--	--	--	--
TOTAL	492 kg	1 kg	19 kg	37 kg	44 kg	49 kg	32 kg	54 kg	1 kg	174 kg	18 kg

-- not reported

Research, development, and testing of high explosives were conducted at more than 25 different Technical Areas of LANL (Goldie 1984; Repos. No. 658). Many new formulations of the conventional explosives HMX, RDX and TNT were synthesized and tested at LANL since the 1940s (Dobratz 1995). Other high explosives such as Baratol, Comp B, Pentolite, Torpex, and Tetryl were tested at the firing site at TA-14 (IT Corporation 1989; Repos. No. 2192).

Uranium and other metals such as lead, beryllium, aluminum and cadmium (HAI 1993; Johnson and Dahl 1977; Repos. No. 2249) were released to the environment as a result of test shots conducted at LANL since the 1940s. Drake and Eyster (1971; Repos. No. 1412) estimate that between 75,000 and 95,000 kg of uranium has been expended in experimental shots at LANL from 1949-1970. Normal uranium was used until 1954, then depleted uranium was used exclusively. The estimate does not address where the uranium went, only that they don't have it any longer. A 1952 AEC report states that test shots at LASL routinely dispersed 300 lbs of uranium per month and 200 lbs of barium per month (English 1952). Two 1971 memoranda (Drake 1971; Repos. No. 2114) report toxic materials dispersed by GMX Division shots for April and May 1971 as shown in Table 19-6.

Table 19-6. Materials Dispersed by GMX Division Shots for April and May 1971

Toxic Material	April 1971	May 1971
Uranium-238	171 kg (376 lb)	142 kg (312 lb)
Beryllium	0.7 kg	3 kg
Tritium	125 cm^3 STP	208 cm^3 STP
Lead	0.042 kg	0.8 kg
Bromine	0.165 kg	--

-- not reported

Most of the documents describing PCBs at LANL that have been identified by the project team to date are logbooks of analytical results with unidentified sampling locations. Several documents describe storage and disposal of PCB wastes at TAs-21 and 54 (Santa Fe Engineering 1995; Repos. No. 1262). PCB cleanups were conducted at TAs-3, 53, and near groundwater production wells in the mid 1980s and 1990s as a result of leaking transformers and capacitors (Unknown 1997 [Repos. No. 1094]; LANL 1993 [Repos. No. 1269]). Aroclor-1242 was used as a coolant in CMB-11 division in 1961 (Enders 1969; Repos No. 1409).

A 1973 document, "Summary of wastes and effluents for Omega Site TA-2", estimates that 1.4 lb d^{-1} of hexavalent chromium were released to the air in cooling tower effluent. The Omega West Reactor (OWR) primary water was cooled via a 5 MW evaporative cooling tower. Trichloro-s-triazinetrione

($C_3N_3O_3Cl_3$), a common microbicide, was added to the secondary-side water in the tower to control algae growth. A second product containing polyacrylate polymer, polyoxylated aliphatic diamine, and tolyltriazole was added to control scale and corrosion. Cooling tower water was discharged to the environment via entrainment in the exhaust air stream and through discharges of blowdown water to Los Alamos Canyon Creek. These blowdown discharges were another measure used to control scale and corrosion in the secondary (sump) water by eliminating solids. Repos. No. 645 reports that these discharges totaled approximately 60,000 gallons per week in 1973. Another 300 gallons per week of blowdown water came from the heat exchanger for the primary water in the OWR's demineralizer loop. Like the main OWR exchanger, the cooling water for this heat exchanger came from the municipal water supply.

Repos. No. 645 also reports the exhaust air stream from the OWR cooling tower included entrained secondary water that was discharged to the environment at a rate of 3.9 gal min^{-1}. The document states this resulted in the discharge of 20 lb of sulfuric acid and 1.4 lb of hexavalent chromium to the atmosphere per 24 h period.

Draft Comprehensive Environmental Assessment and Response Program (CEARP) documents from 1986 (Repos. No. 525) report a staff member recalling the use of potassium dichromate in the cooling tower water prior to a time when the heat exchanger components were changed from aluminum to steel. CEARP was the Department of Energy's Superfund program for Federal Facilities in the 1980s. The employee stated that mist from the tower would drift about the site and turn things green. This "greening" effect went away with the switch to steel components (and the subsequent reduction in use of potassium dichromate). The use of potassium dichromate as a corrosion inhibitor is confirmed in Repos. No. 645, which states that the blowdown discharges from the cooling tower (~60,000 gal per week) included approximately 14.5 pounds of hexavalent chromium. This same document reports that the blowdown also included 3 lb of chlorophenol biocide and 200 lb of sulfuric acid in the form of sulfate salts (used for pH control). The blowdown from the demineralizer loop heat exchanger contributed another 20 lb of sulfuric acid and 0.5 lb of chlorophenol biocide. Repos. No. 645 also says it was planned to make the switch from aluminum to stainless steel components in fiscal year 1974 to reduce to amount of corrosion inhibitor required and thus reduce the amount of hexavalent chromium in the blowdown water.

An inventory of pollutant releases to the environment for 1971 (Repos. No. 883) states that use of chromates will be discontinued once the aluminum heat exchanger is replaced with a stainless steel unit. This same document reports the average concentration of hexavalent chromium in the TA-2 blowdown to be 25 mg L^{-1}, which was 2,500 times the quality standard of 0.01 mg L^{-1} for that era. The same effluent

stream is reported to contain total dissolved solids at an average concentration of 800 mg/l, which also exceeded the applicable quality standard of 500 mg L^{-1}.

The Water Boiler's cooling tower used potassium dichromate by the hundreds of pounds; waterborne effluent ran down the nearby creek, and sometimes chromium "rained from the sky," and windshields on people's cars had to be replaced (G. Neely, 1999 personal communication). Condensate poured on the ground; there was a tree in the area with Cs-137 in its leaves as a result. There was reportedly also asbestos in some TA-2 buildings.

Repos. No. 2211 reports that a "very serious" mercury spill took place at the Clementine site on December 31, 1948 that required a "prolonged period" of cleanup. This report also mentions that routine monitoring for mercury vapor had been going on at the Clementine site prior to this incident.

Repos. No. 2201 reports that a mercury spill occurred at the Clementine site between January 20, 1951 and February 20, 1951. Air samples were collected and analyzed for mercury vapor and urine samples were collected from three exposed workers. The report states that "the results obtained showed all exposures below hazardous levels."

In late 1952, it was reported that members of H Division had been participating in conferences relative to the large quantity of contaminated mercury to be pumped from the fast reactor at Omega Site. Since the material was contaminated with plutonium, it appeared to the participants that the plutonium hazard was more serious than that of the mercury vapor [Repos. No. 124].

Perchlorate was identified in shallow groundwater in Mortandad Canyon at concentrations ranging from 80 to 220 ppb. Perchlorate was also found in groundwater characterization wells at 12 ppb and in drinking water supply wells at 2 to 3 ppb, just above analytical detection limits. It is assumed that the perchlorate contamination was discharged in effluent from the TA-50 Radioactive Liquid Waste Treatment Facility, and also from legacy waste that was discharged into Acid Canyon from the TA-45 treatment plant which operated from 1943 to 1964.

In August 2002, benzene was identified in soil at TA-48 from historical solvent use.

Accident/ incident files from the Health Divisions were identified for 1944-1991 (Repos. Nos. 3461-3496). However, the files primarily document chemical spills and indoor exposures to workers. Operations related to the presence of the chemical are not described. The documentation of a few incidents that could have resulted in releases to the off-site environment was extracted and entered into the project database. A document titled "Chronological Record of Accidents at LASL" lists a fatality due

to asphyxiation by methyl chloroform at “New” Sigma Building on February 14, 1961 (Unknown 1979; Repos. No. 514). Details of the accident are not provided.

Many of the Health/ Industrial Hygiene Division reports and correspondence files include memoranda regarding the presence of numerous solvents, metals, and acids in various LANL divisions. However, details regarding building locations, quantities used, or the operations involved are rarely provided. The chemicals mentioned are included in Table 13-1.

Preliminary Prioritization for Chemicals

USEPA Region 9 Preliminary Remediation Goals (PRGs) are target cleanup levels based on conservative assumptions regarding direct exposure to soil through ingestion, dermal contact and inhalation, and direct inhalation of vapors and particulates (USEPA 2002). PRGs are based on cancer as an endpoint if available cancer potency factors (“slope factors”) result in a more conservative (lower) PRG than would result based solely on evaluation of non-cancer health effects.

As a first step towards prioritization of potential chemical releases, PRGs for chemicals used and possibly released historically from LANL were used by the LAHDRA team to rank the potential of various chemicals to result in adverse health effects to off-site populations. The lower a PRG, the higher the potential for off-site health effects if the compound were released beyond the site boundary– this preliminary ranking does not address actual quantities released or whether real exposures occurred; however, these factors will be considered as the prioritization process advances.

PRGs for soil were used to rank chemicals usually present in the environment as particulates, and PRGs for air were used to rank volatile chemicals. Both soil and air PRGs were considered for explosives. Toxicity factors are not available for some chemicals used at LANL, and estimates of quantities used have been identified through systematic document review for only a subset of those chemicals with published toxicity factors. Estimates of quantities of a material used on an annual basis are in some cases available. “Annual use” is typically the highest known annual usage of a compound from available data, and in some cases may be based on a single year for which data are available. Reported values are often presented as quantities used, issued, lost, or released, and it is not always clear how the quantities were determined.

Table 19-7 shows a ranking of Los Alamos chemicals based on PRGs for soil, while Table 19-8 presents a ranking based on PRGs for air. Table 19-9 presents a ranking method that takes into account estimates of annual usage and U.S. EPA toxicity values such as slope factors and RfDs. Oral slope factors are used to indicate the strength of the chemical's ability to cause cancer. A cancer slope factor is an upper bound probability estimate of cancer incidence per unit intake of a carcinogen over a lifetime. Therefore, the higher the slope factor, the more carcinogenic a chemical is according to the U.S. EPA. RfDs are used to rank a chemical's ability to cause an adverse health effect other than cancer. According to the U.S. EPA, an RfD is an estimated daily intake that if taken over a lifetime, is not expected to cause an appreciable risk of adverse health effects. Hence, according to the U.S. EPA, the smaller the RfD, the more toxic the chemical. Chemicals were ranked based on slope factors and RfDs independently to distinguish between the most important chemicals in terms of cancer risk and adverse health effects. Chemicals that are considered carcinogens by the U.S. EPA were ranked based on annual usage multiplied by the cancer slope factor. Oral slope factors were used in all but one case because they were more conservative than the inhalation slope factor. All chemicals for which the U.S. EPA has published RfDs were ranked by multiplying the annual usage by the inverse of the RfD. Some chemicals have both ingestion and inhalation RfDs, and in these cases, the more conservative value was used in order to consider the most sensitive health endpoint.

References

Albuquerque Journal. Potential explosive [perchlorate] builds at LANL. March 24, 2000.

Dinegar, R. H. Toxic Material Reports for WX-7, December 1979 through December 1980. Repos. No. 2122.

Dobratz, Brigitta M. The Insensitive High Explosive TATB: Development and characterization-- 1888-1994. LA-13014-H. LANL Technical Report Library. August 1995.

Drake, R. Routine Effluent Reports for GMX-7, May through September 1971. Repos. No. 2114.

Drake, R.W. and E.H. Eyster. Memorandum from E.H. Eyster to G.L. Voelz. Uranium dispersed by experimental test shots at Los Alamos. May 3, 1971. Repos. No. 1412.

Enders, J. H-5 group correspondence re: CMB and CMF, 1948-1969. Repos. No. 1409. [niobium, molybdenum, platinum, samarium, tantalum, aqua regia]

Enders, J. CMR weekly and monthly reports, 1960-70. Repos. No. 919/2072. [tetrahydrofuran, tetrabromoethane]

Table 19-7: Ranking of LANL Chemicals Based on PRGs for Soil

Chemical	PRG for soil [mg/kg]	Rank
Arsenic	3.90E-01	1
RDX (hexahydro)	4.40E+00	2
Thallium	5.20E+00	3
Perchlorate	7.80E+00	4
TNT (2,4,6-trinitrotoluene)	1.60E+01	5
Uranium	1.60E+01	6
Nitrobenzene	2.00E+01	7
Mercury	2.30E+01	8
Antimony	3.10E+01	9
Vanadium	7.80E+01	10
Molybdenum	3.90E+02	11
Silver	3.90E+02	12
Lead	4.00E+02	13
Lithium	1.60E+03	16
Nickel (soluble salts)	1.60E+03	14
Manganese	1.80E+03	15
HMX (octahydro)	3.10E+03	17
Copper	3.10E+03	18
Fluoride	3.70E+03	19
Barium nitrate	5.40E+03	20
NQ (nitroguanidine; Picrite)	6.10E+03	21
Acetone	1.40E+04	22
Iron	2.30E+04	23
Zinc	2.30E+04	24
Aluminum	7.60E+04	25
Bromine	N/A	
Gallium	N/A	
Lanthanum	N/A	
Niobium	N/A	
Platinum	N/A	
Samarium	N/A	
Tantalum	N/A	
Zirconium	N/A	

Table 19-8: Ranking of LANL Chemicals Based on PRGs for Air

Chemical	PRG for air [microgram/m^3]	Rank
Chromium (total)	1.60E-04	1
Beryllium	8.00E-04	2
Cadmium	1.10E-03	3
Polychlorinated biphenyls- Aroclor 1242 (1254)	3.43E-03	4
Trichloroethylene	1.70E-02	5
Chloroform	8.30E-02	6
Hexachlorobutadiene	8.60E-02	7
Carbon tetrachloride	1.30E-01	8
Benzene	2.50E-01	9
Tetrachloroethylene	3.20E-01	10
1,4-Dioxane	6.10E-01	11
Tetrahydrofuran	9.90E-01	12
Hydrogen Cyanide	3.10E+00	13
Methylene chloride	4.10E+00	14
Phosphoric acid	1.00E+01	15
Chloromethane	9.50E+01	16
Xylene	1.10E+02	17
Dichlorodifluoromethane	2.10E+02	18
n-Hexane	2.10E+02	20
Toluene	4.00E+02	19
Ethyl Ether	7.30E+02	21
Methanol	1.80E+03	22
Trichloroethane (methyl chloroform)	2.30E+03	23
Ethyl acetate	3.30E+03	24
Methyl ethyl ketone	5.10E+03	25
Ethylene glycol	7.30E+03	26
1,1-Difluoroethane	4.20E+04	27
Chlorodifluoromethane	5.10E+04	28
Naphthalene	N/A	
Ethanol	N/A	
Isopropanol	N/A	
Kerosene	N/A	
Tetrabromoethane	N/A	
n-Butyl acetate	N/A	
Asbestos (magnesium silicate)	N/A	
Bromide	N/A	
Hydrochloric acid	N/A	
Hydrofluoric acid	N/A	
Nitric acid	N/A	
Oxalic acid	N/A	
Sodium hydroxide	N/A	
Sodium thiosulfate	N/A	
Sulfur hexafluoride	N/A	
Sulfuric acid	N/A	
Baratol (barium nitrate+TNT)	N/A	
Comp B (60% RDX; 40% TNT)	N/A	
Cyclotol (70-75% RDX; 25-30% TNT)	N/A	
Explosive D (NH3 picrate; NH3-1,3,5-trinitrophenol)	N/A	
Nitrocellulose	N/A	
Nitromethane	N/A	
Octol (70-75% HMX; 25-30% TNT)	N/A	
PBX	N/A	
Pentolite	N/A	
PETN (pentaerythritol tetranitrate)	N/A	
Picric acid	N/A	
PTX-2 (2,6-bis-picrylamino-3,5-dinitropyridine)	N/A	
Saltex	N/A	
TATB (1,3,5-triamino-2,4,6-trinitrobenzene)	N/A	
Tetryl (1,3,5-trinitrophenyl-methylnitramine)	N/A	
Torpex (83%Comp B; 17% TNT)	N/A	

Table 19-9: Ranking of LANL Chemicals Based on Toxicity Parameter and Annual Usage[1]

Chemical	Slope Factor (SF) [mg/kg-d]$^{-1}$	Reference Dose (RfD) [mg/kg-d]	Annual Use [kg]	Ranked Based on Cancer Effects		Ranked Based on Non-cancer Effects	
				SF x Annual Use	Rank	1/RfD x Annual Use	Rank
Acetone	-	0.9	18,800	-		20,889	13
Barium nitrate	not in RAIS	not in RAIS	108,873	-		-	
Benzene	0.055	0.004	181	10	7	45,250	9
Carbon tetrachloride	0.13	0.0007	558	73	5	797,143	5
Chlorodifluoromethane[2]	-	14.3	32,200	-		2,252	17
Chloroform[3]	0.0805	0.01	3,088	249	4	308,800	7
Dichlorodifluoromethane[2]	-	0.0571	32,200	-		563,923	6
Dioxane	0.011	-	32	0.35	8	-	
Methanol	-	0.5	6,600	-		13,200	14
Methyl ethyl ketone	-	0.6	22,000	-		36,667	12
Methylene chloride	0.008	0.06	2,200	17	6	36,667	11
n-Hexane	-	0.06	304	-		5,067	16
Tetrachloroethylene	0.54	0.01	10,540	5,692	2	1,054,000	4
Tetrahydrofuran	not in RAIS	not in RAIS	79	-		-	
TNT (2,4,6-trinitrotoluene)	0.03	0.0005	37,950	1,139	3	75,900,909	3
Toluene	-	0.08	3,300	-		41,250	10
chloroform)	-	0.2	39,300	-		16,500	8
Trichloroethylene	0.4	0.0003	27,719	11,088	1	92,396,667	1
Uranium	-	0.0006	47,500	-		79,166,667	2
Xylene[2,4]	-	0.0286	290	-		10,140	15

[1] All values were obtained from the Risk Assessment Information System (RAIS) available at: http://rais.ornl.gov

[2] Inhalation RfD was used because it was more conservative than the oral RfD. In all other cases, oral RfDs were used because they were most conservative

[3] Inhalation cancer slope factor was used because it was more conservative than the oral slope factor. In all other cases, oral slope factors were used because they were most conservative

[4] Combined congener values were used (combined, p-, m-, o-).

English, S.G. Project Crave: Survey of U.S. Atomic Energy Commission Operations and Facilities. Brookhaven National Laboratory. BNL-157. February 25, 1952. Repos. No. 2950.

ESH. Interview with members of the LANL Environmental, Safety and Health Division (ESH-5) Jonathan Tapia and Bill Hargraves on January 6, 1999 by Susan Flack of the project team.

Ferenbaugh, R. W. "Memoranda on LANL Air Emissions: Memo to Harry S. Jordan regarding open burning of explosives at S-Site." January 27, 1981. Repos. No. 611.

Goldie, R.H. Memorandum from R.H. Goldie, HSE-3, to D. Pinyan, HSE-3. Areas containing or contaminated by explosives. October 2, 1984. Repos. No. 658.

HAI. History Associates, Inc. Site History of Los Alamos (Draft). January 1993. [HE metals]

IT Corporation. Sampling and Analysis Plan for Mixed Waste Surface Disposal Area at TA-14. 1989. Repos. No. 2192.

Johnson, L.J. and D.A. Dahl. Aerosolized uranium, lead, and beryllium from LASL dynamic experiments. LA-UR-77-68. 1977. Repos. No. 2249.

LANL. Health Division Annual Report, 1951. LA-1256. May 25, 1951. Repos. No. 1349. [naphthalene]

LANL. Solid Waste Management Units Report. Environmental Restoration Records Processing Facility. November 1990.

LANL. High-Explosives Wastewater Treatment Facility- An environmental success story [HE, acetone, methanol, ethanol]. LALP-98-84. 1998.
LANL. Laboratory releases surveillance well data [oxalate]. LANL News Release. April 17, 1998.

LANL. Lab releases first information from third characterization well [HMX, RDX, TNT]. Los Alamos National Laboratory News Release. January 28, 1999.

LANL. Perchlorate detected in water-supply well. Los Alamos National Laboratory News Release. July 20, 2000.
LANL. Laboratory detects perchlorate in shallow groundwater. LANL News Release. March 2, 2000.

LANL Environmental Restoration Project. RFI Report for OU 1071 – leakiage from PCB transformers. April 1993. Repos. No. 1269.

LANL Environmental Restoration Project. Fact Sheet: Material Disposal Areas. February 4, 1999. [HE]

Ramsay, John B. "HE Incidents and Accidents at LANL 1951-1999", LA-13697-H, March 2001.

Santa Fe Engineering. Storm Water Pollution Prevention Plan. June 1995. Repos. No. 1262.

Santa Fe New Mexican. "LANL finds still-potent explosives during excavation of dump site." November 10, 1999.

Schulte, H.F. Industrial Hygiene Progress Reports, 1949-1950. Repos. No. 668. [naphthalene]

Unknown author. Summary of wastes and effluents at Omega Site (TA-2). August 27, 1973. Repos. No. 645. [chromium]

Unknown author. Chronological record of accidents at LASL. 1979. Repos. No. 514.

Unknown author. PCB cleanup at TA-3 (OU#1114), 1995-97. Repos. No. 1094.

Unknown author and date. Disposal of hazardous materials by burning. Central Records Center. Repos. No. 672.

U.S. Congress. Office of Technology Assessment. Complex Cleanup- The environmental legacy of nuclear weapons production. February 1991.

USDOE. U.S. Department of Energy. The 1996 Baseline Environmental Monitoring Report. Volume III – New Mexico – Wyoming. DOE/EM-0290. June 1996.

USEPA Region 9 Preliminary Remediation Goals.
http://www.epa.gov/region09/waste/sfund/prg/files/02table.pdf
October 1, 2002.

Chapter 20: A Screening-Level Evaluation of Airborne Beryllium Releases from LANL Operations

Introduction

Historical records indicate that beryllium was used at Los Alamos for some time before its health hazards were fully recognized (Shipman 1951, Hempelmann and Henrickson 1986). While beryllium became recognized as a worker health hazard, potential exposures to members of the public who lived in Los Alamos have not been as well characterized. Because residents lived closer to production and testing areas at Los Alamos than at any other nuclear weapons complex site, this screening-level assessment of potential public exposures was undertaken**.**

Identification of Sources of Beryllium Releases at LANL

Based upon the review of information collected under the LAHDRA project, screening level assessments were completed for the following historical operations at Los Alamos that involved processing or use of significant quantities of beryllium:

- Early machining operations at a shop in the Original Technical Area, TA-1, known as V Shop
- Machining in shops at TA-3, Building SM-39, that started late in 1953
- The testing of atomic bomb components by firing them from a 20-mm anti-aircraft autocannon in an annex to B Building at TA-1
- The hot pressing of beryllium oxide powder in Q Building at TA-1 to make reactor components
- The expenditure of beryllium in explosive tests conducted at the PHERMEX facility at TA-15

Estimation of Release Rates over Averaging Periods Shorter Than a Year

Limits on occupational and public exposures to beryllium are stated as concentrations that vary with averaging time, including those specified for instantaneous concentrations as well as 8-h and 30-d average concentrations. Generally, the shorter the exposure (or stack sampling) time is, the higher the allowed concentration. However, reported LANL air concentrations of beryllium are often reported or can only be estimated in terms of annual averages or totals released over a year. During any year, concentrations over short periods will be greater than (and at other times also less than) the annual average. Because there is evidence to suggest that the occurrence of chronic beryllium disease is not related to duration of exposure (ATSDR 2002), indicating that exposures over short periods can be of health significance, the LAHDRA

team recognized the need for a method to predict the upper bounds of airborne beryllium concentrations over time intervals from less than an hour to 30 d based on data that represent concentrations or releases over a full year.

In order to estimate the magnitude of the variations of airborne concentrations that one would expect within a year, a study was made of another material released in particulate form by LANL, plutonium. Like beryllium, facilities that exhaust plutonium to the air have been subject to increasingly stringent controls, resulting in the use of filters on the exhausts in the 1950s and high efficiency particulate air (HEPA) filters by the mid-1960 for both contaminants. Like beryllium, samples of the exhaust air from plutonium facilities at LANL have been collected on filters to assess effluent air concentrations. Further discussion of similarities between particles of plutonium and beryllium, how they behave, and how they have been assessed by others is provided elsewhere (Shonka 2009). Unlike beryllium, however, plutonium samples have been routinely reported for time intervals as short as a work day.

In order to estimate how high beryllium release rates from chronic release sources could have been over averaging periods shorter than a year, the detailed monitoring data that are available for airborne plutonium releases from DP West Site stacks for 1956 and 1957 were analyzed. The relationships between work-day averaged concentrations and weekly, monthly, and annual average concentrations were characterized, and a table of multipliers was generated that can be applied to annual data to estimate peak releases over a series of shorter durations. To support this preliminary screening, airborne beryllium releases were assumed to vary over time like the measured airborne plutonium releases (that is, having similar ratios of annual averages to averages over shorter periods), and estimated annual beryllium releases were converted to release rates over shorter durations so that airborne concentrations over appropriate averaging periods could be compared to occupational and ambient exposure limits. If further evaluation of historical beryllium operations and releases is undertaken, a more detailed analysis of operational and air sampling data for beryllium activities might support a more direct characterization of the temporal variations of beryllium concentrations in exhaust streams.

Nine-hour averaged air concentrations of plutonium (corresponding to weekday working hours) for the four main stacks on Building 12 at DP West Site for calendar years 1956 and 1957 were entered into a spreadsheet. Raw daily data have not been located for earlier years. HEPA filters were added to the process exhaust system at DP West in 1959, and because the bulk of the releases from the facility appear to have come from exhausts that were not HEPA filtered, the earlier data was chosen as most representative of the conditions of greatest interest.

Averages were computed for 9 h (the raw data) as well as for weekly (45 h), monthly (196 h) and annual (2,349 h) averages. The data were maintained as 9-h working days in order to match the recorded data. In addition, the actual days for each week and month within 1956 and 1957 were maintained. Except for the annual average data, which had only one data point for each series (1956 and 1957), the data for each averaging period were fit to lognormal distributions with excellent residuals.

One can fit a lognormal distribution to an equation of the form $y = a \times e^{bx}$, where y is the natural log of the observed concentration and x is the standard deviation. The exponential constant (e^b in the equation $y = a \times e^{bx}$) provides the geometric standard deviation of the lognormal distribution. Both 1956 and 1957 had similar exponential factors, and the data were averaged for a best estimate. Examination of the data showed no general time dependence in concentration over the course of a year (such as slow falloff with time), even though LANL emissions did trend lower over the decades of DP West operations. The "b" value was plotted as a function of the log of the integration time and fit to a linear equation. With this equation, the geometric standard deviations (e^b) for treated particulate releases were predicted for various integration times ranging from 6 min to one month.

The analyses of the releases from DP West are summarized in Table 20-1 below. The 95th percentile for monthly data would correspond (roughly) to a concentration reached on one day of each month. As one goes to shorter time intervals, the 95th percentile is reached more and more often, and is not a useful factor to use for a conservative analysis. For example, using the 95th percentile, the 1-h data would be expected to either be larger or smaller than the annual average by a factor of 8.2 for 1 h out of every 20. Thus, hourly data would expect to be exceeded every 1 or 3 d, and 6 min (0.1 h) data would be seen as often as twice a day. As a result, the table also lists the multiplicative factor that would be found for a concentration that would be attained once per 1600-h work year. Using the "once per year" values, one can see from Table 20-1 that the 1-h data would exceed the annual average values by a factor of 30 for the estimated highest hour of the 1600 hour work year. Although the regulatory requirements dictate an instantaneous limit, this analysis has limited the averaging period to a minimum of 0.1 h. The data indicate that at 30 min of sampling or exposure time (0.5 h) the concentration would exceed annual averages by a factor of 47 once per year. No "once per year" multipliers are provided for weekly or monthly time periods. The 95th percentile should be used for screening for those time periods. The duration factors are not used in the estimation of episodic releases, for which releases for each event were estimated and converted to average concentrations over longer periods based on assumed numbers of events of stated material content within each period.

Table 20-1. Geometric standard deviation data based on analysis of detailed DP West plutonium stack sampling data, with factors to estimate release rates over periods shorter than 1 y

			Multiplicative factors to be applied to annual values to estimate values over specified intervals	
Time Interval	**Equivalent Hours**	**"b" Value [a]**	**95th Percentile**	**Once per year**
6 min	0.1	1.3	13.6	149
30 min	0.5	1.1	9.5	47
Hour	1	1.1	8.2	30
Work Day	8	0.8	5.2	8.3
Day	24	0.7	4.1	4.6
Work Week	40	0.6	3.6	
Week	168	0.5	2.7	
Month	730	0.3	1.9	
Work Year	1,600	0.2	1.6	
Year	8,760	0	1	

[a] The term e^b represents the geometric standard deviation of the lognormal distribution fitted to DP West stack sample analysis results.

Estimation of Beryllium Release Rates for Identified Emission Sources

Fabrication of components from beryllium metal and oxide (TA-1 and TA-3)

a) New Beryllium Shop (TA-3, South Mesa Building 39, "SM-39," Beryllium Shop 4)

South Mesa Building 39, "SM-39," Beryllium Shop 4 was outfitted with a HEPA filter on the exhaust in 1964. Release measurements after this time period were found for 6 y in the 1960s and reported in a manner that permits annual average releases to be computed. The study of DP West stack particulate releases of plutonium, discussed earlier, provide a means to estimate the concentrations for shorter time periods. The exhaust system apparently ran only during normal working hours. LAHDRA does not know if the stack sampler pump was only operated when the stack exhaust fan was operating. This assessment assumes that the sampler pump also only ran during the hours of operation. If it did not, then the "sampler hours of operation" correction would provide an additional factor of 5.5 increase for the total beryllium released, (= 8760 h / 1600 h) since the concentration in the stack would be expected to be much lower when the machining operations ceased during non-working hours. The documentation of the data for 1964 through 1966 did not identify fan hours of operation, so the average of the operating hours (1600) for the 1968 through 1970 period was chosen.

Table 20-2 and Table 20-3 below summarize the release data found (LASL 1969, 1970). Table 20-3 has the duration factors from Table 20-1 for each time interval applied to the data from 1970 to

permit comparison with applicable limits. The screening calculations utilize 1970, the highest year that has been found to date.

The annual release rate for 1600 h (0.0245 µg s^{-1} for 1970) must be adjusted by 1600 h /8760 h to correctly express the average release rate in a year. In Table 20-2, the "Working Hours" column refers to the fan operating time, which is also the operational release period. The Mass Released column is the release for the specified year. The stack flow rate was 2,000 ft^3 min^{-1} (LASL 1970).

In Table 20-3, the time periods of one day or longer have been corrected for the fact that the release occurs over a shorter time than the integration period. For example, the year release rate is 0.0245 µg s^{-1} times 1602.6 h of operation divided by 8760 h y^{-1}. For time periods less than the operating period (i.e., 1 h or less), this factor is no longer applied, since the 6 to 9 h workday was longer than those time periods, so correcting for the time the stack exhaust was not operating is not needed.

The work day time period corresponds to an 8 h day, the work week to a 40 h period, the month to a 730 h period, and the year to 8760 h. These were chosen in order to permit comparison to occupational and ambient exposure limits.

Table 20-2. Measured beryllium releases from SM-39 shop at TA-3 after 1963

Year	Working Hours	Mass Released, g	Working Hours Release Rate, µg s^{-1}
1964	1600	0.0105	0.0018
1965	1600	0.0106	0.0018
1966	1600	0.0188	0.0033
1967	No data found		
1968	1545.7	0.0089	0.0016
1969	1687.7	0.0378	0.0062
1970	1602.6	0.1416	0.0245

Table 20-3. Estimated SM-39 beryllium shop release rates after 1963 based on measurements made in 1970 and application of duration factors

Year	Release Rate for Stated Averaging Period, µg s^{-1}						
	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1970	3.65	1.16	0.73	0.20	0.089	0.0086	0.0045

b) TA-3, SM-39 Beryllium Shop Operations 1953 - 1963

The beryllium shop at SM-39 was put into operation in 1953 to replace the inadequate facilities in the main shop at V Building in the Original Technical Area. At the start of operations, no provisions were made for HEPA filtration of exhausts. Release measurements were not found for the SM-39 shop in this era. In order to estimate a lower bound for air concentrations and releases from the SM-39 beryllium shop from 1953 to 1963, measurements from the late 1960s were adjusted to account for the fact that no HEPA filters were in place. In general, HEPA filters are considered to attain a filtering efficiency of 99.97% (USDOE 2003). This corresponds to a reduction of the effluent by a factor of 3,333 (=1/ (1-0.9997)). This efficiency is obtained at a particle size diameter of 0.3 µm in diameter, with better efficiencies realized for smaller and larger particles. Data indicate that the filter systems used during this era attained efficiencies in the 90% range. An assumed 95% efficiency would attain reduction by a factor of 20. The ratio of the pre- and post-1964 filter reduction factors is 167 (=3,333/20). For this assessment, SM-39 exhaust monitoring data from 1970 were multiplied by 167 to estimate release rates for 1953 through 1963 (see Table 20-4). Use of this factor likely understates the releases by a considerable amount, given that the airborne particles larger or smaller than 0.3 micron diameter would have been filtered more efficiently. A partially offsetting factor for this conservatism may come from the fact that an improperly installed HEPA filter may not have attained 99.97% efficiency. Because the values represent long term averages, they were multiplied by the factors in Table 20-1 for the desired sampling or exposure time to provide the data in Table 20-5. For comparison purposes, the 1970 data that were the basis for 1953-1964 is repeated in Table 20-5. The 1,600 h y^{-1} exhaust operating period was also assumed. The impact of the lack of HEPA filters before 1964 is readily seen in Table 20-5 by comparing the 1953–1963 data with the 1970 values.

Table 20-4. Estimated airborne releases from the SM-39 beryllium shop from 1953 to 1963

Year	Working Hours	Annual Average Concentration, µg m^{-3}	Mass Released, g	Working Hours Release Rate, µg s^{-1}
1953 – 1963	1600	4	24	4
1970	1602.6	0.0260	0.1416	0.0245

Table 20-5. Estimated SM-39 beryllium shop release rates for 1953–1963 based on measurements in 1970, correction for non-HEPA filtration, and application of duration factors

Year	Release Rate for Stated Averaging Period, µg s^{-1}						
	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1953-1963	610	194	122	34	15	1.4	0.7
1970	3.65	1.16	0.73	0.20	0.089	0.0086	0.0045

c) V-Building Shop Operations at TA-1 between 1949 and 1953

The main shops in V Building at the Original Technical Area, TA-1, were used for machining beryllium prior to the startup of the SM-39 shop at TA-3 in 1953. Around late 1948, when LANL was informed of the hazardous nature of beryllium, the high speed machining operations were relocated into an annex to V Building and an exhaust system was added with filters. For the purposes of this analysis, it was assumed that the non-HEPA filters that were used had comparable filtering efficiencies to the filtering system used at the SM-39 shop at TA-3 before HEPA filtration was added. Because the operations in the V Building shop appear to have been grossly similar to those at the SM-39 shop, the estimated release rate for the SM-39 shop for 1953-1963 was used for V Building shop from 1949 to 1953. The main difference between the two emission sources in terms of prioritization will be the shorter separation of V Building from nearby residences. Estimated beryllium releases are summarized in Table 20-6 and applied to various averaging periods in Table 20-7.

Table 20-6. Estimated airborne releases from the V-Building shop at TA-1 from 1949 to 1953

Year	Working Hours	Annual Average Concentration, µg m^{-3}	Mass Released, g	Working Hours Release Rate, µg s^{-1}
1949 – 1953	1600	4	24	4

Table 20-7. Estimated V-Building beryllium shop release rates for 1949 through 1953 with duration factors applied

Year	Release Rate for Stated Averaging Period, µg s^{-1}						
	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1953-1963	610	194	122	34	15	1.4	0.7

d) V-Building Shop Operations at TA-1 between 1943 and 1948

At the start of LANL, the main shops in V Building at TA-1 were used for machining beryllium. Prior to around 1948, when LANL was informed of the hazardous nature of beryllium, the operations occurred in the shop itself with no specialized exhaust ventilation. Because the nature of the operations at the V-Building shop appear to have been grossly similar to the SM-39 shops at TA-3, use of that release rate estimate is appropriate. However, the releases were not collected by a process exhaust system and were not released through a stack. We assume that the releases occurred from the normal ventilation of the shop area, perhaps a ventilation fan. In contrast to the case of the post-1949 V-shop operations, the main change in prioritization will be the diffuse release through building

ventilation as opposed to a stack. As in the case of the V-Building shops 1949 - 1953, because the nature of the operations was grossly similar to the TA-3 shops, use of the release rate estimate for the SM-39 shop 1953-1963 is appropriate. As for all sources of chronic releases, the Table 20-1 factors were applied to correct the annual average to the sampling or exposure time of interest. Estimated beryllium releases are summarized in Table 20-8 and applied to various averaging periods in Table 20-9.

Table 20-8. Estimated airborne releases from the V-Building shop at TA-1 from 1943 to 1948

Year	Working Hours	Annual Average Concentration, µg m^{-3}	Mass Released, g	Working Hours Release Rate, µg s^{-1}
1943 – 1948	1600	87	472	82

Table 20-9. Estimated V-Building beryllium shop release rates for 1943 through 1948 with duration factors applied

Year	Release Rate for Stated Averaging Period, µg s^{-1}						
	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1943-1948	12,156	3,859	2,427	679	297	29	15

Gun Testing of Atomic bomb Initiators Containing Beryllium– B Building Annex at TA-1

If one approximates an atomic bomb initiator as a sphere of beryllium of a radius given by the 20-mm barrel diameter of the gun at B Building, each of the daily initiator tests used 566 g (the mass of a metal sphere of beryllium of 10 mm radius), and an estimated 10% was aerosolized and exhausted from the room, or 57 g per test. Documents that describe initiator testing have a data block that lists typical values of 90 to 120 “Gr” projectile weights. This mass is close to the mass of a normal projectile the auto-cannon would fire, and would be consistent with grams rather than grains. If the projectile weight was in grains, only 8 g would be used for the entire projectile, which seems too low in mass to be realistic. Using the stated mass of the projectile would mean that the beryllium released would be five times less that stated earlier (solid sphere of beryllium of 20 mm diameter) for each shot. For this initial assessment, 120 g is assumed expended, of which 10% was released. During the first 180 d of the program, 180 initiator tests were conducted. That being the case, it appears that the B- Building Annex alone released more than 2160 g (10% of 120 g for 180 tests) over the one half year in 1944 for which data were found. This would amount to 4,320 g y^{-1}.

After each test was fired, the 10% fraction assumed to be aerosolized was dispersed into the room and removed by the ventilation system. It as assumed that a flow rate sufficient to produce 12 air changes per hour was used. If the beryllium was uniformly mixed into the room volume, the concentration would drop exponentially with a time period equal to the inverse of the ventilation rate. A time sufficient to produce two air changes (0.1 h or 6 min) would remove most of the beryllium and was assumed to be the release period. Thus, the release would correspond to 12 g of beryllium over 360 s, or 0.033 g s^{-1}. The data sheets reviewed indicate test frequency of roughly once per day. Thus, a test was assumed to occur 365 days per year. Because the release rate considers the release time, the duration factors of Table 20-1 are not applied for these episodic releases. With a release each day (365 d y^{-1}) and duration of 0.1 h, the release is assumed to occur over a 36.5-h operating period. However, the release rate when averaged over longer periods of time drops with the ratio of the averaging period to that of the considered duration of release. No annual average concentration is provided. The hours of operation of what is believed to have been a nominal 600 ft^3 min^{-1} ventilation fan are not known. Estimated beryllium releases are summarized in Table 20-10 and applied to various averaging periods in Table 20-11.

Table 20-10. Estimated airborne beryllium releases from B-Building gun testing at TA-1, 1944-1948

Years	Operating Period, h	Mass Released, g	Release Rate, µg s^{-1}
1943 – 1948	36.5	4,320	33,333

Table 20-11. Estimated beryllium release rates from B-Building gun testing (duration factors not applied)

Years	Release Rate for Stated Averaging Period, µg s^{-1}						
	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1943-1948	33,333	6,667	3,333	417	417	139	139

Explosive testing of bomb components containing beryllium

During the peak year of dynamic testing, 1964, a total of 106 kg of beryllium was used at TA-15, a fraction of which was aerosolized into fine particulate form that would distribute downwind. While LANL has traditionally assumed 2% of the mass is aerosolized, this assumption (along with others) fails to account for the mass of beryllium expended at the firing sites and found in nearby soils. Lawrence Livermore National Laboratory (LLNL) has used assumptions that 8% of the mass is aerosolized. Both of those values (either 2% or 8%) were the result of experiments conducted by the laboratories. Finally, the Dual-Axis Radiographic Hydrodynamics Test (DARHT) facility EIS, which was published more

recently, assumed a value of 10%. For this analysis, it was assumed that 10% of the 106 kg expended in 1964 was aerosolized.

The amount of beryllium used in a specific experiment is classified. In order to estimate a release rate, it was assumed that between 50 and 150 experiments were performed at the three firing sites during the year (less than once per week), with a total of 100 experiments performed. It was assumed that 80% of the experiments did not use beryllium at all, and of the 20 experiments that did, 16 used small amounts of beryllium (together accounting for 50% of the total mass) and 4 of them used larger amounts (together accounting for 50% of the total mass). Each of the larger experiments might have used 13.25 kg.

The duration of the exposure from the explosive test was taken to be 0.25 h as the puff drifted off-site with the prevailing wind. This heuristic estimate is based partially on the estimated size of the puff a short time after detonation and subsequent dispersion of that puff as it drifts approximately 5,000 m off site with an average wind speed.

Because the release rate considers the release time, the factors of Table 20-1 are not needed. Table 20-12 provides the annual average values (10% of 106 kg dispersed in 0.25 h × 100 tests = 25 h) as well as the peak (one of 4 tests in the year that dispersed 10% of 13.25 kg in 0.25 h). Table 20-13 applies the peak rate to time intervals of a week or less, and assumes the annual release rate for the year and the month. If one had assumed that one of the shots that month was one in which 13.25 kg was used (and the rest averaged the 1.06 kg), then the month would be a factor of 2.3 times larger. This was not used in order to maintain a simpler set of assumptions. Using this method provides an average rate for the month equal to the annual rate. In fact, it is likely that the month in which a larger than average quantity of beryllium was used in shots had higher release rates than 336 µg s^{-1} over the 730 h period. This can be accounted for if assessment of beryllium releases continues and detailed (classified) shot records are retrieved and summarized in a manner that would be publicly releasable.

Table 20-12. Estimated airborne beryllium releases from TA-15 explosive testing

Year	Duration of Exposure, h	Mass Released, g	Release Rate, µg s^{-1}
1964 (year)	25	10,600	117,778
1965 (month)	2.08	1,766	235,467
1964 (maximum shot)	0.25	1,325	1,472,222

Table 20-13. Estimated beryllium release rates from TA-15 explosive testing (duration factors not applied)

Year	Release Rate for Stated Averaging Period, µg s^{-1}						
	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1964	1,472,222	736,111	368,056	46,007	9,201	672	336

Hot Pressing of Beryllium Oxide Powder in Q Building at TA-1

LANL ordered 6,100 lbs of beryllium oxide (BeO) for use in reactors by January 15, 1944 (LASL 1944). For this assessment, it was assumed that the 6,100 lbs of BeO powder that was ordered was actually used in 1944. This is a metric ton of the element beryllium alone.

In order to estimate the amount of BeO (and Be) that would be released; the methods of the USDOE Handbook of Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities were used (USDOE 1994). For this application, it was necessary to estimate an Overall Release Fraction (ORF). The Atmospheric Release Fractions (ARF) and Respirable Factions (RF) were then multiplied to get a range of Overall Release Fractions (ORF). The geometric mean of the ORF, computed as 0.0025 (the square root of the product of the upper and lower bounds), was then applied to the total BeO ordered for 1944.

The ARF was estimated as between 5% of the mass on the high end, and 0.5% of the mass on the low end. The RF was estimated as the mass fraction below 5 µm diameter. The upper bound was estimated from the known upper size limit (-325 mesh or 44 µm) and an assumed geometric standard deviation of 3 for the particle size. Two standard deviations (3×3 = 9) were used to estimate the geometric mean of 5 µm, which means one half of the mass of BeO was below 5 µm and was respirable. A value for respirable fraction (RF) that was ten times smaller was used as an estimate for the lower bound. These values are summarized in Table 20-14.

Table 20-14. Release fraction parameter values for BeO powder processing

	Upper Bound	Lower Bound
Airborne Release Fraction (ARF)	0.05	0.005
Respirable Fraction (RF)	0.5	0.05
Overall Release Fraction (ORF)	0.025	0.00025
Geometric Mean of ORF	0.0025	

Applying the geometric mean of the overall release fraction (0.25%) to the 6,100 pounds of BeO used in 1944 results in a release of 6,932 g of respirable BeO from Q Building during the year, which would have contained 2,495 g of beryllium. Table 20-15 and Table 20-16 provide the total releases and the release rates with duration factors applied for Q-Building BeO powder pressing during 1944. It can be assumed that these releases likely continued to occur until the late 1940s, when LANL began to impose more stringent controls on beryllium operations.

Table 20-15. Estimated airborne beryllium releases from BeO powder pressing in Q Building at TA-1

Year	Duration of Exposure, h	Mass Released, g	Release Rate, μg s^{-1}
1944	1600	2,495	433

Table 20-16. Estimated beryllium release rates from BeO pressing in Q Building at TA-1 with duration factors applied

Year	Release Rate for Stated Averaging Period, μg s^{-1}						
	6 min	30 min	Hour	Work Day	Work Week	Month	Year
1944	64,475	20,468	12,872	3,600	1,574	152	79

Estimation of Atmospheric Dilution Factors

Beryllium Machining at V Shop in the Original Technical Area

Based on review of drawings and 1940s photographs of the Original Technical Area, there was no stack on V Building that met or exceeded the 2.5-times building height criterion for avoidance of building ake effects. Because of this, building wakes will be a consideration. Based on review of drawings and photographs of the Original Technical Area, the surface area of V Building, A_G, was approximately 39 m × 15 m = 585 m^2, the square root of which is 24.2 m; 2.5 times that value is 60.5 m. The distance from V Building to the nearest residence, the southernmost Sundt apartment on 24th Street, was approximately 165 m (see Fig. 20-1). As this value exceeds both 2.5-times the square root of A_G and 100 m, this is a case of exposure outside the near-wake region.

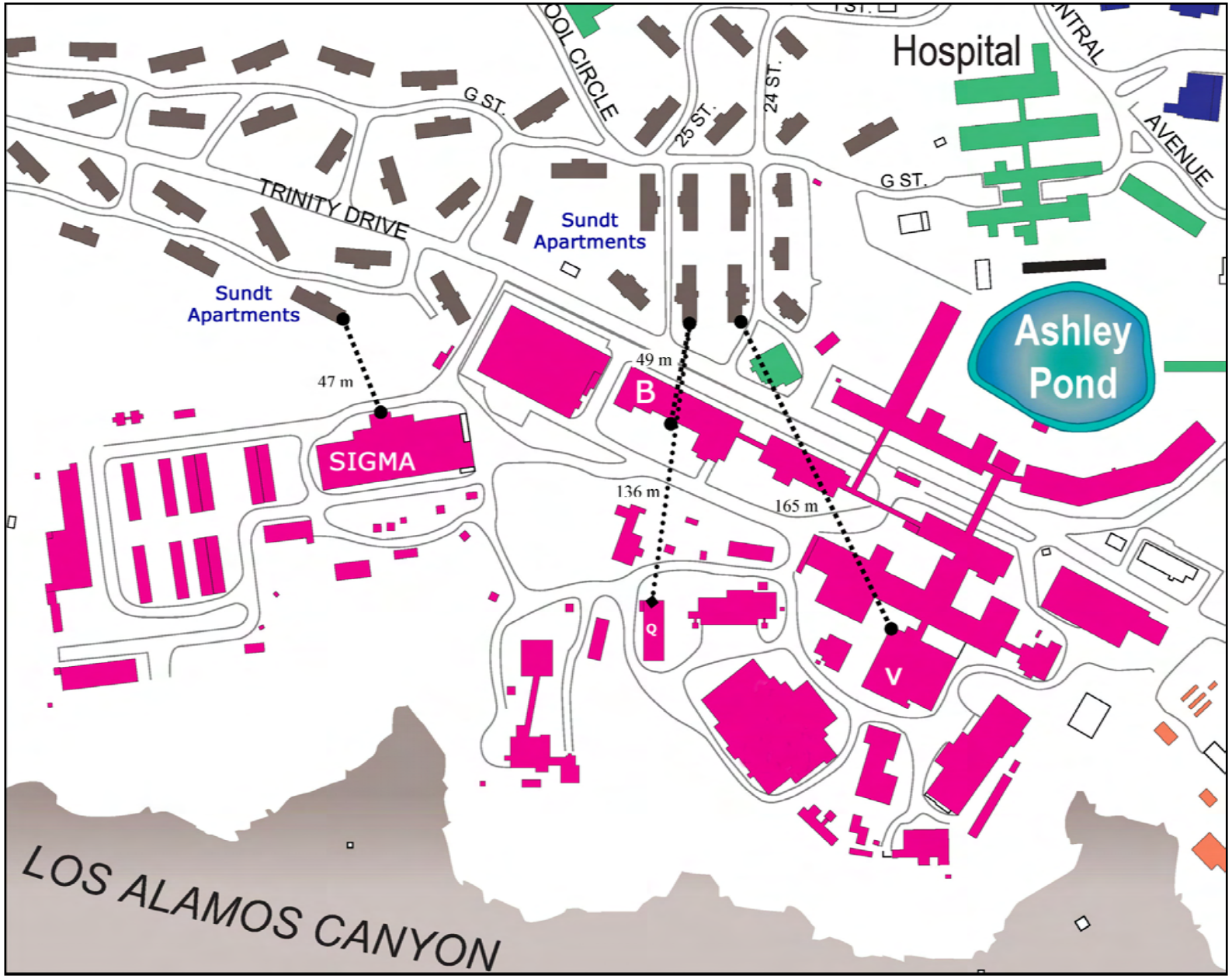

Fig. 20-1. Approximate distances from Original Technical Area beryllium facilities to nearest residences

The concentration at the exposure point can therefore be estimated as follows (NCRP 1996):

$$C = \frac{f\ Q\ B}{u}$$

Where:

C = average atmospheric concentration at receptor, μg m^{-3}

f = fraction of time that the wind blows toward the receptor of interest

Q = effluent release rate (μg s^{-1} in this application)

B = the Gaussian plume model diffusion factor modified for building wake effects

u = mean wind speed, m s^{-1}

Because the distance, x, to the nearest potentially exposed individual is less than 2 km, Figure 1.5 of NCRP Report 123 was used to determine B. That figure indicates that a value of 9×10^{-4} m^{-2} should be used for B when x = 165 m and A_G falls between 300 and 1,000 m^2. The NCRP Report 123 method incorporates a value of 0.25 for f, and recommends a default of 2 m s^{-1} for u when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), C/Q, as follows:

$$C/Q = (0.25)\ (9\times10^{-4}\ m^{-2})\ (2\ m\ s^{-1})^{-1} = 1.13\times10^{-4}\ s\ m^{-3}$$

This value can be multiplied by the estimated release rate of beryllium from V Building (μg s^{-1}) to estimate the airborne beryllium concentration (μg m^3) at the southernmost Sundt apartment on 24th street in Los Alamos. For evaluation of episodic releases, when it is appropriate to assess concentrations when the wind is blowing toward the identified nearest exposure point, f will be set to 1, and relative concentrations will be four times the C/Q value shown above.

Beryllium Oxide Pressing at Q Building in the Original Technical Area

Based on review of drawings and 1940s photographs of the Original Technical Area, there was no stack on Q Building that met or exceeded the 2.5-times building height criterion. Because of this, building wakes will be a consideration. Based on review of drawings and photographs of the Original Technical Area, the surface area of the Q Building, A_G, was approximately 10 m × 5 m = 50 m^2, the square root of which is 7.1 m; 2.5 times that value is 17.7 m. The distance from Q Building to the nearest residence, the southernmost Sundt apartment on 25th Street, was approximately 136 m (see Fig. 20-1). As this value

exceeds both 2.5-times the square root of A_G and 100 m, this is a case of exposure outside the near-wake region.

The concentration at the exposure point can therefore be estimated as follows (NCRP 1996):

$$C = \frac{f\ Q\ B}{u}$$

Where:

C = average atmospheric concentration at receptor, μg m^{-3}

f = fraction of time that the wind blows toward the receptor of interest

Q = effluent release rate (μg s^{-1} in this application)

B = the Gaussian plume model diffusion factor modified for building wake effects

u = mean wind speed, m s^{-1}

Because the distance, x, to the nearest residence is less than 2 km, Figure 1.5 of NCRP Report 123 was used to determine B. That figure indicates that a value of 2×10^{-3} m^{-2} should be used for B when x = 136 m and A_G falls between 0 and 100 m^2. The NCRP Report 123 method incorporates a value of 0.25 for f, and recommends a default of 2 m s^{-1} for u when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), C/Q, as follows:

$$C/Q = (0.25)\ (2\times10^{-3}\ m^{-2})\ (2\ m\ s^{-1})^{-1} = 2.5\times10^{-4}\ s\ m^{-3}$$

This value can be multiplied by the estimated release rate of beryllium from Q Building (μg s^{-1}) to estimate the airborne beryllium concentration (μg m^3) at the southernmost Sundt apartment on 25th street in Los Alamos. For evaluation of episodic releases, when it is appropriate to assess concentrations when the wind is blowing toward the identified nearest exposure point, f will be set to 1, and relative concentrations will be four times the C/Q value shown above.

<u>Beryllium Processing in the SM-39 Shops at TA-3</u>

The photographs and documents that have been reviewed indicate that associated releases were not exhausted through a stack that met or exceeded the 2.5-times building height criterion for nearby structures. Because of this, building wake will be a consideration. The distance from Building SM-39 to the closest residential area, Western Area housing, is approximately 960 meters (Fig. 20-2). Based on review of aerial photographs of SM-39, the width of the north end of the building is approximately 76 m. Based on review of historical photographs, the height of that building is approximately that of a two story

building, or roughly 7 m. The cross-sectional area of the north end of the building is therefore 532 m^2, the square root of that value is 23, and 2.5-times the square root is 58. As the distance to the nearest public exposure point exceeds 2.5-times the square root of A_G, this is a case of exposure outside the near-wake region. The concentration at the exposure point can be estimated as follows (NCRP 1996):

$$C = \frac{f\ Q\ B}{u}$$

Where:

C	=	average atmospheric concentration at receptor, µg m^{-3}
f	=	fraction of time that the wind blows toward the receptor of interest
Q	=	effluent release rate (µg s^{-1} in this application)
B	=	the Gaussian plume model diffusion factor modified for building wake effects
u	=	mean wind speed, m s^{-1}

Because the distance to the nearest residence, x, is less than 2 km, Figure 1.5 of NCRP Report 123 was used to determine B. That figure indicates that a value of 5.5×10^{-5} m^{-2} should be used for B when x = 960 m and A_G falls between 300 and 1,000 m^2. The NCRP Report 123 method incorporates a value of 0.25 for f, and recommends a default of 2 m s^{-1} for u when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), C/Q, as follows:

$$C/Q = (0.25)\ (5.5\times10^{-5}\ m^{-2})\ (2\ m\ s^{-1})^{-1} = 6.88\times10^{-6}\ s\ m^{-3}$$

This value can be multiplied by the estimated release rate of beryllium from the SM-39 shops to estimate the airborne beryllium concentration (µg m^3) at the southernmost residences of the Western Area in Los Alamos. For evaluation of episodic releases, when it is appropriate to assess concentrations when the wind is blowing toward the identified nearest exposure point, f will be set to 1, and relative concentrations will be four times the C/Q value shown above.

Gun Testing of Weapon Components in the Annex to B Building in the Original Technical Area

Based on review of drawings and 1940s photographs of the Original Technical Area, there was no stack on B Building that met or exceeded the 2.5-times building height criterion. Because of this, building wakes will be a consideration. The surface area of the building, A_G, is approximately 62 m × 15 m = 930 m^2, the square root of which is 30.5 m; 2.5 times that value is 76.2 m. The distance from the center of the rear (southern facing) side of B Building to the southernmost Sundt apartment on 25th Street in Los Alamos was 49 m (Fig. 20-1). As this is less than both 2.5-times the square root of A_G and 100 m, this is

Fig. 20-2. Approximate distance from Building SM-39 at TA-3 to the southernmost residences of the Western Area in Los Alamos

a case of exposure in the near-wake region. The concentration at the exposure point can therefore be estimated as follows (NCRP 1996):

$$C = \frac{f\ Q}{\pi\ u\ h\ K}$$

Where: k = a constant of value 1 m, and

h = the smaller of the building height or building width, m.

In this case, building height, h_b (~15 m) is less than its width, h_w (~62 m).

The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), *C/Q*, as follows. Because the B-Building gun tests were episodic releases, concentrations will be estimated for the conditions when the wind was blowing toward the identified nearest exposure point by setting *f* to 1.

$$C/Q = (1)[(3.14) \times (2\ \text{m s}^{-1}) \times (15\ \text{m})]^{-1} = 1.06 \times 10^{-2}\ \text{s m}^{-3}$$

This value can be multiplied by the estimated release rate (μg s^{-1}) of beryllium from the back center of B Building to estimate the airborne beryllium concentration (μg m^3) at the southernmost Sundt apartment on 25th Street in Los Alamos.

<u>Beryllium Expended in Explosive Testing at TA-15 (PHERMEX facility)</u>

Based on review of drawings, photographs, and descriptions of the TA-15 facilities, associated releases were not exhausted through a stack that met or exceeded the 2.5-times building height criterion for nearby structures. Because of this, building wakes (or wakes from nearby structures) will be a consideration. The distance from the main PHERMEX building to the nearest residential area, the Royal Crest Trailer Park on East Jemez Road, is approximately 4,500 m (see Fig. 20-3). There were no large buildings in the immediate area of PHERMEX. As the distance to the nearest public exposure point exceeded 2.5-times the square root of A_G for all buildings in the area of the testing, this is a case of exposure outside the near-wake region. Because the distance to the nearest public exposure point exceeds 2 km, the concentration at the exposure point can be estimated as follows (NCRP 1996):

$$C = \frac{f\ Q\ B}{u}$$

Where: C = average atmospheric concentration at receptor, μg m^{-3}

f = fraction of time that the wind blows toward the receptor of interest

Q = effluent release rate (μg s^{-1} in this application)

P = the Gaussian plume model diffusion factor as a function of downwind distance assuming a release height (H) at ground level, 0 m.

u = mean wind speed, m s^{-1}

Because x is greater than 2 km, Figure 1.4 of NCRP Report 123 is used to determine P. That figure indicates that a value of 5×10^{-6} m^{-2} should be used for P when x = 4500 m and H = 0 m. The NCRP Report 123 method incorporates a value of 0.25 for f, and recommends a default of 2 m s^{-1} for u when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), C/Q, as follows. Because the PHERMEX explosive tests were episodic releases, concentrations will be estimated for the conditions when the wind was blowing toward the identified nearest exposure point by setting f to 1.

$$C/Q = (1)\ (5\times10^{-6}\ m^{-2})\ (2\ m\ s^{-1})^{-1} = 2.5\times10^{-6}\ s\ m^{-3}$$

This value can be multiplied by the estimated release rate of beryllium from explosive testing at TA-15 (μg s^{-1}) to estimate the airborne beryllium concentration (μg m^{-3}) at the Royal Crest Trailer Park on East Jemez Road in Los Alamos.

Estimation of Concentrations at Points of Interest

Concentrations of airborne beryllium at the nearest residence (μg m^{-3}) from each identified beryllium operation were estimated by multiplying the estimated release rate (μg s^{-1}) by the applicable relative concentration value (s m^{-3}). Results are shown in Table 20-17. The estimated release rate and concentration values for BeO powder pressing, V Shop, and SM-39 Shop releases are presented as 6-min, 30-min, and 8-h average values that would be expected to be reached or exceeded once per year and monthly average concentrations that would be expected to be reached or exceeded 5% of the time. For the explosive tests at TA-15, the results in Table 20-17 for periods longer than a week are values averaged over the periods shown based on 100 shots in a year, each with 0.25-h duration of exposure, that together released 10% of the total beryllium reported expended in 1964. For periods shorter than a month, the results are values averaged over the periods shown based on one shot, with 0.25-h duration of exposure, occurring during the period and releasing 1.25% of the total beryllium reported expended in 1964.

Fig. 20-3. Approximate distance from TA-15, PHERMEX area, to the Royal Crest Trailer Park on East Jemez Road in Los Alamos

Table 20-17. Results of screening-level assessment of potential airborne beryllium concentrations in residential areas of Los Alamos

	B-Building Gun Tests[a]	BeO Powder Pressing	V-Shop Machining 1943-48	V-Shop Machining 1949-53	SM-39 Shop 1953 to 1963	SM-39 Shop after 1963	PHERMEX Explosive Tests[a]
Distance to exposure point (m)	49	140	170	170	960	960	4,500
Relative concentration (s m^{-3})	1.1×10^{-2}	2.5×10^{-4}	1.1×10^{-4}	1.1×10^{-4}	6.9×10^{-6}	6.9×10^{-6}	2.5×10^{-6}
Release rates (µg s^{-1}) for stated averaging periods:							
0.1 h:	33,000	64,000	12,000	610	610	3.7	1,500,000
0.5 h:	6,700	20,000	3,900	190	190	1.2	740,000
8 h:	420	3,600	680	34	34	0.20	46,000
730 h (1 month):	140	150	29	1.4	1.4	0.0086	670
Exposure point concentrations (µg m^{-3}) for stated averaging periods:							
0.1 h:	**350[c,d]**	**16[d]**	**1.4[d]**	**0.069[d]**	0.0042	0.000025	**3.7[d]**
0.5 h:	**71[c,d]**	**5.1[d]**	**0.44[d]**	**0.022[d]**	0.0013	0.0000080	**1.8[d]**
8 h:	**4.4[b,d]**	**0.90[d]**	**0.077[d]**	0.0038	0.00023	0.0000014	**0.12[d]**
730 h (1 month):	**1.5[d,e]**	**0.038[d,e]**	0.0033	0.00016	0.000010	0.000000059	0.0017

[a] Episodic releases
[b] Possible exceedance of OSHA/AEC 8-h time weighted average limit = 2 µg m^{-3}
[c] Possible exceedance of OSHA/AEC ceiling limit = 25 µg m^{-3}
[d] Possible exceedance of USEPA Reference Concentration = 0.02 µg m^{-3}
[e] Possible exceedance of National Emission Standard for ambient air averaged over a 30-d period = 0.01 µg m^{-3}

Identification of Relevant Toxicologic or Regulatory Benchmarks

The current OSHA permissible exposure limit (PEL) for occupational exposure to beryllium is 2 µg m^{-3} (8-h time weighted average). A ceiling limit of 5 µg m^{-3} must not be exceeded during the work shift, except that a 30-minute excursion over the ceiling limit is allowed as long as the air concentration never exceeds 25 µg m^{-3} during the 30-minute period (NIOSH 2003).

The U.S. Atomic Energy Commission issued "Recommendations for Control of Beryllium Hazards" in August 1951 that included three standards: a 2 µg m^{-3} in plant 8-h average beryllium concentration; a 25 µg m^{-3} beryllium air concentration which can never be exceeded; and, a 0.01 µg m^{-3} monthly average concentration at the breathing zone in the neighborhood of a plant handling beryllium (Mitchell and Hyatt 1957).

The current USEPA Reference Concentration (RfC) for beryllium is 0.02 µg m^{-3} (USEPA 2009). The RfC is an estimate (with uncertainty spanning an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfC is based on beryllium sensitization and progression to chronic beryllium disease (CBD) identified in studies published in 1996 (Kreiss et al. 1996) and 1949 (Eisenbud et al. 1949).

The Kreiss et al. (1996) occupational exposure study identified a LOAEL (Lowest Observed Adverse Effect Level) for beryllium sensitization in workers exposed to 0.55 µg m^{-3} (median of average concentrations). A cross-sectional study was conducted of 136/139 of the then-current beryllium workers in a plant that made beryllia ceramics from beryllium oxide powder. Measurements from 1981 and later were reviewed and included area samples, process breathing-zone samples, and personal lapel samples (the last year only). The Eisenbud et al. (1949) study, using relatively insensitive screening methods, suggests a NOAEL (No Observed Adverse Effect Level) of 0.01-0.1 µg m^{-3} in community residents living near a beryllium plant. The LOAEL from the Kreiss et al. study was used for the operational derivation of the RfC because the screening method used in the Eisenbud et al. (1949) study was less sensitive than the method used in the Kreiss et al. (1996) study.

According to the Agency for Toxic Substances and Disease Registry (ATSDR 2002), there is evidence to suggest that the occurrence of chronic beryllium disease is not related to duration of exposure and can have a long latency period. Very few studies assessing the occurrence of chronic beryllium disease also measured airborne beryllium levels. Eisenbud et al. (1949) found no cases of chronic beryllium disease in

residents living at least 0.75 miles away from a beryllium manufacturing facility. The airborne beryllium concentration at this distance was estimated to range from 0.01 to 0.1 µg m^{-3}.

It is the opinion of the ATSDR that the available database does not support the derivation of acute, intermediate, or chronic duration inhalation MRLs (minimal risk levels). Eisenbud et al. (1949) found no cases of chronic beryllium disease among community residents chronically exposed to 0.01-0.1 µg m^{-3} of beryllium. The study used relatively insensitive methods to detect chronic beryllium disease, therefore it's not know if the residents exposed to 0.01 µg m^{-3} of beryllium would test positive for sensitization or subclinical chronic disease. No human acute or intermediate duration studies that identify a NOAEL or LOAEL for respiratory effects were identified. Animal studies have not identified a reliable NOAEL, and the LOAELs are several orders of magnitude higher than the LOAEL from the Kreiss et al. (1996) occupational exposure study. Although the critical target of beryllium toxicity has been identified as the respiratory tract, an animal model that mimics all aspects of chronic beryllium disease has not been identified. Therefore, it is inappropriate to derive inhalation MRLs from the animal data (ATSDR 2002).

Several studies attempted to associate beryllium sensitization and/or chronic beryllium disease with mean, cumulative, and peak exposure levels and duration of employment, but no consistent associations were found. Although the data are insufficient for establishment of concentration-response relationships, the available occupation exposure studies do provide exposure levels that may result in beryllium sensitization. Beryllium sensitization and/or chronic beryllium disease have been detected at exposure levels of 0.5 µg m^{-3}. Respiratory disease is not likely to occur from exposure to beryllium levels in the general environment because ambient air levels (0.00003–0.0002 µg m^{-3}) are very low (ATSDR 2002).

Comparison of Estimated Concentrations with Relevant Benchmarks

The results of the preliminary screening of airborne beryllium concentrations in residential areas of Los Alamos, in terms of estimated airborne concentrations over four different averaging periods, are represented in Fig. 20-4 along with representations of the regulatory limits that can be applied to beryllium concentrations in occupational or public settings. The estimated airborne beryllium concentrations that exceeded one or more of those limits are also identified with footnotes in Table 20-17. While occupational exposure limits are not directly applicable to exposures of members of the public, they are presented as benchmarks to which the calculated concentrations can be compared. Limits imposed on exposures to members of the public are generally lower than those imposed on worker exposures, so concentrations in residential areas must be maintained lower than those accepted in workplace environments.

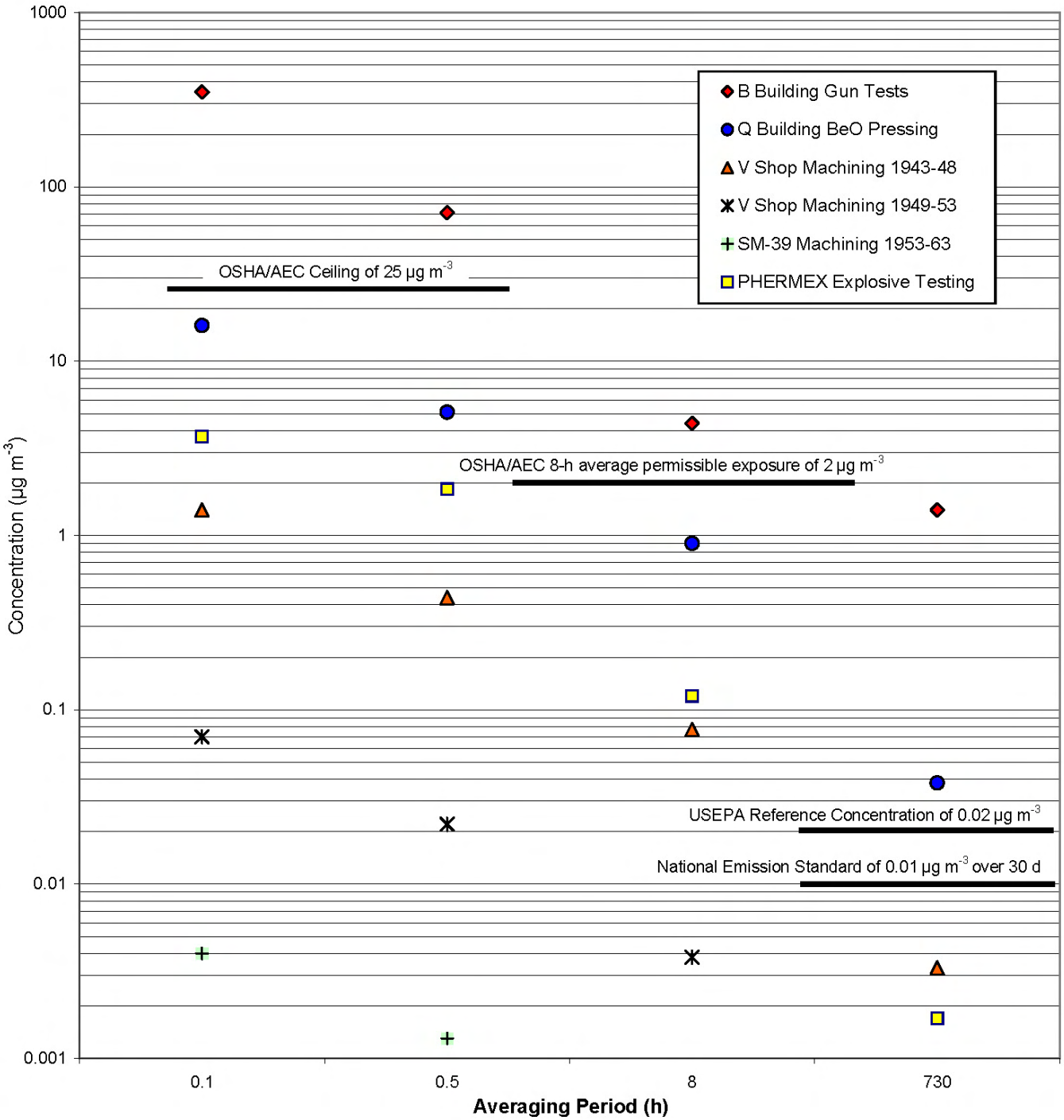

Fig. 20-4. Screening-level estimates of airborne beryllium concentrations in public areas near LANL for six historical operations

Conclusions

The screening results indicate that the 8-h time weighted average permissible exposure limit of 2 µg m^{-3} for beryllium adopted for workers by OSHA and the AEC could have been exceeded in residential areas by releases from the B-Building gun tests. The OSHA/AEC ceiling limit of 25 µg m^{-3} for workers could also have been exceeded for releases from those tests based on concentrations estimated for 0.5-h and 0.1-h averaging periods. The USEPA reference concentration of 0.02 µg m^{-3} could have been exceeded in residential areas by releases from B-Building gun testing, BeO powder pressing, V-Shop machining, and tests at PHERMEX. The National Emission Standard of 0.01 µg m^{-3} for beryllium in ambient air averaged over a 30-d period could have been exceeded in residential areas from the B-Building gun tests and BeO powder pressing.

References

ATSDR. Toxicological Profile for Beryllium. Atlanta, GA: Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services 2002.

Eisenbud MR, Watna RC, Dustan RC, Steadman LC, Harris WB, Wolf BS. Non-occupational berylliosis Journal of Industrial Hygiene and Toxicology 31: 282-294; 1949.

Hempelmann LH, Henrickson PW. Transcript of an oral history interview of Dr. Louis Hempelmann conducted by Paul Henrickson on 31 January 1986; LANL Archives Collection A-2006-006. 1986. Repos. No. 8008.

Kreiss K, Mroz MM, Newman LS. Machining risk of beryllium disease and sensitization with median exposures below 2 ug/m^3. American Journal of Industrial Medicine 30: 16-25; 1996.

LASL. Beryllium memos from LANL Archives Collection A-1984-019, Box 36, Folder 1 Los Alamos Scientific Laboratory. 1944. Repos. No. 4975.

LASL. H-5 Air Sample Data Sheet - Beryllium Shops and Exhaust Los Alamos Scientific Laboratory. 1969. Repos. No. 7816

LASL. SD-1 Shop 4 Beryllium Shop 1954-1962 Folder from TA-59 EH&S Records Los Alamos Scientific Laboratory. 1970. Repos. No. 7814

Mitchell RN, Hyatt EC. Beryllium - Hazard Evaluation and Control Covering a Five-Year Study. Los Alamos Scientific Laboratory, presented at the American Industrial Hygiene Association Meeting. 1957. Repos. No. 1874.

NCRP. Screening Models for Release of Radionuclides to Atmosphere, Surface Water, and Ground. Bethesda, MD: National Council on Radiation Protection and Measurements; NCRP Report No. 123; 1996.

NIOSH. Pocket Guide to Chemical Hazards. Washington, DC: National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Department of Health and Human Services; 2003.

Shipman T. Memorandum dated 16 May 1951 to N. E. Bradbury regarding beryllium toxicity [subject redacted]. Los Alamos Scientific Laboratory. 1951. Repos. No. 4723.

Shonka JJ. LAHDRA Project Memo to File: LANL Beryllium Source Terms. Shonka Research Associates. 2009. Repos. No. 8009.

USDOE. DOE Handbook - Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities; Volumes I and II. Washington, DC: U.S. Department of Energy; DOE-HDBK-3010-94; 1994.

USDOE. DOE Nuclear Air Cleaning Handbook. Washington, DC: U.S. Department of Energy; HDBK-1169-2003; 2003.

USEPA. Integrated Risk Information System, Beryllium and compounds (CASRN 7440-41-7). 2009.

Chapter 21: Public Involvement within the LAHDRA Project

Unlike some dose reconstruction projects that have been conducted, the LAHDRA project team was not advised by a committee formed in accordance with the Federal Advisory Committee Act. Public meetings were held once or twice each year at various locations in the Los Alamos-Española-Taos-Pojoaque-Santa Fe region. The meetings included presentations and discussions concerning progress in information gathering, knowledge gained about historical activities of relevance to off-site releases, problems that were being encountered in accessing and obtaining relevant documents, plans for completion of information gathering, and progress toward prioritizing historical releases. Updates on noteworthy aspects of project activities were also presented at annual conferences of relevant professional societies.

Postings on the LAHDRA Web site included summaries of all public meeting presentations and associated public comments and discussion, summaries of workshops that were conducted to offer more detailed overviews of project-related topics for interested parties from LANL and the public, downloadable copies of Interim Reports of the project, video clips of excerpts of public meeting presentations, and information concerning contacting LAHDRA team members and accessing the project document collection and the DocSleuth database at local libraries. CDC and contractor team members also met with and offered briefings to representatives of the Eight Northern Pueblo Council and many of the individual pueblos in Northern New Mexico.

Through 2008, there were 15 public meetings and two workshops hosted by CDC and the LAHDRA project team. These meetings were held in Pojoaque (6 occasions), Los Alamos (5), Española (3), Santa Fe (2), and Taos (1). Eight interim versions of the report of the LAHDRA project were issued as information gathering progressed.

Fig. 21-1. A view of the LAHDRA public meeting in July 2008

Dates and major topics of the meetings are listed below, in order of most recent to earliest. Summaries of all public meetings and workshops, including copies of the presentations and paraphrasing of public comments and questions, are available on the project Web site at http://www.lahdra.org/meetings/meetings.htm

Fig. 21-2. A photographic display presented at the July 2008 public meeting

- Wednesday, July 23, 2008 - Project update, status of document review
- Wednesday, July 18, 2007 - Progress in document reviews, study of plutonium releases in the 1940s and 1950s, public exposures from the Trinity test, report updated
- Wednesday, July 26, 2006 - Project update, status of document review, new database
- Thursday, June 23, 2005 - Project update, discuss new contract
- Tuesday, July 27, 2004 - CDC announces completion of work under first LAHDRA contract
- Tuesday, March 30, 2004 - Release of Draft Interim report.
- Wednesday, July 9, 2003 - Project update, outlook for continued work
- Wednesday, July 10, 2002 - Project update, impact of access restrictions
- Tuesday, November 27, 2001 - Project update, access to records
- Tuesday, April 24 and Thursday, April 26, 2001 - Project update, access restored, document availability
- Wednesday, September 13, 2000 - Project update, draft report, access issues
- March 8, 2000 - Project update
- October 5, 1999 - Interviews with current and retired workers
- July 27, 1999 - Project update and sample documents
- February 23, 1999 - Project introduction

Chapter 22: Findings of the LAHDRA Project

The LAHDRA project has significantly expanded the quantity of original documentation that is publicly available relevant to past operations at Los Alamos, activities by LANL personnel within New Mexico, and the potential for public health effects from past environmental releases.

The body of information that has been gathered by LAHDRA document analysts is not perfect or complete, and the project team was only able to scratch the surface toward careful analysis of its contents. Some documents that were generated at LANL will never be found due to their loss or destruction, others are difficult or impossible to read because of their age and repeated photocopying, and many of the authors and participants from the periods of highest releases have passed away. In spite of these factors, the members of the LAHDRA study team believe that enough information exists to reconstruct public exposures from the most significant of LANL's releases to a degree of certainty sufficient to allow health professionals to judge if significant elevations of health effects should be expected or measurable.

For the latter part of the project, some documents containing certain categories of sensitive information were withheld from review by LAHDRA analysts. Because documents in these categories included nuclear weapon design details, foreign intelligence, and other types of information that are truly not relevant to studies of off-site releases or health effects, it does not appear that any information needed for dose reconstruction was withheld. The existence of an appeal process by which a federal employee from CDC could review withheld documents to verify that they contained no needed information was a key consideration in the adoption of that conclusion. And while text was redacted from many selected documents prior to public release, LAHDRA analysts had access to original and redacted copies and could verify that the redacted text did not contain information that would be needed for dose reconstruction.

The LAHDRA project has been conducted with a high level of transparency, so that interested parties could review documents as the team members have selected, perform their own assessments if they so choose, and see if they come to the same conclusions. Significant effort was directed to making DocSleuth and the LAHDRA collection of over 8,000 documents available to all interested parties in the most readily usable fashion. From the beginning of the project, search plans were shared at public meetings, and progress reports highlighted significant milestones, accomplishments, and challenges. Preliminary prioritization assessments were openly shared, even though there was the possibility that information obtained later might prompt revisions of approaches, assumptions, or conclusions. Members of the public, activist groups, and LANL personnel were encouraged to comment on the search plans and draft work products and make recommendations for refinement or follow-up work. The quality and

utility of the products of the LAHDRA project has been enhanced by this interaction with scientists and members of the public.

The information gathered by the LAHDRA team indicates that airborne releases to the environment from Los Alamos operations were significantly greater than has been officially reported or published to the scientific community. The preliminary prioritization steps that have been performed within the LAHDRA project, while they have been quite simple, have provided information regarding the relative importance of past releases of airborne radionuclides, waterborne radionuclides, and chemicals. In general, it has been shown that early releases were most important (1940s-1960s) than those that followed, and that plutonium was the most important radionuclide in those early years. Airborne activation products from accelerator operations were most important after the mid-1970s, and gross alpha-emitting radioactivity was important for waterborne releases from the mid-1950s to the mid-1970s. Among chemicals, organic solvents as a class were likely most important, followed by TNT and uranium as a heavy metal.

While prioritization analyses have provided relative rankings of contaminants within categories, the preliminary analyses described herein provided no estimates of concentrations to which members of the public were exposed, resulting intakes, or doses to members of the public that could be converted to estimated health risks or compared to toxicologic benchmarks or decision criteria. Priority Indices based on dilution volumes required to be in compliance with maximum allowable effluent concentrations do not reflect how uptake factors vary between radionuclides or the decay that occurs between release point and the location of potential public exposure. And because of the paucity of details regarding uses and releases of chemicals before the 1970s, the preliminary ranking process used for toxic chemicals did not incorporate estimates of the fractions of quantities of chemicals that were on-hand or used were available for release to the environment or were likely released.

Within the effort to prioritize past releases from LANL activities, it was possible for the project team to advance to screening-level analyses of potential public exposures from airborne releases of plutonium, beryllium, tritium, and uranium. While those analyses have yielded information that is relevant to evaluation of the potential health significance of the four evaluated materials, it is important to keep in mind that screening results are not meant to represent actual doses that were received by members of the public or concentrations to which residents could have been exposed. They are meant to support decisions concerning whether further investigation of identified releases should be pursued.

LAHDRA has been almost exclusively an information gathering effort. If estimates of historical exposures to members of the public are desired for the releases that have been identified and prioritized by the LAHDRA team, it will be necessary to delineate pathways of human exposure that were complete, to characterize environmental fate and transport, and to calculate doses and the subsequent health risks to

groups who were exposed. Methods to perform these steps have been developed and applied for numerous other atomic weapons complex sites, but would have added dimensions to properly reflect the effects of the complex terrain in which LANL is set and to represent the transport of waterborne releases that often soak into dry stream beds before they travel very far, to be transported to a large part by occasional high flow events that wash contaminants toward the Rio Grande.

A number of historical operations have been identified by LAHDRA analysts as areas that might have been particularly important in terms of off-site exposures. In addition, critical information gaps have been identified in several areas.

- **Early airborne releases of plutonium.** Plutonium was processed in crude facilities in D Building during World War II, and many roof-top vents were unfiltered and unmonitored. After DP West Site took over production late in 1945, there was some filtering of releases, but poor monitoring practices caused releases to be underestimated. Documents indicate that DP West releases for 1948-1955 alone were over 100-times the total reported by the Lab for operations before 1973. A screening-level assessment of public exposures from releases of plutonium in 1949 showed that airborne plutonium releases warrant further evaluation.

- **Airborne beryllium releases.** Los Alamos used significant quantities of beryllium before the health hazards of the material were fully appreciated, and it was processed very close to residential areas. Preliminary screening indicated that early beryllium processing could have resulted in concentrations in residential areas that exceeded worker exposure limits, the USEPA reference concentration, and the National Emission Standard for beryllium.

- **Public exposures from the Trinity test.** Residents of New Mexico were not warned before the 1945 Trinity blast or informed of health hazards afterward, and no residents were evacuated. Exposure rates in public areas from the world's first nuclear explosion were measured at levels 10,000-times higher than currently allowed. Residents reported that fallout "snowed down" for days after the blast, most had dairy cows, and most collected rain water off their roofs for drinking. All assessments of doses from the Trinity test issued to date have been incomplete in that they have not addressed internal doses received after intakes of radioactivity through inhalation or consumption of contaminated water or food products.

- **Airborne uranium releases.** LANL has used uranium since its beginnings in enrichments ranging from depleted to highly enriched. It has been machined and fabricated into weapon and reactor components and large quantities have been expended in explosive testing. Preliminary screening assessments indicate that enriched uranium releases do not warrant high priority in terms of potential

health risk, but show that releases of depleted uranium warrant further investigation. None of these evaluations, however, consider releases from LANL's early operations. Early releases could have been much larger than those from the 1970s forward, for which effluent data have been summarized. Further investigation is needed before a conclusive assessment can be made of potential health risks from LANL's airborne uranium releases.

- **Tritium releases before 1967.** Los Alamos used tritium as early as 1944, and received it in increasing quantities in the decades that followed for use at ten or more areas of the Lab. In spite of this, LANL compilations of effluent data include no tritium releases before 1967. LAHDRA team members located scattered documents that describe numerous episodic releases within the 22-year period of tritium usage for which official reports of LANL releases include no data for the radionuclide. These documents call into question the release estimates reported by LANL for 1967 forward and indicate that releases before 1967 constitute a data gap that must be addressed if the health significance of LANL tritium releases is to be evaluated.

Based upon the and the information that has been gathered and the findings of the LAHDRA project, CDC and other interested parties will judge if the available information indicates that past releases of any materials could have been sufficiently high that detailed investigation of past releases and public exposures is warranted, and if it appears that sufficient information exists to support detailed investigation if the requisite funding could be made available. Potential further investigations that could be undertaken for one or more contaminants of highest priority could range from screening level assessments of potential public exposures to more rigorous exposure assessments like those that have been conducted for other MED/AEC/DOE sites and have become known as dose reconstructions. Unlike the prioritization analyses performed to date, these assessments would likely incorporate modeling of environmental transport, exposure pathway analysis, and reflection of the uncertainties and variability associated with input data, assumptions, and models so that the ranges of exposures received by likely members of the public can be specified at a stated level of confidence. Assessments of that type are often performed in an iterative fashion, with uncertainty analyses focusing research on components of the assessment that are contributing most to the overall uncertainty of results. Further refinement can be directed to those elements, and the process repeated until the uncertainty of results is acceptable or cannot be further reduced.