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Considerations in the Use of Historical Dosimetry and Exposure Records



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Purpose of today's presentation



- Briefly discuss some of the **potentially high-exposure activities at LASL** in the 1940s.
- Discuss **typical limitations** of early exposure information.
- **Review important considerations when using historical personnel exposure data** for epidemiologic studies.
- Briefly note, as additional **resource material**, some previous epi studies, publications, and reports that used Los Alamos historical exposure information.



Potentially Important Sources of Exposures at Los Alamos



- 1) **Criticality Experiments including “Tickling the Dragon’s Tail”**
- 2) **RaLa experiments**
- 3) **Water Boiler Reactor**
- 4) **Use of Beryllium (chemical exposure)**
- 5) **Plutonium purification and processing, pit fabrication and nuclear device assembly**



1) Criticality Experiments (1/2)



Nuclear criticality experiments were a particularly hazardous type of investigation but necessary to understand the parameters of sustaining a chain reaction. Understanding criticality safety was also paramount consideration in the handling of fissile and fissionable materials such as plutonium-239. Uncontrolled nuclear chain reactions can result in dangerous bursts of high energy radiation and when these reactions are triggered accidentally, injuries or even fatalities may result.

Such experiments first moved from Omega Site (TA-2) to Pajarito Site in April of 1946 following a fatal radiation injury. A second fatal radiation injury about a year later prompted a ban on hand-operated critical experiments and, as a consequence, a need for a facility for remotely operated critical assemblies.

The Integral Assembly Building (commonly known as Kiva 1) was therefore commissioned, with operations there beginning in April of 1947.

1) Criticality Experiments: Tickling the Dragon's Tail (2/2)



The phrase "tickling the dragon's tail" refers to a dangerous criticality type experiment performed by scientists at Los Alamos in 1946.

The experiment involved exposing a nuclear core to near criticality.

The experiment was high risk for radiation exposure and resulted in two scientists, Harry Daghljan and Louis Slotin, being exposed to lethal doses of primarily neutron radiation.

Others (~10) involved were exposed to lesser degrees (see LA-UR-79-280).



Too few people involved to be valuable for an epidemiologic study but is, nonetheless, part of the exposure history of the Manhattan project.

2) What were RaLa tests? (1/3)



RaLa (*radioactive lanthanum*), was a series of tests and experiments during (and after) the Manhattan Project designed to study the behavior of converging shock waves to achieve the spherical implosion necessary for compression of the plutonium pit. The experiment used high activity sources of La-140, a strong source of gamma radiation and radiation detectors around the source.

The La-140 source was located in the center of a metal sphere to simulate the Pu core. The test measured changes of absorption of gamma rays (over 40-50 microseconds) in the metal of the sphere as it underwent compression from conventional explosives detonated around the core.

Over 250 RaLa 'shots' were conducted 1944 - 1962.

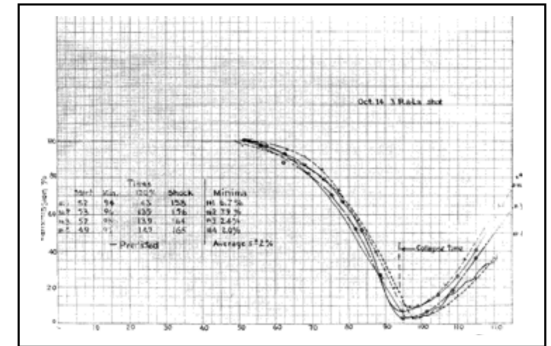


Figure 17. Decrease in percent transmission versus time (in microseconds)

2) RaLa test facilities (2/3)



TA-10, Bayo Canyon Site, was used between 1944 and 1961 for a set of experiments with conventional high explosives, RaLa, and depleted or natural uranium for implosion diagnostics. The 254 shots used RaLa sources ranging in size from about 25 Ci to 7,090 Ci of ^{140}La . The explosions resulted in the dispersion of depleted and natural uranium, La-140 , and Sr-90 in the form of aerosols and debris to the atmosphere and onto the ground.

Radiochemical operations conducted at the site resulted in the generation of liquid and solid radioactive wastes, which were disposed in subsurface pits and leach fields. The site was decommissioned by 1963.



Wartime "remote handling" of a kilocurie source of radiolanthanum for RaLa testing, Bayo Canyon (TA-10)

2) Possible RaLa exposures (3/3)



- La-140 sources were generally about 1,000 Ci each ($\sim 3.7 \text{ E13 Bq}$). The exposure rate from a 1,000 Ci La-140 source is 1,130 R/hr at 1 meter distance. A 1,000 Ci La-140 source weighs about 1.8 mg was encapsulated into a source about the size of a small pea.
- Conventional high explosives surrounding common metals (surrogates for plutonium) and a radioactive source, as small as one-eighth inch in diameter and containing up to several thousand curies of radioactive lanthanum, were involved in each experimental detonation.
- The cloud from the detonation contained radioactive lanthanum and other vaporized materials and moved with the prevailing winds and was deposited on the ground (fallout), often to distances of several miles.
- Doses to participants and off-site residents in Los Alamos and other settlements are discussed in references in list at end of presentation.

3) Beryllium: How and for what purposes was it used? (1/2)



- Beryllium is not radioactive but exposure to the element is a health concern and was a well-known hazard at multiple Manhattan project sites including Los Alamos.
- Beryllium is used to create a solid shell around the plutonium cores, or pits, that trigger nuclear warheads. Beryllium's properties include reflecting neutrons back into the pit, increasing the force of the explosion, and generating additional neutrons.
- Beryllium was used in the neutron initiator for the earliest plutonium atomic bombs, such as the Gadget and Fat Man.
- Chronic beryllium disease (CBD), also known as berylliosis, is a lung disease that can develop from exposure to beryllium, a metal used in the nuclear weapons industry

3) Beryllium (2/2)

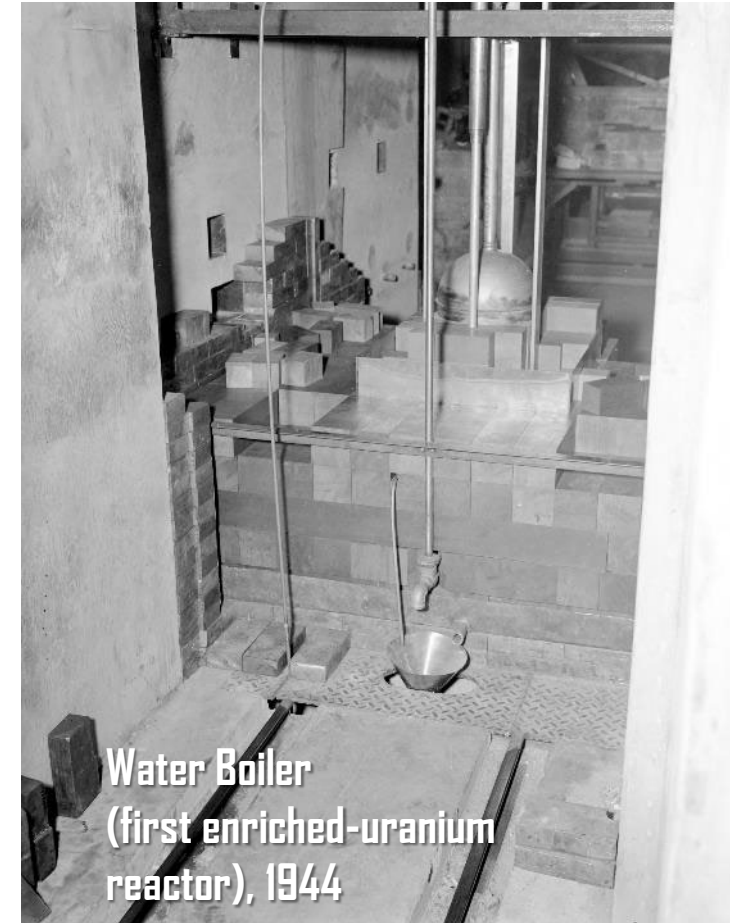


- Beryllium operations and accompanying medical surveillance of workers at Los Alamos National Laboratory began in the 1940s. In 1999 a Former Workers Medical Surveillance Program that includes screening for chronic beryllium disease was initiated.
- As part of that program, historical beryllium exposure conditions have been reconstructed from archived paper and electronic industrial hygiene data sources (see reference list at end).
- Archived industrial hygiene sampling reports indicated beryllium was principally used in TA-01 and -03, primarily from being machined. Beryllium was also used at 15 other technical areas at Los Alamos in activities that ranged from explosives detonation to the manufacture of X-ray windows.
- A total of 4,528 personal breathing zone and area air samples for beryllium, combined for purposes of calculating summary statistics, were identified during the records review phase of Stefaniak et al. (2003).
- Exposures could only be derived from episodic air concentrations (group level measurements, unlike individualized radiation doses).

4) The LASL Water Boiler Reactor (1/2)



- The first Water Boiler reactor, nicknamed LOPO (low power output,) went critical at Los Alamos on May 9, 1944 with Enrico Fermi at the controls. It used “liquid fuel”, a uranium – water slurry which looked like “boiling water”.
- The LOPO reactor was dismantled after a couple of months of measurements to make way for a higher-power version, aptly called HYPO (“high power”). Completed in December 1944, HYPO had a maximum power output of 5.5 kilowatts and was used as a source of neutrons for a number of experiments at Los Alamos.



4) LASL Water Boiler Reactor: possible exposures (2/2)



The first Water Boiler Reactor (assembled late in 1943 in Los Alamos Canyon, TA-2-1) used enriched uranium (14% ^{235}U) for the reactor fuel which was the country's total supply of enriched uranium at that time. The general purpose was for neutron experiments and isotope production.

Routine exposures in operating and using the reactor are unknown (to me). The involvement of military personnel is also unknown to me.

The Water Boiler Reactor was upgraded several times and was eventually decommissioned in 1988 (which may make it not of interest to this project). Contamination from fission products was reported distributed throughout reactor-related systems. Neutron activation of the reactor vessel and nearby components gave exposure rates ranging from 1 R/h to 150 R/h.

The Project Management Plan (see reference list) for decommissioning estimated a total dose over the life of the project was 27.3 man-rem. The actual total dose over the life of the project was reported as 4.35 man-rem.

5) Plutonium purification / processing / pit fabrication and nuclear device assembly (1/2)

- Los Alamos was the first site in the world to receive quantities of plutonium large enough to manufacture weapons components.
- The assignments given to Los Alamos in the early 1940s were to perform the final purification of the plutonium received from Hanford; reduce the plutonium to its metallic state, determine the relevant physical and metallurgical properties, develop the necessary weapons component fabrication technologies.
- The history of activities at Los Alamos is complex and involved multiple sites and activities at the lab, too many to be summarized here. See <https://www.cdc.gov/niosh/ocas/pdfs/tbd/lanl2.pdf> for a summary. This reference discusses potential radiation exposure conditions encountered during LANL's early critical assembly experiments which reportedly could be found in Omega notebooks 101, 186, 408, 480, 595, 603, 607, 685, and 733 (LASL 1946) but this 2004 CDC report was unable to locate the notebooks.

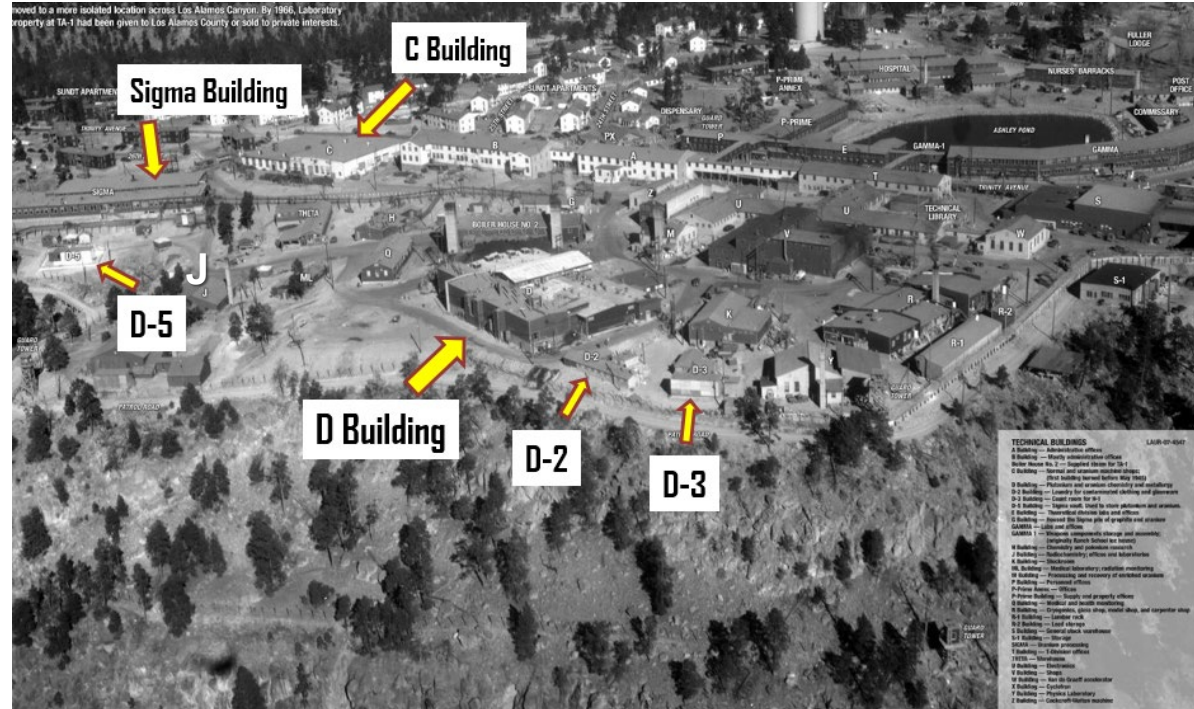
5) Pu (2/2)



The original lab grounds

Plutonium chemistry: D
Other radiochemistry: J

As programs and operations grew in complexity, Pu operations were moved to TA-21 (not in photo) in 1945.



See <https://www.cdc.gov/niosh/ocas/pdfs/tbd/lanl2.pdf> for a history of activities in specific buildings. Exposures from Pu-related activities are not available for this presentation.

Summary of accidents and non-routine radiation exposures



From <https://www.cdc.gov/niosh/ocas/pdfs/tbd/lanl2.pdf>, p. 50, a list of eight accidents leading to radiation exposures from 1943 through 1946. The circumstances are weighted to criticality experiments. Doses from each event are not available for this presentation except where noted below.

Table 2-4. Accidents and incidents.

Date	Location	Description ^a	Source ^b
1943	TA-1, X Bldg	Overexposure to radiation from the cyclotron	1
Aug 1944	TA-1, D Bldg	10 mg of plutonium exploded in a worker's face	1
Jan 1945	TA-1, C Bldg	Fire in oil quench tank spread through frame shop building	3
Feb 11, 1945	TA-2 Omega Site	Criticality during experiment with EUH ₃ Dragon assembly for prompt bursts (no personnel exposure)	4
June 6, 1945	TA-2 Omega Site	Criticality during an experiment to establish the critical mass of EU (3 exposures of 66 rep, 66 rep, 7 rep)	2
July 1945	CM-5	Four workers exposed to more than 1 µg of Pu by urine tests	1
Aug 21, 1945	TA-2 Omega Site	Criticality while creating a Pu core critical assembly (fatality 510 rem; one exposure of 50 rem)	3
May 21, 1946	TA-18 Pajarito Lab	Criticality during demonstration of a Pu core critical assembly (fatality 2,100 rem; seven exposures of 360, 250, 160, 110, 65, 47, and 37 rem)	3

Typical limitations of Early (1940s) Exposure Information (1/2)



- Small number of exposed persons was typical. Is the cohort large enough for an epidemiologic study of acceptable power?
- Medical surveillance on those exposed? For how long?
- Reliability of the medical diagnoses? And for causes of death?
- Age(s) at exposure and disease diagnosis recorded?
- Data on possible confounding factors (e.g., smoking, etc.) available?

Typical limitations of Early (1940s) Exposure Information (2/2)



- Incomplete exposure data for individuals (incomplete over space and/or time)
- Monitoring data (e.g., air concentrations) are sometimes measured and reported only for groups of workers (e.g., those working in a facility)
- Lack of representativeness of exposure measurements for all locations or for the entire period of time
- Unknown precision of exposure measurement data
- Unknown or poorly quantified limits of detection of exposure
- Inadequate or poorly described QA procedures for exposure measurements
- Lack of quantified statements of exposure uncertainty
- Lack of information about occupational, medical or natural sources of exposures prior to or after known work period

Important Considerations When Using Historical Exposure Information



- What dose units were originally reported? How are those units to be converted to current dose units to enable comparisons with more modern-day risk assessments?
- Were exposure pathways completely understood when measurements were taken?
- How are “less than detectable” doses to be handled?
- How are “missing data” to be handled?
- Is there data available on confounding factors, e.g., smoking, medical radiation, background radiation exposure available?
- Were historic measurements taken useful and reliable for dose estimation for target tissues of concern today? Are there records specifying energy range (spectra)? Exposure time? Dose-rate?
- Do reported doses apply to the target tissues of interest today? If not, can they be “converted” to doses for the target tissue of interest? If not, how will surrogate doses be posited? If yes, what biases or uncertainties will be introduced by the “conversion”?
- Are there any independent (or secondary) sources of dose estimates for confirmation?

When considering performing an analytical epidemiological study, the quality and applicability of historical exposure data to the specific purpose of the study is always an important concern.



Some References and Resource Material (1/2)



JOURNAL ARTICLES

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Anderson JL, Daniels RD. **Bone marrow dose estimates from work-related medical x-ray examinations given between 1943 and 1966 for personnel from five U.S. nuclear facilities.** Health Phys. 2006 Jun;90(6):544-53.

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Voelz GL, Lawrence JN. **A 42-y medical follow-up of Manhattan Project plutonium workers.** Health Phys. 1991 Aug;61(2):181-90.

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NIOSH Dose Reconstruction Project. 2004.

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Final Project Report Ta-2 Water Boiler Reactor Decommissioning Project

<https://www.osti.gov/servlets/purl/5758959>

The RaLa/Bayo Canyon Implosion Program

<https://hpschapters.org/snv/RaLaProgramSNChapter.pdf>

The Bayo Canyon/radioactive Lanthanum (RaLa) Progra, LA-13044-H

https://digital.library.unt.edu/ark:/67531/metadc664017/m2/1/high_res_d/233350.pdf

What Has Happened To The Survivors Of The Early Los Alamos Nuclear Accidents?

[accidentsurvivorslanl.pdf \(orau.org\)](#) LA-UR-79-280.