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ENVIRONMENTAL MONITORING AT THE LAWRENCE LIVERMORE LABORATORY 1976 ANNUAL REPORT

W. J. Silver
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E. H. Willes
J. H. White

March 11, 1977

MASTER

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LAWRENCE LIVERMORE LABORATORY

University of California Livermore, California 94550

UCRL-50027-76

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THE LAWRENCE LIVERMORE LABORATORY
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Foreword

This report is prepared for the U. S. Energy Research & Development Administration by the Environmental Evaluations Group of the Hazards Control Department, Lawrence Livermore Laboratory. Data are obtained through the combined efforts of the Radiochemistry Division, the Bio-Medical Division and the Hazards Control Department. In addition to the authors listed, the following personnel made significant contributions to this report:

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Lawrence Livermore Laboratory (Looking From Southeast)

①	LLL	⑦	Vasco Road
②	Sandia	⑧	East Avenue
③	South Bay Aqueduct	⑨	Greenville Road
④	Arroyo Seco	⑩	Lupin Way
⑤	Arroyo Las Positas	⑪	Interstate 580
⑥	Nearest residential area		

ENVIRONMENTAL MONITORING AT THE LAWRENCE LIVERMORE LABORATORY 1976 ANNUAL REPORT

Introduction

The Lawrence Livermore Laboratory (LLL) is located about 64 km east of San Francisco in the Livermore Valley in southern Alameda County, approximately 5 km east of the city of Livermore, California. The site occupies an area of 2.54 km². Open agricultural areas surround the Laboratory on the north, east, west, and part of the south side. Sandia Laboratories — Livermore occupies a portion of the adjoining property on the south.

Established in 1952, the Laboratory is operated for the Energy Research and Development Administration by the University of California under contract number W-7405-Eng-48, and currently employs approximately 6300 people. Although nuclear weapons research and development has always been the prime mission of LLL, additional programs include controlled thermonuclear research, peaceful uses of nuclear explosives, biomedical studies, and laser fusion research. Most recently, major programs to develop nonnuclear energy technologies have been established at Livermore.

Much of the materials testing and high-explosive diagnostic work of the Laboratory is carried on at Site 300, about 16 km southeast of Livermore. This site, located in the sparsely populated hills of the Diablo Range, covers an area of 27 km².

The Livermore Valley has a climate characterized by mild, rainy winters and warm, dry summers. Annual rainfall averages about 360 mm; rains occur predominantly between November and April, usually in connection with Pacific storms. Surface water drainage from the Valley is from east to west through various arroyos, with the outfall near Sunol in the southwestern corner of the valley. Prevailing winds are from the west and southwest during April through September. During the remainder of the year, the winds from the east and northeast often occur as frequently as those from the west and southwest.

The Livermore site is developed on a northwesterly sloping alluvial flood plain bordering the low hills of the Livermore Uplands to the south. Lithology of the area consists of a

series of unconsolidated marine and continental sedimentary units such as sandstones, gravels, silts, and clays overlaying the interbedded sandstones of the Franciscan Formation. The hilly terrain surrounding the Valley is used for cattle and sheep pasture. Principal agricultural products in the vicinity of LLL are grapes and wine, cattle, poultry, and eggs.

Water bodies adjacent to the Laboratory include the South Bay Aqueduct, which runs from northeast to southwest at a closest distance of 1.8 km to the southeast, the Patterson Pass water treatment facility about 2 km east of LLL, and Frick Lake 4 km north of LLL (Frick Lake is dry most of the year). LLL normally receives all of its treated water from the Hetch Hetchy Aqueduct (which supplies San Francisco), located 11 km southwest of Livermore. Laboratory storm water is channeled through storm sewers designed to accommodate a ten-year flow. Open ditches are used in undeveloped areas of the site. Two arroyos traverse LLL. Arroyo Seco crosses at the southwest corner of the project, and Arroyo Las Positas originally crossed the northeast section of the site, entering from the east at a point on Greenville Road between Patterson Pass Road and Lupin Way. However, in 1965, as part of an erosion control program the arroyo was channeled north to the northeast

corner of the site, and then west along the north perimeter to an outlet at the northwest corner. This outlet, which also constitutes the principal pathway for the Laboratory's surface drainage (storm and irrigation) runs north in a $5.7 \times 10^{-3} \text{ km}^2$ easement zone to the Western Pacific tracks, then westward where it joins Arroyo Seco.

The total present population within 80 km of the Laboratory is approximately 4.3×10^6 , distributed as indicated in Fig. 1. The population of the city of Livermore is approximately 50,000, and the nearest residential area is 0.8 km from the Laboratory's west perimeter.

A strict effluent control program which places maximum emphasis on controlling effluents at the source has been in continuous existence within the Laboratory since it began operation. An environmental surveillance program is conducted to ensure that this control program is indeed restricting the release of effluents from the Livermore Laboratory and Site 300 to concentrations well below applicable standards. This program employs techniques with sensitivities usually capable of detecting radioactive and nonradioactive pollutants well below environmental background levels. The program includes the collection and analysis of air, soil, water, sewer effluent, vegetation, and milk samples. Environmental

Fig. 1. Estimated population distribution by sectors within 80 km of LLL.

background radiation is measured at numerous locations in the vicinity of the Livermore Laboratory by means of thermoluminescence dosimeters.

Results of these analyses are provided in this report. Appendix A contains all data in tabular form. To facilitate interpretation, graphical presentation techniques have been employed in the body of the report. When appropriate, the tabulated data contain maximum, minimum, and average values. Error limits, when accompanying these data, reflect the uncertainties in the analyses at the 95% confidence level. Unless otherwise

stated, the minimum detection limit of these measurements is assumed to have been reached when the 2σ error is $\pm 100\%$. In the case of radioactivity, an attempt has been made to assess the potential impact from the observed environmental levels of artificially produced radionuclides by calculating the whole body or critical organ doses delivered to an adult. In evaluating these radiation doses which are typically less than 1 mrem per year, they should be compared with doses of approximately 100 mrem received locally each year from natural sources.

Summary

The average airborne gross beta activity from air filters collected during the first three quarters of 1976 was 2.2×10^{-14} $\mu\text{Ci/ml}$, about half of the average level observed during 1975. However, the atmospheric nuclear tests by the Peoples Republic of China on September 26 and November 17 elevated the fourth quarter values sufficiently to raise the annual average gross beta concentration to 7.6×10^{-14} $\mu\text{Ci/ml}$, higher than the 1975 average. Airborne ^{238}U concentrations at Site 300 were higher than those at Livermore perimeters because of the use of "depleted" uranium (a byproduct of

^{235}U enrichment) at the site. These uranium concentrations were well below the standards set by ERDA. Both Laboratory perimeter and Site 300 annual average airborne beryllium concentrations were less than 0.002% of the appropriate standard.

Soil samples collected in the off-site vicinity of the Laboratory and at Site 300 were analyzed for plutonium. There were negligible changes from the levels previously reported.

Water samples collected within the Livermore Valley and Site 300 exhibited gross beta and tritium activities within the ranges previously observed in these areas. As

part of this monitoring program, a study was also undertaken to assess the origin and disposition of tritium in the tributaries of Alameda Creek. Tritium concentrations of about an order of magnitude above surface water backgrounds have frequently been observed in Arroyo de la Laguna and have been attributed to upstream releases by LLL. However, elevated tritium concentrations were also found in Vallecitos Creek, which indicate an additional release source. All of these tritium concentrations were well below ERDA guide levels.

Vegetation samples collected in areas generally downwind from the Laboratory contained tritium activities which were on the average higher than those collected in areas where the Laboratory's contribution should be minimal. This same trend applied to grapes grown in the Livermore Valley when compared with grapes from outside the Valley. Tritium levels in Site 300 vegetation were essentially unchanged from those observed in 1975.

As a special study, a group of California jackrabbits was collected

on the LLL site and compared with a control group to determine if Laboratory operations have contributed measurable radioactivity to these animals above that due to global fallout. Above-background plutonium levels were observed in the LLL rabbits. The source of this activity may be the waste treatment area, where low-level radiation spills have occasionally occurred in the past.

The median annual gamma radiation dose rate at the Laboratory perimeter was 62 mrem compared with 60 mrem as the median background dose rate in the off-site vicinity. Operation of a 14-MeV neutron generator near the south site perimeter continues to be a source of elevated radiation.

Assessment of the calculated radiation doses to an individual from the environmental concentrations listed in this report demonstrates that the dose contribution from Laboratory operations in 1976 was small compared with the approximately 100 mrem/yr dose locally received from natural sources.

Monitoring Data — Collection, Analysis, and Evaluation

RADIOACTIVE MONITORING

Airborne Radioactivity

Concentrations of various airborne radionuclides were measured at

Laboratory perimeters, in the off-site vicinity of the Laboratory, and at Site 300. Sampling locations are shown in Figs. 2, 3, 4, and 5. The

Fig. 2. LLL on-site environmental sampling locations.

six samplers on the Laboratory perimeter and the ten samplers at Site 300 use $5.2 \times 10^{-2} \text{ m}^2$ Whatman 41 cellulose filters. These samplers are operated at an average flow rate of 700 l/min. Laboratory perimeter and Site 300 air filters are also analyzed for beryllium as part of our nonradioactive

monitoring program. An easily dissolved filter and a low trace metal background are requirements for these analyses. Whatman 41 represents a balance between such requirements and particulate collection efficiency.¹ Off-site samplers throughout the Livermore Valley use $4.56 \times 10^{-3} \text{ m}^2$

Fig. 3. LLL off-site environmental sampling locations.

glass fiber filters (Flanders F-700) and are operated at 80 l/min. All air filters are changed weekly. Perimeter and Site 300 filters are cut in half, and half of each filter is retained for beryllium analysis (see Non-Radioactive Monitoring).

After a four-day delay for the decay of radon-thoron daughters, gross alpha and beta activities on the

filters are determined using an automatic gas flow proportional counter. Monthly composites of the Laboratory perimeter and Site 300 filters are also counted for specific gamma-emitting radionuclides by means of a Ge(Li) detector equipped with Compton suppression.² Following gamma counting, the monthly composite of the Laboratory perimeter filters is separated

Fig. 4. Air, water and vegetation sampling locations inside Site 300 boundary.

according to sampling locations. These samples and the Site 300 composite are analyzed for ^{239}Pu , ^{238}Pu , ^{137}Cs , ^{235}U , and ^{238}U . Strontium-90 analyses on environmental air filters were replaced by ^{137}Cs measurements in 1976. The latter measurements, based on separation of the cesium as the chloroplatinate, is as sensitive as the ^{90}Sr determination, and gives

essentially the same nuclear fallout information. Since gamma counting of the filters also provides ^{137}Cs data, comparison of the two cesium values serves as a cross check of the two methods.

Tables 1 and 2 in Appendix A show airborne gross alpha and gross beta activities on the Livermore Valley samples. Tables 3 and 4 show the

Fig. 5. Water and vegetation sampling locations in the Site 300 area.

corresponding activities for Site 300.

Average annual gross beta activity in both Livermore and Site 300 air samples was higher than that observed during 1975.³ During the first three quarters of 1976 the gross beta activity averaged 2.2×10^{-14} $\mu\text{Ci/ml}$, about half of the average level observed during 1975. However, the Peoples Republic of China atmospheric nuclear explosions on September 26 and November 17, 1976 elevated the fourth quarter values sufficiently to

raise the annual average concentration to 7.6×10^{-14} $\mu\text{Ci/ml}$, higher than the 1975 average. Figure 6 is a plot of the weekly average beta activities at the two sites. Tables 5 and 6 list the activities of the more abundant gamma-emitting radionuclides which contribute to the beta activity in Livermore and Site 300 samples. Tables 7 and 8 show the concentrations of airborne ^{239}Pu , ^{137}Cs , ^{235}U , and ^{238}U in Livermore perimeter and Site 300 air samples. Figure 7 is a distribution plot of ^{239}Pu in the LLL

Fig. 6. Weekly average gross beta activity on air filters from Livermore Valley and Site 300 sampling locations during 1976.

Fig. 7. Distribution plot of ^{239}Pu in LLL perimeter air samples during 1976.

perimeter air samples. For comparison, indicating the reduction observed the least-squares fit line for the during 1976. The higher concentration of ^{238}U at Site 300 is due to corresponding 1975 data is shown,

the use of "depleted" uranium (a byproduct of ^{235}U enrichment) at the site. As noted, however, the uranium concentrations are well below the Concentration Guides of ERDAM Chapter 0524.

Airborne tritiated water (HTO) concentrations were determined at each of the LLL perimeter sampling locations shown in Fig. 2. Water vapor was collected on silica gel samplers operated at about 0.5 l/min for 2-week periods. The collected water was recovered by vacuum-drying at 150°C , and the HTO was measured by liquid scintillation counting. Table 9 shows monthly average concentrations observed at each location with an average annual concentration for the set of 8.0×10^{-11} $\mu\text{Ci/ml}$. The highest HTO concentration was observed at Location 12 at the west site boundary during the month of April. As noted, during the late fall and winter the winds are from the east and northeast almost as frequently as from the west and southwest, the latter being the prevailing wind directions in the Livermore Valley. It should also be pointed out that Location 12 shows the highest annual average concentration, probably because it is downwind from one source (gaseous chemistry) in the winter and downwind from another (14-MeV neutron generator) during the other seasons. However, it is of interest that even

the highest concentration at the site boundary (3.5×10^{-10} $\mu\text{Ci/ml}$) is less than 0.2% of the Concentration Guide of 2.0×10^{-7} $\mu\text{Ci/ml}$ specified by ERDA Manual Chapter 0524.

Radioactivity in Soil

An intensive soil sampling program in 1971 and 1972 has provided a data base for the concentration range of various radionuclides in soils in the vicinity of the Laboratory and at Site 300. Since 1972, soil sampling in the vicinity of LLL and at Site 300 has been part of a continuing surveillance program to document any changes in environmental levels of radioactivity that may have occurred and to evaluate any increase that might be due to Laboratory operations. During 1976, several locations in the vicinity of LLL were resampled. Fourteen of these locations were chosen by a random selection process from the group of over 200 locations that were sampled as part of the 1971-72 survey. Three samples were collected east of Greenville Road at the same locations that have been sampled annually since 1973. Figure 8 shows the location of the 1976 sample group, and Fig. 9 shows with more detail the locations of the east of Greenville Road group. Figure 10 indicates the locations at Site 300 where annual samples have been collected since 1973.

Fig. 8. Locations of soil samples collected in the vicinity of LLL.

In previous years, these samples have been collected to a depth of 1 cm. Under field conditions, it is difficult to uniformly maintain such a shallow sampling depth. Accordingly, in 1976 all samples were collected to a depth of 5 cm. A number of locations were sampled at both depths for purposes of comparison. Samples were dried, ground, and blended. Plutonium-239 was determined in each of these

samples following acid leaching using the HASL procedure.⁴ Since leaching also represents a change from the total acid dissolution procedure previously employed at LLL, several of the 5-cm samples were compared using the two preparatory techniques. Since the plutonium activity is predominately aged and weathered fallout, there was little difference between the 1- and 5-cm samples. Comparison

Fig. 9. Locations of soil samples collected East of Greenville Road.

of leached and totally dissolved samples also showed agreement in plutonium activities, usually within the error attributed to counting statistics. Table 10 lists the plutonium activities observed in the 5-cm-depth samples collected within the Livermore Valley during 1976.

Figure 11 is a distribution plot of these activities. The two samples with the highest values both came from the same geographical area (Figs. 8 and 9) and as previously reported,⁵ probably reflect past, low-level releases from solar evaporation of liquid radioactive wastes.

Fig. 10. Locations of soil samples collected inside Site 300 boundary.

These operations were discontinued several years ago. Table 11 compares the plutonium levels in soil samples from this area with those collected at the same locations during 1975. Much of this area was tilled during the spring of 1976, which explains the generally lower plutonium levels compared with the 1975 samples. For gamma spectra analysis, approximately

300-g aliquots of soil were sealed in 200-cm³, thin-walled aluminum cans and counted in the Ge(Li) spectrometer previously referenced.² The results of the gamma spectra analysis of the Livermore Valley soil samples are also shown in Table 10.

High-explosive tests at Site 300 often involve the use of depleted uranium. Accordingly, soil samples

are taken annually to determine the extent to which the natural $^{235}\text{U}/^{238}\text{U}$ ratio of the soil is perturbed by these operations. To date the analyses have indicated that isotopic perturbation is essentially restricted to areas adjacent to the firing bunkers.⁶ A direct measurement of ^{238}U was employed using the 63-keV transition gamma from ^{234}Th , the first daughter of ^{238}U .⁷ Besides providing essentially a direct measurement of ^{238}U , gamma spectrometry has the additional advantage that the ^{235}U and ^{238}U data may also be obtained simultaneously with the measurement of other gamma-emitting radionuclides in soil. The isotopic uranium data, shown in Table 12, are comparable to those observed during 1975. Plutonium and ^{137}Cs levels are also in the range which were present in Site 300 soils in 1975.

Radioactivity in Sewage

Liquid radioactive wastes are treated to reduce activity levels to as low as practicable and well below standards set by ERDAM Chapter 0524. Following this treatment, the liquid waste is released to the city of Livermore's sanitary sewer system at the LLL outfall shown in Fig. 2. This effluent is continuously monitored for pH and radioactivity.

The Livermore water reclamation plant is a 200- ℓ /s tertiary treatment

sewage plant serving the residential, commercial, and industrial users in Livermore. Sanitary sewage from LLL contributes about 13 ℓ /s which is approximately 6% of the capacity of the plant. After primary settling to remove solid matter, the liquid passes through trickling filters, an aeration stage, and final sedimentation. The purified sewage is filtered through charcoal, chlorinated to kill pathogenic bacteria, and dechlorinated before release from the plant. The treated effluent is used for irrigating the Livermore Municipal Golf Course, lawns of the Livermore Airport, and nearby agricultural land. Treated water is also supplied to the California Department of Transportation for irrigation of landscaping of I-580. The balance is discharged into Arroyo Las Positas.

Solids from the settling tanks are pumped to anaerobic digesters where bacteria break down the organics to yield stabilized sludge and methane. This sludge is then pumped into one of two large lagoons. During the summer, a portion of this sludge is removed to drying beds. The dried sludge is primarily used by the city of Livermore as a soil conditioner.

Weekly samples are collected from each digester, the aeration tank, and the liquid effluent. Average monthly gross alpha and beta activities are shown in Table 13. Table 14 compares

the activity levels of certain radio-nuclides in the LLL effluent with those in the effluent from the Livermore treatment plant. These data, which are comparable to those observed in 1975, indicate no buildup of radioactivity within the plant.

Radioactivity in Water

Water samples are collected from various locations in the Livermore Valley and at Site 300, as shown in Figs. 2 through 5. These samples are analyzed for gross alpha and beta activities using a gas proportional counter. There were no samples with an alpha activity above the minimum detection limit of 1.2×10^{-9} $\mu\text{Ci/ml}$. The gross beta activities for the Livermore Valley samples are listed in Table 15. Locations 11, 16, and 24 are surface sources such as ponds, creeks, and reservoirs. Livermore rainfall is sampled at Location 20. The balance are domestic water sources. Annual average gross beta activity in Livermore waters in 1976 was essentially unchanged from that observed in 1975. Gross beta activities in Site 300 water samples are shown in Table 16. These samples are collected from on-site wells supplying Site 300 (Locations 1 through 7) and off-site creek sources (Locations 11 and 14). Location 20 represents Site 300 rainwater, and Location 21 is a spring-fed pond near Bunker 812. With the excep-

tion of rainwater and the two off-site creek sources, the Site 300 samples came primarily from deep wells and springs. Annual average gross beta activity of Site 300 water during 1976 was also unchanged from 1975.

These samples are also analyzed for tritium activity. Because of the low activities, it was necessary to distill and electrolytically enrich samples for liquid scintillation counting. Tables 17 and 18 show the data for Livermore and Site 300 samples, respectively. Inspection of the data indicates that the samples exhibit concentrations that are well below the recommended concentration guide value. The tables also include an estimate of the annual dose that may be delivered to an adult consuming water containing the listed tritium concentrations. The doses, which are typically less than 0.1 mrem, are based upon a daily water consumption of 1 l/day and the model of Anspaugh et al.⁸

As part of the environmental monitoring program, a study was made to determine the origin and disposition of tritium in the tributaries of Alameda Creek. Aquifers in the Niles Cone area of Alameda County serve as a domestic water source for the City of Fremont. These aquifers are recharged by water from Alameda Creek which in turn is fed by a number of tributaries, as shown in Fig. 12.

Fig. 11. Distribution plot of ²³⁹Pu in soil samples collected in the Livermore Valley during 1976.

The treated effluent from the Livermore Water Reclamation Plant is seasonally discharged into Arroyo Las Positas, one of these tributaries. Operational releases to the sewer at

the Lawrence Livermore Laboratory contribute low, but measurable levels of tritium in this treated effluent.

In March 1976 a group of water samples was taken in the Niles Cone

Fig. 12. Water sampling locations in Niles Cone Area.

area to establish the levels of tritium in the aquifers. Accordingly, these samples were taken primarily from deep wells (50-150 m) and from surface sources in the immediate recharge area. Figure 12 also shows the general sampling locations. Each sample was distilled and electrolytically enriched. Following enrichment, the tritium content was determined by liquid scintillation counting.

Table 19 presents the tritium concentrations observed.

In September, a sample set was taken from the principal tributaries of Alameda Creek at the locations schematically indicated in Fig. 13. These samples were processed in the same manner as the previous set, and the data are shown in Table 20.

The tritium concentrations in all the samples were well below the ERDA

Fig. 13. Tributaries of Alameda Creek showing water sampling locations.

guide level. The highest concentration in the March samples (Table 19) is from a sample collected at the Alameda Creek gaging station. While Alameda Creek itself is not routinely sampled, samples from an immediate

upstream location (Location 8, Fig. 13 Arroyo de la Laguna) have been collected since 1972. Tritium concentrations in the 10^{-6} $\mu\text{Ci}/\text{ml}$ range have often been observed in these samples, and it has been assumed that

such levels were related only to LLL releases as previously noted. However, the highest tritium concentration in the tributary samples (Table 20) is from Vallecitos Creek, indicating at least one other additional release source.

Radioactivity in Vegetation

Vegetation samples (usually native grasses) are collected at monthly intervals throughout the Livermore Valley, at Site 300, and in the off-site vicinity of Site 300 at the locations shown in Figs. 3, 4, and 5. These samples are freeze-dried and the tritium activity in the recovered water is determined by liquid scintillation counting. Table 21 shows the tritium data on vegetation collected in the Livermore Valley. The data indicate somewhat higher tritium concentrations downwind of the Laboratory (north and east) compared with those found in normally upwind areas. The whole-body radiation doses shown in the table were derived from the model of Anspaugh *et al.*,⁸ assuming that the observed activities were typical of edible vegetation grown in this area. The potential doses, which are less than 1 mrem per year, are based upon the direct daily consumption of 400 g of vegetation,⁹ assumed to be 80% water.

In addition to the native grasses, samples of Livermore Valley grapes

were collected during the 1976 harvest. For comparison, grape samples were also obtained from a number of vineyards outside the Valley. These samples were analyzed for tritium using the procedures previously described. The data are shown in Table 22. Slightly elevated tritium levels were found in some Livermore Valley grapes, but these are within the range observed for other vegetation in the Valley.

Table 23 shows the tritium data for Site 300 vegetation. With the exception of Locations 6 and 13, the tritium levels in Site 300 vegetation are lower and show less fluctuation than do the Livermore Valley samples. Location 6 is adjacent to an area containing tritium-contaminated debris from a firing table. Under the influence of seasonal rains, the tritium has apparently entered an aquifer whose outflow is in the area where Location 13 samples are routinely collected.

Radioactivity in Milk

During 1976, milk samples were obtained at monthly intervals from a dairy located about 10 km southwest of Tracy in the San Joaquin Valley. Before analysis, the samples are concentrated by heat evaporation and oven drying, and the concentrates are gamma-counted in a Ge(Li) system. In addition, each sample is analyzed for tritium activity by counting the

vacuum-distilled sample in a liquid scintillation counting system. Activities of ^{137}Cs , ^{40}K , and ^3H are shown in Table 24. No other radionuclides were detected. Also shown are the calculated annual adult whole-body or critical organ radiation doses from consumption of this milk. These calculations are based on an intake of 260 g/day and the models previously referenced. The only dose to an individual above 1 mrem is that from naturally occurring ^{40}K .

Environmental Radiation Measurements

Environmental radiation measurements are made at 12 LLL perimeter locations shown on Fig. 2, and at 41 off-site locations shown in Fig. 14. These measurements are obtained with thermoluminescence dosimeters using a procedure published elsewhere.¹⁰ Exposure periods are three months. Based on past measurements,¹¹ the environmental terrestrial exposure rates in the Livermore Valley vary between 3 and 7 $\mu\text{R/hr}$; cosmic radiation, calculated from the local elevation and geomagnetic latitude according to the data of Lowder and Beck,¹² is approximately 4 $\mu\text{R/hr}$. Table 25 shows quarterly and annual doses in millirem derived from the measured exposure rates at perimeter locations. Operation of a 14-MeV neutron generator located adjacent to the south boundary

fence has been responsible for elevated dose rates at Location 5.³ During 1976, TLD measurements were also made at a point on the site boundary directly opposite this facility since maximum exposure rates are observed there. This perimeter monitoring location, identified in Table 25 as Location 5a, is about 25 m west of Location 5 (see Fig. 2). It has been estimated that during 1976 the maximum radiation dose to an individual from this would be less than one-tenth the radiation protection standard of ERDA Manual Chapter 0524. Locations 10, 11, and 12 are near a linear accelerator facility. Figure 15 shows an annual frequency distribution of environmental dose rates observed at the 41 off-site locations. The dosimeter recording the highest dose (163 mrem) is near an off-site industrial plant where radiography is frequently performed. The median off-site dose rate of 60 mrem is comparable to the 59 mrem observed during 1975. The median perimeter dose rate was 62 mrem, which was the same value observed for 1975. Figure 16 is a dose distribution plot combining Laboratory perimeter and off-site measurements. The doses above those typical of environmental background have each been identified in the comments above, or are appropriately noted in Table 25.

Fig. 14. Location of TLDs in the vicinity of LLL.

NON-RADIOACTIVE MONITORING

Airborne Beryllium

Beryllium monitoring, both of in-plant air and at or near the property boundaries, has always been a part of the LLL safety program. Each month half of each LLL perimeter and Site 300 filter is composited by sampling location, wet-digested, and the beryllium content of the solutions is determined by atomic absorption analysis.

Tables 26 and 27 show monthly average airborne beryllium concentrations for LLL perimeter and Site 300 sampling locations, respectively. There appears to be no difference between the levels at Site 300, where beryllium is frequently expended in high-explosive experiments, and those observed at Livermore. The concentrations, which are 3 to 4 orders of magnitude below the emission standard, can be accounted for by resuspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 ppm of beryllium. Livermore's air typically contains 10-100 μg of particulates per cubic metre. Using a value of 50 $\mu\text{g}/\text{m}^3$ for an average dust load and 1 ppm for the beryllium content of this dust would give an airborne beryllium concentration of 5.0×10^{-5} $\mu\text{g}/\text{m}^3$, in agreement with the data in the tables. These concentrations are plotted in

Fig. 15. Annual off-site gamma radiation background (m rem) for 1976.

Figs. 17 and 18. Normally, these plots would show a maximum concentration during the dry dusty summers and minimum concentrations during the wet winter season. However, due to the lack of rain during 1976, there is little difference between summer and winter concentrations. As a result the annual average beryllium concentration at both sites is somewhat higher than 1975, but are less than 0.002% of the appropriate standard.

Fig. 16. TLD dose distribution plot for LLL perimeter and Livermore Valley during 1976.

Heavy Metals Released to
Livermore Sanitary Sewer

As noted in the previous section,
sanitary sewage from the Laboratory

is treated at the Livermore Water
Reclamation Plant, a 200-l/s tertiary
treatment sewage plant serving the
residential, commercial, and industrial

Fig. 17. Be concentration in LLL perimeter air filter during 1976.

Fig. 18. Be concentration in Site 300 air filters during 1976.

users in Livermore. The LLL sewage effluent is continuously monitored for pH and radioactivity prior to entering the Livermore system.¹³ Samples of sewage representative of daily flow are collected and composited on a monthly basis. These composites are analyzed for the metals shown in Table 28.

Physical and Chemical Analysis of LLL and Site 300 Sewage

Samples of Laboratory sewage effluent are collected at quarterly intervals throughout the year. These samples are subjected to a variety of analyses including biochemical oxygen demand, ammonia, nitrate, total

nitrogen content, alkalinity, and total solids. Table 29 shows the data for 1976 which are well below the discharge requirements of Appendix B. Table 30 shows results obtained on similar quarterly samples collected from the oxidation pond at Site 300.

Noise Pollution

As noted elsewhere in this report, the Laboratory's high-explosive diagnostic work is carried out at Site 300. Because of the remoteness of this site, these experiments can be performed with minimal off-site impact from annoying noises or damaging overpressures. Based on meteorological measurements made twice daily, a limit is set on the weight of high explosives that can be detonated without impact in populated areas. To monitor the correctness of these limits, four microbarograph sensors are maintained in or near Tracy. The probability of overpressure is greatest in this area due to the direction of the prevailing winds. In 1976, there was one incident involving a noticeable overpressure which was caused by an unexpected change in the direction of the upper winds. There were no complaints of damage.

Pesticide Monitoring

Starting in 1975, the nonradioactive environmental surveillance program was expanded to include pest-

icide monitoring. At Livermore, pesticide use includes herbicides, fungicides, and insecticides, and while a wide variety of these materials are employed, none has shown a regular pattern of heavy use.

The most probable way pesticides used at LLL could be transported to the off-site environment is via entrainment in surface run-off water. Most of this surface drainage leaves the site in a ditch at the northwest corner of the property. Samples have been collected from this ditch during rains in 1976.

Samples were extracted with hexane and ether, and the extracts were analyzed in a Finnigan 3000 D gas chromatograph/mass spectrometer. Data obtained were compared with those from pesticides known to have been used at LLL which included Benefin, Bromacil, Carbaryl, Chlordane, Dicofol, Diuron, Folpet, Simazine, and 2,4-D. Samples collected during 1976 showed no residues of these pesticides exceeding the limits of detection. Details of the analytical technique have been published.¹⁴

ENVIRONMENTAL IMPACT OF LLL EFFLUENTS

Radioactive Airborne Effluents

During 1976, radioactive airborne effluents consisted of an estimated 470 Ci of ⁴¹Ar from Building 281

(reactor); combined tritium releases from Buildings 212 (14-MeV neutron generator) and 331 (gaseous chemistry) totaled 3990 Ci, and a total of 1035 Ci of $^{15}\text{O}_2$ - $^{13}\text{N}_2$ was released from Building 194 (electron-positron linear accelerator). With the exception of tritium, all these radionuclides are short-lived. Comparative releases in 1975 were 600 Ci of ^{41}Ar , 3380 Ci of tritium, and 1200 Ci of $^{15}\text{O}_2$ - $^{13}\text{N}_2$. The levels of radioactive airborne effluents during 1976 are essentially the same as those observed during 1975.

Table 31 contains estimates of the radiation dose to the public from these radioactive airborne effluents, indicating that the total dose to the nearest resident from these effluents is less than 2 mrem. The following three dose reference points were employed: (1) the "fence post" dose at the location on the site boundary where the maximum exposure rates exist, (2) the dose to nearest resident, and (3) the man-rem dose within a radius of 80 km. Dose calculations are based on the use of a continuous point source computer code.¹⁵ This code provides estimates of concentration at distances between 0.1 and 100 km from the point of release. The code is based upon meteorological data derived from wind direction, speed, and variability observations taken at 1/2-hour intervals. Concentration

contour plots are provided at various probability levels. Source terms for those calculations were based on data from continuously operating stack monitoring equipment. Tritium doses are conservative since it is assumed that all tritium is in the form of tritiated water, whereas a significant fraction of that released may be in the gaseous form (HT). The difference in man-rem doses between wet and dry seasons is due to difference in prevailing wind direction during these periods and is not related to "rainout." At Livermore, the wet season normally extends from November through April. Figure 19 shows that the annual average winds are predominantly from the southwest. During the wet season, the winds tend to be reversed. Since population is not distributed uniformly, there are accompanying seasonal man-rem dose differences.

Radioactive Liquid Effluents

Except for low-level radioactive liquid wastes which are discharged to the Livermore sanitary sewers, LLL does not release radioactive liquids to the environment. During 1976, the principal radionuclides released to the sewer were 1.5×10^{-4} Ci ^{239}Pu and 10 Ci of HTO. Table 15 shows the concentration of these radionuclides in the treated effluent from the

Wind rose shows relative frequency of wind direction (by the length of the line) obtained from the tabulated annual data below.

Frequency of Wind In Percent for Livermore — 1971

Mo	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm
Jan	2.7	2.2	7.2	12.1	17.8	6.8	6.2	2.2	3.9	3.8	4.9	7.0	9.7	7.6	2.0	2.6	1.3
Feb	2.2	2.5	6.9	12.9	14.8	7.2	5.1	2.6	3.5	3.0	4.9	6.0	11.2	6.5	3.4	2.0	1.4
Mar	2.1	2.2	6.4	12.3	13.5	6.9	4.9	2.7	3.3	2.6	4.6	10.5	12.2	9.1	3.1	1.8	1.7
April	2.1	2.3	4.6	8.7	9.4	5.1	3.2	2.1	3.0	4.8	10.8	16.1	13.9	7.4	2.2	1.8	2.3
May	2.2	1.9	3.6	6.5	7.1	4.0	2.4	1.7	2.4	4.7	15.3	17.7	16.7	6.0	1.9	1.9	3.8
June	2.1	1.7	3.4	5.6	6.2	3.5	2.1	1.4	2.2	4.6	16.9	19.6	17.7	5.4	1.7	1.6	3.9
July	1.7	1.4	2.8	4.6	5.1	2.9	1.8	1.3	2.0	5.3	19.5	22.9	17.2	4.6	1.4	1.4	4.0
Aug	1.6	1.4	2.7	4.5	5.0	2.6	1.7	1.3	2.1	5.3	19.8	23.5	17.0	4.5	1.4	1.4	4.1
Sept	1.9	1.4	2.5	4.0	4.4	2.5	1.6	1.3	2.2	5.4	21.1	23.3	17.3	4.7	1.4	1.2	3.7
Oct	2.4	1.6	2.7	4.1	4.5	2.7	1.6	1.3	2.2	5.7	20.6	22.5	16.3	4.6	1.5	2.2	3.5
Nov	2.6	2.5	3.4	4.5	4.9	2.7	1.9	1.9	2.6	5.4	19.2	20.5	15.5	4.7	2.0	2.3	3.3
Dec	2.8	3.0	3.9	4.6	5.3	3.0	2.6	2.2	2.7	5.1	17.7	19.2	15.3	4.8	2.1	2.4	3.1
Annual Average	2.2	2.0	4.2	7.0	8.2	4.2	2.9	1.8	2.7	4.7	14.6	17.6	15.0	6.0	2.0	1.9	3.0

Fig. 19. Typical annual average wind pattern for Livermore (LLL data — 1971).

Livermore Water Reclamation Plant to be 3.7×10^{-11} and 3.8×10^{-6} $\mu\text{Ci/ml}$ for ^{239}Pu and HTO , respectively. These concentrations represent $7.4 \times 10^{-4}\%$ and 0.1% of the ERDAM Chapter 0524 drinking water standard for ^{239}Pu and HTO , respectively. In addition, during 1/76 the average annual gross beta activity of the LLL

sewage effluent was 1.9×10^{-8} $\mu\text{Ci/ml}$. It is assumed that this activity is due to beta-gamma emitters which are released to the sewer system in accordance with ERDAM Chapter 0524. Analysis of samples collected at the point of discharge show the presence of ^{134}Cs , ^{137}Cs , ^{65}Zn , ^{56}Mn , ^{60}Co , ^{95}Zr , ^{95}Nb , ^{125}Sb , and ^{110}Ag . Even

if any of these radionuclides were assumed to be the sole source of the 1.9×10^{-8} $\mu\text{Ci/ml}$, Table 32 shows that none would account for over 0.3% of the CG of ERDA Manual Chapter 0524.

Ecology Study

There are numerous California jackrabbits (*Lepus californicus*) on the Livermore site. A special study was undertaken in 1976 to determine if Laboratory operations have contributed to the radioactivity of these animals over that due to the fallout background. Since fallout from weapons testing has resulted in a worldwide plutonium background, it was necessary to compare local rabbits with a control group from a different geographical area having a similar habitat. For this study control groups were selected from the semi-arid Susanville area in Lassen County (northeastern California).

Thirteen rabbits were collected on the LLL site and nine control rabbits were obtained in the Susanville area. These rabbits were sacrificed and dissected. The organs were composited according to type and source, and then freeze-dried and ashed. The ashed residues were dissolved in acid, and plutonium separations were made using standard radiochemical separations. The plutonium measurement data are shown in Table 33.

The source of the plutonium found in the LLL rabbits may be from an area adjacent to the LLL waste treatment site, where low-level radiation spills have occasionally occurred in the past. Jackrabbits do not constitute a local food source.

Quality Assurance

Sampling and analytical procedures employed in the LLL environmental monitoring program have been outlined in a draft quality assurance plan. This plan includes such internal quality control features as the frequency of counting equipment calibrations, source and background check, and the use of spikes and blanks. During 1976 the analytical laboratories supporting the environmental monitoring effort participated in the Interlaboratory Comparisons program established by the Quality Assurance Branch of the EPA-Las Vegas. Starting in September, they also participated in the quality assurance program of ERDA's Division of Safety, Standards and Compliance developed by ERDA's Health and Safety Laboratory (HASL). Additionally, in 1976 LLL participated in the 2nd International Intercomparison of Environmental Dosimeters sponsored by ERDA-HASL, the University of Texas, and the German Nuclear Standards Council.

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Appendix A

Tables

Error values accompanying individual radioactive measurements in these tables are those due to counting statistics, and those for groups of data (e.g., annual averages) are calculated standard deviations of the mean. The errors from counting statistics are designated as the 2σ error, and the minimum detection limit is assumed to have been reached when the 2σ error is $\pm 100\%$. The standard deviations of the mean (average) have been calculated using classical statistical methods, and are reported at the 95% confidence level.

Table 1. Gross alpha activity in air filters in the Livermore Valley during 1976.

Location ^a	(Units -- 10^{-15} μ Ci/ml)												Av	±error (%)	%CG ^b
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec			
1	0.7	1.0	0.6	0.5	0.5	0.8	0.6	0.7	1.0	4.4	3.0	3.2	1.4	54	7.0
2	0.9	0.6	0.7	0.6	0.6	0.8	0.5	0.8	0.8	7.5	2.8	5.0	1.8	72	9.0
3	1.1	0.9	0.9	0.7	0.9	0.9	0.8	1.0	1.1	2.6	1.8	1.7	1.2	26	6.0
4	2.4	0.9	1.2	0.8	1.1	0.8	1.0	1.5	2.2	8.8	2.4	4.7	2.3	58	11.5
5	0.9	1.3	1.2	0.9	1.0	0.8	1.2	1.0	1.2	2.9	5.0	2.3	1.7	44	8.5
6	1.2	0.9	0.8	1.2	1.0	1.0	0.8	1.1	1.0	3.8	2.4	3.6	1.6	40	8.0
7	1.1	0.9	1.0	1.0	0.9	1.1	0.8	1.0	1.0	2.9	3.2	2.2	1.4	34	7.0
8	1.8	1.1	1.0	0.8	0.8	0.8	1.1	1.0	1.4	3.3	3.4	3.2	1.7	36	8.5
9	1.4	1.0	0.8	0.9	0.9	1.0	1.1	1.1	1.6	6.2	3.2	2.8	1.8	50	9.0
10	0.9	0.9	0.7	1.0	0.6	0.9	0.8	0.7	1.7	4.6	3.1	2.8	1.6	48	8.0
11	1.1	1.1	1.3	0.8	1.0	0.9	0.8	1.1	1.2	4.8	3.7	2.9	1.7	41	8.5
12	1.2	0.7	0.8	0.6	0.7	0.9	0.7	0.7	1.1	4.7	3.7	4.1	1.7	53	8.5
13	0.7	0.6	0.5	0.5	0.5	0.7	0.5	0.6	1.1	5.1	3.4	2.1	1.4	62	7.0
14	0.8	0.8	0.7	0.7	0.8	0.9	0.9	1.0	1.0	3.8	2.2	4.5	1.5	50	7.5
15	0.7	0.7	0.6	0.6	0.7	0.7	0.6	0.6	1.0	3.3	2.9	3.0	1.3	48	6.5
16	1.3	2.5	1.6	0.7	0.7	0.7	0.6	0.9	1.2	3.5	2.4	2.0	1.5	35	7.5
Annual Av													1.6	14	8.0

^aSee Figs. 2 and 3 for sampling locations.^bConcentration Guide (CG) = $2E-14$ for gross alpha activity (ERDAM 0524).

Table 2. Gross beta activity in air filters in the Livermore Valley during 1976.

Location ^a	(Units - 10^{-14} $\mu\text{Ci/ml}$)												Av	$\pm$ error (%)	%CG ^b
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec			
1	2.8	3.2	1.6	1.3	1.7	1.3	0.7	1.0	1.6	37.7	22.6	10.1	7.1	94	7.1
2	2.3	1.8	1.6	1.3	1.7	1.4	0.9	1.1	1.5	69.5	30.0	9.6	9.4	121	9.4
3	2.7	3.1	2.4	2.1	2.5	2.2	1.9	1.9	2.0	19.2	11.9	5.6	4.8	64	4.8
4	5.8	6.0	3.0	1.7	2.2	2.7	2.5	3.6	4.0	60.9	20.4	7.6	10.0	98	10.0
5	3.9	3.7	2.9	2.1	3.0	2.6	2.0	2.5	2.5	30.4	42.6	9.1	8.9	96	8.9
6	3.1	3.4	2.4	2.2	2.5	2.1	1.9	2.1	2.2	35.0	17.6	10.2	6.7	96	6.7
7	2.7	2.6	2.1	1.9	2.6	2.2	1.9	2.1	2.4	25.2	22.2	7.3	6.3	76	6.3
8	3.3	3.1	2.8	2.6	2.9	2.4	1.9	2.5	2.7	30.2	22.9	10.1	7.3	74	7.3
9	4.4	3.8	3.0	2.8	3.5	2.6	1.8	2.4	3.1	54.1	23.5	11.3	9.7	91	9.7
10	3.3	3.3	2.2	1.7	2.3	1.4	0.9	1.3	1.8	43.4	25.8	9.8	8.1	94	8.1
11	3.2	3.3	3.2	2.7	2.9	2.6	1.5	2.4	2.5	46.8	25.6	9.1	8.8	90	8.8
12	3.2	3.5	2.1	1.5	2.0	1.6	0.9	1.2	1.7	40.2	28.4	11.6	8.2	90	8.2
13	2.8	2.9	1.6	1.2	1.7	1.2	0.8	1.1	1.5	48.9	26.6	7.9	8.2	104	8.2
14	2.6	3.1	1.8	1.4	1.8	1.5	0.9	1.1	1.8	37.8	13.5	10.1	6.5	96	6.5
15	2.6	2.7	1.5	1.2	1.6	1.3	0.8	1.0	1.4	30.3	18.8	7.6	5.9	90	5.9
16	2.5	1.9	0.9	1.2	1.6	1.4	0.8	1.1	1.4	29.8	17.9	7.1	5.6	92	5.6
Annual Av													7.6	24	7.6

^a See Figs. 2 and 3 for sampling locations.^b CG = $1.0\text{E-}12$ $\mu\text{Ci/ml}$ for gross beta activity in air.

Table 3. Gross alpha activity in air filters at Site 300 during 1976.

Location ^a	(Units - 10^{-15} $\mu\text{Ci/ml}$)												Av	$\pm$ error (%)	%CG ^b
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec			
1	0.7	0.7	0.5	0.5	0.6	0.6	0.6	0.7	0.8	4.3	3.2	3.4	1.4	58	7.0
2	0.6	0.6	0.5	0.6	0.7	0.7	0.5	0.5	0.9	4.8	3.2	3.4	1.4	60	7.0
3	1.0	0.9	0.9	0.7	0.9	0.5	0.5	0.8	1.1	5.2	3.5	2.2	1.5	56	7.5
4	0.8	0.7	1.0	0.9	0.9	0.8	0.7	0.6	1.0	5.4	2.8	2.3	1.5	54	7.5
5	1.1	0.9	0.7	0.7	0.5	0.5	0.5	0.6	1.3	4.3	2.2	1.7	1.3	51	6.5
7	0.6	0.8	0.5	0.7	1.5	0.7	0.6	0.7	0.8	3.5	2.4	2.6	1.3	46	6.5
8	0.9	0.8	0.9	0.8	0.7	0.9	0.8	0.7	1.0	3.5	2.6	2.5	1.3	41	6.5
9	0.9	1.1	0.7	0.7	0.7	0.9	0.7	0.9	1.1	4.4	2.5	2.4	1.4	46	7.0
10	1.3	1.2	0.9	0.5	0.8	0.6	0.5	0.7	0.7	3.9	2.9	2.5	1.4	48	7.0
11	0.9	0.9	0.7	0.6	0.9	0.6	0.5	0.5	1.0	4.5	2.9	3.0	1.4	53	7.0
Annual Av													1.4	17	7.0

^aSee Fig. 4 for sampling locations.

^bCG = $2.0\text{E-}14$ $\mu\text{Ci/ml}$ for gross alpha activity in air.

Table 4. Gross beta activity in air filters at Site 300 during 1976.

Location ^a	(Units - 10^{-14} $\mu\text{Ci/ml}$)												Av	±error (%)	%CG ^b
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec			
1	2.7	2.5	1.7	1.6	2.3	1.7	1.4	1.5	1.8	39.3	23.3	10.7	7.5	90	7.5
2	2.9	3.3	1.9	1.5	2.5	1.7	1.4	1.6	2.0	38.4	24.6	10.1	7.7	88	7.7
3	3.0	2.8	2.3	1.7	3.0	1.1	1.0	1.4	1.7	45.1	20.3	6.8	7.5	99	7.5
4	3.4	3.0	2.6	2.2	3.1	2.0	1.5	1.4	1.9	53.6	19.5	8.2	8.5	100	8.5
5	2.8	3.3	2.2	1.5	2.2	1.5	1.3	1.4	2.0	36.7	17.7	6.5	6.6	92	6.6
7	2.4	2.6	1.9	1.7	2.4	1.6	1.1	1.2	1.4	30.9	17.3	7.8	6.0	88	6.0
8	3.0	3.2	2.6	1.9	3.0	1.9	1.7	1.6	1.6	38.7	18.7	8.5	7.2	88	7.2
9	2.2	2.6	1.7	1.3	2.2	1.4	1.2	1.3	1.6	40.7	21.6	8.4	7.2	96	7.2
10	3.7	5.3	3.0	1.5	2.5	1.3	1.3	1.3	1.6	35.5	21.2	9.2	7.3	84	7.3
11	3.5	2.8	2.2	1.9	2.8	1.8	1.4	1.4	1.9	34.9	22.6	9.7	7.2	84	7.2
Annual Av													7.3	31	7.3

^aSee Fig. 4 for sampling locations.

^bCG = $1.0\text{E-}12$ $\mu\text{Ci/ml}$ for gross beta activity in air.

Table 5. Results of gamma-ray spectral measurements of LLL perimeter air filters during 1976.

Month	$10^{-13} \mu\text{Ci/ml} \pm 2\sigma$	$10^{-16} \mu\text{Ci/ml} \pm 2\sigma$							
	^7Be	^{40}K	^{95}Zr	^{103}Ru	^{106}Ru	^{125}Sb	^{137}Cs	^{141}Ce	^{144}Ce
Jan	$1.2 \pm 2\%$	$3.8 \pm 64\%$	$0.5 \pm 43\%$	$<0.1 \pm 100\%$	$8.4 \pm 15\%$	$1.6 \pm 30\%$	$4.3 \pm 9\%$	$<0.1 \pm 100\%$	$15.0 \pm 19\%$
Feb	$1.2 \pm 2\%$	$<1.0 \pm 100\%$	$0.7 \pm 47\%$	$0.8 \pm 47\%$	$9.9 \pm 11\%$	$2.4 \pm 19\%$	$6.0 \pm 6\%$	$1.0 \pm 52\%$	$18.0 \pm 11\%$
Mar	$1.4 \pm 2\%$	$3.0 \pm 69\%$	$0.5 \pm 53\%$	$<0.1 \pm 100\%$	$10.0 \pm 17\%$	$2.7 \pm 19\%$	$6.0 \pm 6\%$	$<0.1 \pm 100\%$	$19.0 \pm 14\%$
Apr	$1.1 \pm 2\%$	$<1.0 \pm 100\%$	$0.2 \pm 72\%$	$<0.1 \pm 100\%$	$8.7 \pm 16\%$	$2.0 \pm 23\%$	$5.5 \pm 6\%$	$<0.1 \pm 100\%$	$15.0 \pm 12\%$
May	$1.6 \pm 2\%$	$4.4 \pm 50\%$	$<0.05 \pm 100\%$	$<0.1 \pm 100\%$	$14.0 \pm 12\%$	$0.4 \pm 17\%$	$8.8 \pm 5\%$	$<0.1 \pm 100\%$	$22.0 \pm 11\%$
June	$1.3 \pm 2\%$	$4.9 \pm 40\%$	$<0.05 \pm 100\%$	$<0.1 \pm 100\%$	$<0.1 \pm 100\%$	$<0.03 \pm 100\%$	$6.4 \pm 10\%$	$<0.1 \pm 100\%$	$<1.2 \pm 100\%$
July	$0.8 \pm 2\%$	$6.3 \pm 38\%$	$<0.05 \pm 100\%$	$<0.1 \pm 100\%$	$<0.1 \pm 100\%$	$<0.03 \pm 100\%$	$3.1 \pm 8\%$	$<1.1 \pm 100\%$	$5.9 \pm 24\%$
Aug	$0.8 \pm 2\%$	$4.8 \pm 26\%$	$<0.05 \pm 100\%$	$<0.1 \pm 100\%$	$2.4 \pm 20\%$	$<0.03 \pm 100\%$	$1.8 \pm 7\%$	$<0.1 \pm 100\%$	$3.5 \pm 36\%$
Sept	$1.1 \pm 8\%$	$9.2 \pm 21\%$	$<0.05 \pm 100\%$	$<0.1 \pm 100\%$	$3.7 \pm 34\%$	$<0.03 \pm 100\%$	$1.9 \pm 11\%$	$<0.1 \pm 100\%$	$<1.2 \pm 100\%$
Oct	$1.5 \pm 2\%$	$<1.0 \pm 100\%$	$600.0 \pm 1\%$	$432.0 \pm 2\%$	$21.0 \pm 30\%$	$<0.03 \pm 100\%$	$5.3 \pm 14\%$	$750.0 \pm 2\%$	$120.0 \pm 12\%$
Nov	$1.3 \pm 3\%$	$6.7 \pm 60\%$	$296.0 \pm 2\%$	$511.0 \pm 2\%$	$43.0 \pm 16\%$	$<0.03 \pm 100\%$	$7.8 \pm 8\%$	$460.0 \pm 2\%$	$82.0 \pm 13\%$
Dec	$1.7 \pm 2\%$	$13.8 \pm 24\%$	$49.0 \pm 3\%$	$98.0 \pm 2\%$	$16.4 \pm 15\%$	$<0.03 \pm 100\%$	$3.9 \pm 13\%$	$69.3 \pm 3\%$	$18.0 \pm 15\%$
Annual Av	1.3	<5.0	<78.9	<86.9	<11.5	<1.0	5.1	<106.8	<26.7
error (%)	13	43	135	121	59	70	25	131	79
CG	$4.0\text{E-}08$	$4.0\text{E-}09$	$1.0\text{E-}09$	$1.0\text{E-}09$	$2.0\text{E-}10$	$9.0\text{E-}10$	$5.0\text{E-}10$	$5.0\text{E-}09$	$2.0\text{E-}10$
%CG	$3.3\text{E-}04$	$1.3\text{E-}05$	$7.9\text{E-}04$	$2.9\text{E-}04$	$5.8\text{E-}04$	$1.1\text{E-}05$	$1.0\text{E-}04$	$2.1\text{E-}04$	$1.3\text{E-}03$

Table 6. Results of gamma-ray spectral measurements of Site 300 air filters during 1976.

Month	$10^{-13} \frac{\mu\text{Ci}/\text{ml}}{\text{Be}} \times 2\sigma$	$10^{-13} \frac{\mu\text{Ci}/\text{ml}}{\text{F}}$	$10^{-13} \frac{\mu\text{Ci}/\text{ml}}{\text{F}}$	$10^{-16} \frac{\mu\text{Ci}/\text{ml}}{\text{Ru}}$	$10^{-16} \frac{\mu\text{Ci}/\text{ml}}{\text{Ru}}$	$10^{-16} \frac{\mu\text{Ci}/\text{ml}}{\text{Sb}}$	$10^{-16} \frac{\mu\text{Ci}/\text{ml}}{\text{Cs}}$	$10^{-16} \frac{\mu\text{Ci}/\text{ml}}{\text{Ce}}$	$10^{-16} \frac{\mu\text{Ci}/\text{ml}}{\text{Ce}}$
Jan	1.1 ± 22	$1.0 \pm 100^*$	$0.6 \pm 46^*$	$0.1 \pm 100^*$	$8.1 \pm 11^*$	$1.7 \pm 22^*$	$1.4 \pm 22^*$	$0.1 \pm 100^*$	$15.0 \pm 10^*$
Feb	1.3 ± 22	$1.8 \pm 58^*$	$0.7 \pm 25^*$	$1.1 \pm 25^*$	$10.2 \pm 8^*$	$2.3 \pm 14^*$	$6.1 \pm 5^*$	$1.7 \pm 29^*$	$20.0 \pm 6^*$
Mar	1.3 ± 22	$1.9 \pm 59^*$	$0.5 \pm 63^*$	0.1 ± 100	11.5 ± 10	2.2 ± 12	$6.7 \pm 5^*$	$0.1 \pm 100^*$	$19.0 \pm 8^*$
Apr	1.5 ± 21	$1.0 \pm 100^*$	$0.5 \pm 22^*$	0.1 ± 100	$11.0 \pm 23^*$	$2.6 \pm 14^*$	$2.6 \pm 5^*$	$0.1 \pm 100^*$	$17.7 \pm 8^*$
May	2.5 ± 27	$4.8 \pm 31^*$	$0.5 \pm 68^*$	0.1 ± 100	24.0 ± 13	$3.0 \pm 10^*$	$13.8 \pm 3^*$	$0.1 \pm 100^*$	$33.0 \pm 6^*$
June	1.6 ± 27	2.8 ± 38	$0.05 \pm 100^*$	0.1 ± 100	11.2 ± 10	$0.03 \pm 100^*$	$2.2 \pm 5^*$	$0.1 \pm 100^*$	$15.5 \pm 6^*$
July	1.2 ± 27	$3.3 \pm 37^*$	$0.05 \pm 100^*$	$0.1 \pm 100^*$	$3.1 \pm 100^*$	$0.03 \pm 100^*$	$4.6 \pm 5^*$	$0.1 \pm 100^*$	$9.3 \pm 12^*$
Aug	1.2 ± 27	$2.3 \pm 55^*$	0.1 ± 23	0.1 ± 100	3.6 ± 18	$0.03 \pm 100^*$	$2.6 \pm 6^*$	$0.1 \pm 100^*$	$5.7 \pm 23^*$
Sept	1.5 ± 21	$5.6 \pm 20^*$	$0.05 \pm 100^*$	$0.1 \pm 100^*$	$3.6 \pm 26^*$	$0.2 \pm 12^*$	$2.6 \pm 8^*$	$0.1 \pm 100^*$	$11.2 \pm 100^*$
Oct	1.8 ± 22	$3.9 \pm 60^*$	872.0 ± 1	210.0 ± 1	$06.0 \pm 35^*$	$1.1 \pm 9.5^*$	$2.6 \pm 8^*$	$1210.0 \pm 2^*$	$188.0 \pm 7^*$
Nov	1.2 ± 22	3.6 ± 36	$182.0 \pm 2^*$	66.0 ± 3	$34.0 \pm 13^*$	$0.03 \pm 100^*$	$6.2 \pm 7^*$	05.0 ± 22	50.3 ± 105
Dec	1.6 ± 27	$2.4 \pm 20^*$	$192.0 \pm 2^*$	120.0 ± 3	$12.8 \pm 13^*$	$0.03 \pm 100^*$	$5.4 \pm 7^*$	85.0 ± 22	$25.0 \pm 12^*$
Annual Av	1.5	3.3	105.6	99.8	13.9	1.6	6.2	133.5	33.1
Error (Z)	15	36	139	122	35	65	28	152	88
CG	$4.0\text{E}-08$	$5.0\text{E}-09$	$1.0\text{E}-09$	$3.0\text{E}-09$	$5.0\text{E}-10$	$9.0\text{E}-10$	$5.0\text{E}-10$	$5.0\text{E}-09$	$2.0\text{E}-10$
ZCG	$3.8\text{E}-06$	$8.3\text{E}-06$	$1.0\text{E}-03$	$3.3\text{E}-05$	$2.0\text{E}-03$	$1.8\text{E}-05$	$1.2\text{E}-04$	$2.7\text{E}-04$	$1.7\text{E}-03$

Table 7. Plutonium, cesium, and uranium in air filters at LLL perimeter locations during 1976.

Month	Location ^a	$10^{-17} \mu\text{Ci}/\text{ml} \pm 2\sigma$	$10^{-16} \mu\text{Ci}/\text{ml} \pm 2\sigma$	10^{-2}	$10^{-7} \mu\text{g}/\text{m}^3 \pm 2\sigma$	$10^{-5} \mu\text{g}/\text{m}^3 \pm 2\sigma$	10^{-3}
		$^{239}\text{Pu}^b$	^{137}Cs	$^{239}\text{Pu}/^{137}\text{Cs}$	^{235}U	^{238}U	$^{235}\text{U}/^{238}\text{U}$
Jan	1	$0.7 \pm 13\%$	N.A.	—	$2.2 \pm 2\%$	$3.2 \pm 2\%$	7.0
	2	$0.4 \pm 17\%$	N.A.	—	$2.6 \pm 2\%$	$4.6 \pm 4\%$	5.4
	12	$0.8 \pm 12\%$	N.A.	—	$5.2 \pm 2\%$	$8.0 \pm 3\%$	6.6
	13	$0.6 \pm 14\%$	N.A.	—	$2.4 \pm 2\%$	$3.6 \pm 3\%$	6.7
	14	$0.6 \pm 14\%$	N.A.	—	$2.8 \pm 2\%$	$4.1 \pm 3\%$	6.9
	15	$0.6 \pm 14\%$	N.A.	—	$3.0 \pm 2\%$	$4.7 \pm 3\%$	6.3
Feb	1	lost	N.A.	—	$2.6 \pm 2\%$	$3.4 \pm 3\%$	7.7
	2	lost	N.A.	—	$1.5 \pm 2\%$	$2.1 \pm 2\%$	7.0
	12	lost	N.A.	—	$7.8 \pm 3\%$	$11.2 \pm 3\%$	7.3
	13	lost	N.A.	—	$2.4 \pm 2\%$	$3.5 \pm 2\%$	7.0
	14	lost	N.A.	—	$7.3 \pm 2\%$	$9.9 \pm 3\%$	7.5
	15	lost	N.A.	—	$2.8 \pm 2\%$	$4.0 \pm 3\%$	7.1
Mar	1	$0.9 \pm 4\%$	$5.8 \pm 5\%$	1.5	$2.4 \pm 2\%$	$4.0 \pm 3\%$	6.1
	2	$0.8 \pm 5\%$	$5.7 \pm 5\%$	1.4	$2.2 \pm 2\%$	$3.7 \pm 3\%$	6.0
	12	$1.0 \pm 5\%$	$6.9 \pm 5\%$	1.4	$4.6 \pm 2\%$	$8.0 \pm 3\%$	5.7
	13	$0.7 \pm 5\%$	$5.3 \pm 5\%$	1.3	$2.6 \pm 2\%$	$4.1 \pm 3\%$	6.3
	14	$4.6 \pm 3\%$	$7.0 \pm 6\%$	6.6	$5.1 \pm 2\%$	$8.0 \pm 3\%$	6.2
	15	$0.7 \pm 6\%$	$5.2 \pm 6\%$	1.4	$3.1 \pm 2\%$	$4.8 \pm 3\%$	6.4
April	1	$1.5 \pm 4\%$	$6.1 \pm 6\%$	2.5	$2.6 \pm 2\%$	$3.7 \pm 3\%$	7.0
	2	$1.0 \pm 5\%$	$5.2 \pm 5\%$	1.9	$2.2 \pm 2\%$	$3.1 \pm 3\%$	7.1
	12	$1.2 \pm 6\%$	$6.5 \pm 6\%$	1.8	$4.8 \pm 2\%$	$9.4 \pm 3\%$	5.1
	13	$0.8 \pm 6\%$	$5.6 \pm 5\%$	1.5	$3.3 \pm 2\%$	$4.6 \pm 3\%$	7.2
	14	$2.9 \pm 4\%$	$6.2 \pm 6\%$	4.7	$4.4 \pm 2\%$	$6.3 \pm 3\%$	7.0
	15	$1.1 \pm 5\%$	$4.6 \pm 7\%$	2.4	$3.8 \pm 2\%$	$5.4 \pm 3\%$	7.1
May	1	$1.3 \pm 14\%$	N.A.	—	$4.8 \pm 2\%$	$6.9 \pm 4\%$	6.9
	2	$1.1 \pm 16\%$	N.A.	—	$3.7 \pm 4\%$	$5.2 \pm 5\%$	7.2
	12	$1.6 \pm 15\%$	N.A.	—	$8.1 \pm 2\%$	$1.2 \pm 3\%$	7.0
	13	$1.2 \pm 15\%$	N.A.	—	$5.9 \pm 2\%$	$8.2 \pm 3\%$	7.2
	14	$5.4 \pm 6\%$	N.A.	—	$9.0 \pm 2\%$	$12.9 \pm 3\%$	7.0
	15	$1.2 \pm 11\%$	N.A.	—	$8.2 \pm 2\%$	$11.3 \pm 3\%$	7.2
June	1	$0.7 \pm 10\%$	$5.4 \pm 10\%$	1.2	$3.1 \pm 6\%$	$4.3 \pm 9\%$	7.2
	2	$0.8 \pm 12\%$	$5.8 \pm 10\%$	1.3	$3.2 \pm 3\%$	$4.5 \pm 3\%$	7.3
	12	$0.9 \pm 56\%$	$6.6 \pm 10\%$	1.4	$5.2 \pm 2\%$	$8.0 \pm 2\%$	6.6
	13	$0.6 \pm 14\%$	$2.7 \pm 10\%$	2.3	$3.1 \pm 2\%$	$4.3 \pm 3\%$	7.3
	14	$5.1 \pm 11\%$	$6.3 \pm 12\%$	8.1	$6.8 \pm 2\%$	$9.6 \pm 2\%$	7.2
	15	$7.8 \pm 15\%$	$6.0 \pm 8\%$	13.0	$4.3 \pm 4\%$	$6.0 \pm 6\%$	7.3

Table 7. (Continued)

Month	Location ^a	10^{-17} uCi/ml $\pm$ 2 σ	10^{-16} uCi/ml $\pm$ 2 σ	10^{-2}	10^{-7} ug/m ³ $\pm$ 2 σ	10^{-5} ug/m ³ $\pm$ 2 σ	10^{-3}
		^{239}Pu ^b	^{137}Cs	$^{239}\text{Pu}/^{137}\text{Cs}$	^{235}U	^{238}U	$^{235}\text{U}/^{238}\text{U}$
July	1	0.3 $\pm$ 17%	1.9 $\pm$ 16%	1.6	2.6 $\pm$ 2%	3.8 $\pm$ 2%	6.9
	2	0.6 $\pm$ 16%	2.8 $\pm$ 18%	2.2	3.1 $\pm$ 2%	4.3 $\pm$ 2%	7.2
	12	0.5 $\pm$ 20%	2.6 $\pm$ 16%	1.8	5.4 $\pm$ 2%	8.2 $\pm$ 2%	6.6
	13	1.0 $\pm$ 9%	5.0 $\pm$ 14%	1.9	2.7 $\pm$ 2%	3.8 $\pm$ 3%	7.2
	14	9.4 $\pm$ 6%	2.4 $\pm$ 26%	39.0	8.2 $\pm$ 2%	11.6 $\pm$ 2%	7.1
	15	0.4 $\pm$ 16%	2.7 $\pm$ 22%	1.4	3.8 $\pm$ 2%	5.3 $\pm$ 2%	7.3
Aug	1	3.1 $\pm$ 11%	3.3 $\pm$ 12%	9.4	2.0 $\pm$ 2%	2.8 $\pm$ 2%	7.2
	2	0.2 $\pm$ 34%	3.0 $\pm$ 9%	0.7	1.8 $\pm$ 6%	2.4 $\pm$ 8%	7.4
	12	0.4 $\pm$ 17%	3.2 $\pm$ 8%	0.1	4.0 $\pm$ 2%	5.9 $\pm$ 2%	6.8
	13	0.3 $\pm$ 40%	3.5 $\pm$ 15%	0.9	2.4 $\pm$ 2%	3.4 $\pm$ 3%	7.2
	14	0.3 $\pm$ 38%	3.4 $\pm$ 9%	0.9	5.0 $\pm$ 3%	6.7 $\pm$ 4%	7.6
	15	0.3 $\pm$ 22%	4.0 $\pm$ 8%	0.7	2.3 $\pm$ 2%	3.3 $\pm$ 2%	7.1
Sept	1	0.3 $\pm$ 26%	1.6 $\pm$ 10%	1.9	2.7 $\pm$ 2%	3.7 $\pm$ 3%	7.4
	2	0.2 $\pm$ 30%	1.4 $\pm$ 14%	1.4	1.9 $\pm$ 5%	2.7 $\pm$ 7%	7.4
	12	0.3 $\pm$ 30%	1.7 $\pm$ 11%	1.8	4.0 $\pm$ 2%	5.9 $\pm$ 2%	6.9
	13	0.3 $\pm$ 24%	1.5 $\pm$ 10%	2.0	2.8 $\pm$ 2%	3.9 $\pm$ 3%	7.2
	14	0.7 $\pm$ 22%	1.9 $\pm$ 11%	3.6	4.2 $\pm$ 5%	5.7 $\pm$ 7%	7.5
	15	0.2 $\pm$ 42%	1.6 $\pm$ 13%	1.3	3.4 $\pm$ 2%	4.7 $\pm$ 3%	7.4
Oct	1	0.8 $\pm$ 16%	4.9 $\pm$ 5%	3.6	3.9 $\pm$ 3%	6.6 $\pm$ 4%	6.0
	2	1.7 $\pm$ 22%	8.5 $\pm$ 10%	2.0	10.7 $\pm$ 5%	14.3 $\pm$ 7%	7.6
	12	1.2 $\pm$ 11%	5.7 $\pm$ 4%	2.1	4.9 $\pm$ 2%	8.2 $\pm$ 3%	5.7
	13	0.8 $\pm$ 15%	4.9 $\pm$ 5%	1.6	4.3 $\pm$ 10%	7.5 $\pm$ 11%	5.8
	14	0.9 $\pm$ 15%	4.4 $\pm$ 5%	2.0	4.0 $\pm$ 3%	7.8 $\pm$ 3%	5.2
	15	0.7 $\pm$ 15%	3.9 $\pm$ 8%	1.8	3.6 $\pm$ 3%	6.5 $\pm$ 3%	5.7
Nov	1	0.7 $\pm$ 12%	5.6 $\pm$ 3%	1.3	5.3 $\pm$ 2%	12.9 $\pm$ 2%	4.2
	2	0.6 $\pm$ 13%	5.4 $\pm$ 6%	1.1	5.3 $\pm$ 2%	14.8 $\pm$ 3%	3.7
	12	1.6 $\pm$ 8%	7.3 $\pm$ 3%	2.2	9.1 $\pm$ 2%	24.7 $\pm$ 2%	3.7
	13	0.7 $\pm$ 18%	6.0 $\pm$ 5%	1.2	5.4 $\pm$ 2%	8.7 $\pm$ 2%	6.3
	14	0.7 $\pm$ 14%	3.4 $\pm$ 6%	2.1	6.8 $\pm$ 2%	22.1 $\pm$ 2%	3.1
	15	0.7 $\pm$ 14%	4.6 $\pm$ 4%	1.5	7.3 $\pm$ 2%	20.1 $\pm$ 2%	3.7
Dec	1	0.4 $\pm$ 20%	3.5 $\pm$ 6%	1.1	4.1 $\pm$ 2%	6.6 $\pm$ 2%	6.3
	2	0.3 $\pm$ 24%	2.7 $\pm$ 8%	1.1	3.6 $\pm$ 3%	5.7 $\pm$ 4%	6.4
	12	0.7 $\pm$ 18%	4.0 $\pm$ 6%	1.8	5.6 $\pm$ 2%	9.8 $\pm$ 2%	5.8
	13	0.3 $\pm$ 30%	2.3 $\pm$ 14%	1.3	4.4 $\pm$ 2%	6.8 $\pm$ 3%	6.6
	14	0.5 $\pm$ 37%	3.6 $\pm$ 22%	1.4	3.6 $\pm$ 2%	5.6 $\pm$ 2%	6.3
	15	0.5 $\pm$ 38%	2.6 $\pm$ 16%	1.9	3.9 $\pm$ 2%	6.7 $\pm$ 2%	5.9

Table 7. (Continued)

Annual averages

Location ^a	10 ⁻¹⁷ $\mu\text{Ci/ml}$			10 ⁻¹⁶ $\mu\text{Ci/ml}$			10 ⁻⁷ $\mu\text{g/m}^3$			10 ⁻⁵ $\mu\text{g/m}^3$		
	²³⁹ Pu ^b	error (%)	ZCG ^c	¹³⁷ Cs	error (%)	ZCG ^d	²³⁵ U	error (%)	ZCG ^e	²³⁸ U	error (%)	ZCG ^f
1	1.0	50	1.7E-02	4.2	27	8.4E-05	3.2	19	1.7E-05	5.2	31	3.5E-04
2	0.7	39	1.2E-02	4.5	32	9.0E-05	3.5	42	1.8E-05	5.6	45	3.7E-04
12	0.9	29	1.5E-02	4.9	28	9.8E-05	5.7	17	3.0E-05	9.0	35	6.0E-04
13	0.7	26	1.2E-02	4.1	26	8.2E-05	3.5	20	1.8E-05	5.2	22	3.5E-04
14	2.8	63	4.7E-02	4.3	28	8.6E-05	5.6	20	3.0E-05	9.2	30	6.1E-04
15	1.3	100	2.2E-02	3.9	24	7.8E-05	4.1	25	2.2E-05	6.9	38	4.6E-04

^a See Fig. 2 for sampling locations.^b In all tables, activity listed as ²³⁹Pu includes activity also due to the ²⁴⁰Pu isotope.^c ZCG = 6.0E-14 $\mu\text{Ci/ml}$ for ²³⁹Pu in soluble form.^d ZCG = 5.0E-10 $\mu\text{Ci/ml}$ for ¹³⁷Cs in the insoluble form.^e ZCG = 1.9 $\mu\text{g/m}^3$ for ²³⁵U in the insoluble form.^f ZCG = 15.0 $\mu\text{g/m}^3$ for ²³⁸U in the insoluble form.

Table 8. Plutonium, cesium, and uranium concentrations in air filters at Site 300 during 1976.

Month	10^{-17} $\mu\text{Ci}/\text{ml} \pm 2\sigma$ ^{239}Pu	10^{-2} $^{238}\text{Pu}/^{239}\text{Pu}$	10^{-16} $\mu\text{Ci}/\text{ml} \pm 2\sigma$ ^{137}Cs	10^{-2} $^{239}\text{Pu}/^{137}\text{Cs}$	10^{-7} $\mu\text{g}/\text{m}^3 \pm 2\sigma$ ^{235}U	10^{-5} $\mu\text{g}/\text{m}^3 \pm 2\sigma$ ^{238}U	10^{-3} $^{235}\text{U}/^{238}\text{U}$
Jan	$0.7 \pm 4\%$	5.2	$4.4 \pm 7\%$	1.6	$2.3 \pm 3\%$	$4.3 \pm 3\%$	5.3
Feb	$1.2 \pm 3\%$	4.8	$6.1 \pm 4\%$	2.0	$3.3 \pm 3\%$	$6.4 \pm 3\%$	5.2
Mar	$1.3 \pm 5\%$	4.0	$7.2 \pm 2\%$	1.8	$3.8 \pm 4\%$	$9.8 \pm 5\%$	3.9
Apr	$1.7 \pm 2\%$	4.0	$6.9 \pm 4\%$	2.5	$3.2 \pm 2\%$	$6.1 \pm 3\%$	5.2
May	$16.7 \pm 5\%$	3.8	$13.8 \pm 3\%$	12.1	$6.0 \pm 3\%$	$11.3 \pm 4\%$	5.3
June	$2.1 \pm 6\%$	4.0	$6.8 \pm 2\%$	3.1	$3.0 \pm 1\%$	$6.6 \pm 2\%$	4.7
July	$1.1 \pm 7\%$	3.8	$4.1 \pm 2\%$	2.7	$2.6 \pm 2\%$	$5.4 \pm 2\%$	4.9
Aug	$0.7 \pm 4\%$	4.5	$2.2 \pm 5\%$	3.2	$4.9 \pm 2\%$	$16.7 \pm 2\%$	3.0
Sept	$5.3 \pm 6\%$	3.0	$2.0 \pm 3\%$	26.5	$3.6 \pm 2\%$	$6.0 \pm 2\%$	6.0
Oct	$1.1 \pm 5\%$	43.7	$5.4 \pm 3\%$	2.0	$3.6 \pm 2\%$	$1.6 \pm 2\%$	22.9
Nov	$2.5 \pm 5\%$	13.7	$5.2 \pm 1\%$	4.8	$2.0 \pm 2\%$	$84.2 \pm 2\%$	0.2
Dec	$0.5 \pm 8\%$	17.7	$3.0 \pm 2\%$	1.7	$4.1 \pm 2\%$	$35.1 \pm 2\%$	1.2
Annual Av	2.9		5.6		3.5	16.1	
error (%)	90		32		18	83	
CG	6.0E-14		5.0E-10		1.9	15.0	
2CG	4.8E-02		1.1E-04		1.9E-05	1.1E-03	

Table 9. Tritium (HTO) in air at LLL perimeter locations during 1976.

Location ^a	(Units ~ 10 ⁻¹⁰ μ Ci/ml)												Av	error (%)	ZCG ^b	Calculated annual adult whole body dose (mrem)
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec				
1	1.2	0.4	1.7	0.3	0.2	0.2	0.5	0.4	0.4	0.7	0.8	0.3	0.6	42	3.0E-02	9.6E-02
2	2.5	0.7	0.7	0.4	0.2	0.1	0.03	0.3	1.0	1.3	1.2	0.8	0.8	51	4.0E-02	1.3E-01
12	—	1.6	2.9	3.5	0.5	0.6	2.0	1.1	1.1	1.3	0.7	0.5	1.4	42	7.0E-02	2.2E-01
13	1.4	0.3	0.4	0.8	0.2	0.2	0.1	0.3	0.2	0.5	0.5	0.3	0.4	50	2.0E-02	6.4E-02
14	0.7	1.1	0.6	1.3	0.8	0.6	0.9	0.7	2.5	1.5	1.1	0.4	1.0	32	5.0E-02	1.6E-01
15	0.9	0.7	0.9	3.3	0.1	0.2	0.3	0.2	0.4	0.4	0.5	0.3	0.7	73	3.5E-02	1.1E-01
Annual Av													0.8	22	4.0E-02	1.3E-01

^aSee Fig. 2 for sampling locations.^bZCG = 2.0E-07 μ Ci/ml for tritium (HTO) in air.

Table 10. Concentrations of various radionuclides in Livermore Valley soil samples during 1976.

Location ^a	Sampling depth	(Units - $\mu\text{Ci/dry g} \pm 2\sigma$)			(Units - $\mu\text{g/dry g} \pm 2\sigma$)	
		$^{239}\text{Pu}(\times 10^{-9})$	$^{40}\text{K}(\times 10^{-6})$	$^{137}\text{Cs}(\times 10^{-7})$	^{232}Th	^{238}U
606	0-5	4.8 $\pm$ 47%	15.0 $\pm$ 10%	1.6 $\pm$ 8%	6.1 $\pm$ 12%	3.7 $\pm$ 21%
607	0-5	3.9 $\pm$ 9%	9.0 $\pm$ 10%	1.4 $\pm$ 7%	3.6 $\pm$ 16%	2.1 $\pm$ 22%
608	0-5	2.8 $\pm$ 10%	9.2 $\pm$ 8%	1.0 $\pm$ 9%	3.7 $\pm$ 15%	1.8 $\pm$ 25%
609	0-5	3.7 $\pm$ 14%	9.6 $\pm$ 11%	1.3 $\pm$ 7%	4.2 $\pm$ 13%	1.8 $\pm$ 62%
611	0-5	3.0 $\pm$ 7%	13.9 $\pm$ 20%	1.3 $\pm$ 22%	5.9 $\pm$ 15%	2.9 $\pm$ 46%
612	0-5	7.3 $\pm$ 5%	10.4 $\pm$ 13%	3.7 $\pm$ 6%	4.9 $\pm$ 15%	2.0 $\pm$ 40%
613	0-5	12.8 $\pm$ 6%	10.7 $\pm$ 13%	2.5 $\pm$ 4%	5.7 $\pm$ 17%	2.0 $\pm$ 44%
614	0-5	3.2 $\pm$ 8%	13.2 $\pm$ 10%	1.8 $\pm$ 8%	6.5 $\pm$ 11%	2.4 $\pm$ 95%
615	0-5	2.5 $\pm$ 4%	12.8 $\pm$ 14%	1.1 $\pm$ 46%	4.9 $\pm$ 17%	2.7 $\pm$ 100%
616	0-5	3.2 $\pm$ 8%	14.7 $\pm$ 7%	2.0 $\pm$ 7%	5.7 $\pm$ 12%	2.4 $\pm$ 66%
617	0-5	1.6 $\pm$ 9%	13.9 $\pm$ 11%	0.1 $\pm$ 100%	5.7 $\pm$ 13%	2.8 $\pm$ 90%
618	0-5	2.5 $\pm$ 8%	13.9 $\pm$ 15%	1.3 $\pm$ 11%	6.3 $\pm$ 14%	2.9 $\pm$ 94%
620	0-5	6.4 $\pm$ 7%	9.2 $\pm$ 10%	3.5 $\pm$ 6%	5.1 $\pm$ 12%	1.7 $\pm$ 30%
621	0-5	7.1 $\pm$ 6%	10.4 $\pm$ 16%	4.1 $\pm$ 8%	5.1 $\pm$ 16%	1.6 $\pm$ 46%
622	0-5	1.2 $\pm$ 9%	12.9 $\pm$ 14%	0.9 $\pm$ 14%	7.0 $\pm$ 9%	2.6 $\pm$ 30%
632	0-5	5.2 $\pm$ 8%	14.4 $\pm$ 11%	2.5 $\pm$ 8%	5.3 $\pm$ 10%	1.8 $\pm$ 30%
633	0-5	17.3 $\pm$ 4%	13.2 $\pm$ 7%	2.4 $\pm$ 6%	5.8 $\pm$ 11%	2.4 $\pm$ 50%

^aSee Fig. 8 for soil sampling locations.

Table 11. Comparison of plutonium concentrations in off-site samples during 1975 and 1976.

Location ^a	Depth (cm)	1976 ($\mu\text{Ci/dry g}$)					Location	Depth (cm)	1975 ($\mu\text{Ci/dry g}$)				
		($\times 10^{-8}$) ^{239}Pu	$\pm 2\sigma$	($\times 10^{-9}$) ^{238}Pu	$\pm 2\sigma$	($\times 10^{-1}$) $^{238}\text{Pu}/^{239}\text{Pu}$			($\times 10^{-8}$) ^{239}Pu	$\pm 2\sigma$	($\times 10^{-9}$) ^{238}Pu	$\pm 2\sigma$	($\times 10^{-1}$) $^{238}\text{Pu}/^{239}\text{Pu}$
613	0-5	1.3	6%	1.7	10%	1.3	549	0-1	3.0	5%	3.6	8%	1.2
633	0-5	1.7	4%	1.3	6%	0.8	564	0-1	9.9	5%	4.2	7%	0.4
632	0-5	0.5	8%	0.2	25%	0.4	565	0-1	1.2	6%	0.5	16%	0.4

^aSee Fig. 9 for sampling locations.

Table 12. Plutonium, cesium, and uranium concentrations in Site 300 soil samples during 1976.

Location ^a	Sampling depth (cm)	(Units - $\mu\text{Ci/dry g} \pm 2\sigma$)		(Units - $\mu\text{g/dry g} \pm 2\sigma$)	
		$^{239}\text{Pu}(\times 10^{-9})$	$^{137}\text{Cs}(\times 10^{-7})$	$^{235}\text{U}(\times 10^{-2})$	^{238}U
610	0-5	$5.6 \pm 5\%$	$2.9 \pm 7\%$	$1.3 \pm 50\%$	$2.8 \pm 50\%$
623	0-5	$5.8 \pm 4\%$	$3.3 \pm 10\%$	$1.6 \pm 50\%$	$2.4 \pm 50\%$
624	0-5	$17.0 \pm 5\%$	$9.4 \pm 8\%$	$1.4 \pm 35\%$	$2.6 \pm 35\%$
625	0-5	$3.9 \pm 5\%$	$2.2 \pm 8\%$	$1.4 \pm 70\%$	$2.4 \pm 70\%$
626	0-5	$6.5 \pm 10\%$	$3.5 \pm 6\%$	$1.2 \pm 25\%$	$2.4 \pm 25\%$
627	0-5	$6.3 \pm 9\%$	$3.4 \pm 10\%$	$1.2 \pm 40\%$	$2.1 \pm 40\%$
628	0-5	$0.6 \pm 10\%$	$0.3 \pm 45\%$	$2.9 \pm 28\%$	$11.3 \pm 28\%$
629	0-5	$4.4 \pm 5\%$	$2.4 \pm 12\%$	$1.4 \pm 80\%$	$2.5 \pm 80\%$
630	0-5	$5.4 \pm 7\%$	$3.2 \pm 12\%$	$1.3 \pm 50\%$	$2.1 \pm 50\%$
631	0-5	$4.5 \pm 3\%$	$2.4 \pm 12\%$	$48.8 \pm 5\%$	$266 \pm 5\%$

^aSee Fig. 10 for soil sampling locations.

Table 13. Gross alpha and gross beta activities in Livermore Water Reclamation Plant samples during 1976.

Month	Gross alpha activity (10^{-9} $\mu\text{Ci/ml}$)			Gross beta activity (10^{-9} $\mu\text{Ci/ml}$)		
	Digester 1	Digester 2	Aeration tank	Digester 1	Digester 2	Aeration tank
Jan	7.2	7.1	20.0	8.2	7.6	26.9
Feb	10.0	9.3	18.1	11.0	9.0	23.4
Mar	8.7	9.2	24.8	10.3	9.8	28.3
Apr	10.1	11.0	26.9	10.1	10.4	24.5
May	12.2	11.0	24.1	10.2	10.8	24.0
June	10.7	11.8	26.9	10.7	9.8	27.2
July	11.5	13.3	32.9	9.1	12.6	23.6
Aug	11.0	14.6	30.4	9.4	11.1	28.9
Sept	15.5	17.3	40.7	9.1	9.3	25.5
Oct	12.6	10.3	58.8	6.8	8.7	29.3
Nov	10.2	9.4	37.5	8.1	9.2	33.5
Dec	12.3	11.3	42.7	8.6	10.2	33.4
Annual Av	11.0	11.3	32.0	9.3	9.9	27.4
±error (%)	11	14	21	8	7	7

Table 14. Comparison of various radionuclides in LLL and Livermore Water Reclamation Plant effluents during 1976.

Month	^{239}Pu ($\mu\text{Ci/ml} \pm 2\sigma$)		^{90}Sr ($\mu\text{Ci/ml} \pm 2\sigma$)		HTO ($\mu\text{Ci/ml}$)	
	10^{-10}	10^{-12}	10^{-9}	10^{-10}	10^{-5}	10^{-6}
	LLL	LWRP	LLL	LWRP	LLL	LWRP
Jan	$4.1 \pm 4\%$	$<0.9 \pm 100\%$	$1.2 \pm 22\%$	$2.8 \pm 100\%$	2.9	2.7
Feb	$27.0 \pm 4\%$	$9.1 \pm 30\%$	—	$5.6 \pm 100\%$	1.3	1.9
Mar	$1.6 \pm 7\%$	$<1.5 \pm 100\%$	$5.7 \pm 20\%$	$3.0 \pm 100\%$	2.3	5.6
Apr	$4.8 \pm 6\%$	$3.4 \pm 34\%$	$1.3 \pm 21\%$	$2.2 \pm 100\%$	1.6	3.1
May	$1.8 \pm 10\%$	$3.7 \pm 36\%$	$1.5 \pm 14\%$	$2.1 \pm 100\%$	3.2	3.1
June	$6.6 \pm 6\%$	$6.8 \pm 51\%$	$1.1 \pm 19\%$	$2.4 \pm 100\%$	1.8	2.4
July	$1.8 \pm 12\%$	$240.0 \pm 13\%$	$0.5 \pm 63\%$	$7.8 \pm 100\%$	4.5	7.6
Aug	$0.7 \pm 17\%$	$<0.9 \pm 100\%$	$0.5 \pm 55\%$	$5.8 \pm 100\%$	1.5	4.8
Sept	$1.4 \pm 19\%$	$138.0 \pm 25\%$	$0.8 \pm 20\%$	$0.9 \pm 100\%$	0.8	2.5
Oct	$2.7 \pm 14\%$	$<2.4 \pm 100\%$	$0.6 \pm 24\%$	$3.4 \pm 100\%$	1.9	3.6
Nov	$0.4 \pm 45\%$	—	$0.9 \pm 40\%$	$4.2 \pm 100\%$	0.2	1.4
Dec	$0.6 \pm 26\%$	$<0.9 \pm 100\%$	$1.0 \pm 36\%$	$5.7 \pm 100\%$	10.4	7.4
Annual Av	4.4	37	1.4	3.8	2.7	3.8
±error (%)	95	128	62	30	57	31
CG	$3.0\text{E}-05$	$3.0\text{E}-05$	$3.0\text{E}-07$	$3.0\text{E}-07$	$3.0\text{E}-03$	$3.0\text{E}-03$
%CG	$1.5\text{E}-03$	$1.2\text{E}-04$	$4.7\text{E}-01$	$1.3\text{E}-01$	$9.0\text{E}-01$	$1.3\text{E}-01$

Table 15. Gross beta activity in water samples from the Livermore Valley during 1976.

Location ^a	Number of samples	(Units - 10^{-9} μ Ci/ml)			±error (%)	%CG ^b
		Maximum	Minimum	Average		
11	4	4.8	2.6	3.6	26	12
13	12	22.5	1.9	4.5	75	15
15	4	2.6	2.0	2.3	12	8
16	4	4.2	3.0	3.4	16	11
19	4	3.5	1.9	2.4	30	8
20	3	18.6	6.6	8.8	118	9
24	4	5.7	2.4	4.3	39	14
26	4	2.6	1.9	2.3	12	8
Annual Av				3.9	35	13

^aSee Figs. 2 and 3 for sampling locations.

^bCG = $3.0E-08$ μ Ci/ml for gross beta activity in water.

Table 16. Gross beta activity in water samples from Site 300 during 1976.

Location ^a	Number of samples	(Units - 10^{-9} μ Ci/ml)			±error (%)	%CG ^b
		Maximum	Minimum	Average		
1	12	16.8	3.8	6.6	30	22
2	2	6.4	4.0	5.2	46	17
3	2	6.5	5.3	5.9	20	20
4	2	9.7	7.5	8.6	25	29
5	2	5.2	4.9	5.0	5	17
6	12	7.7	2.4	4.5	18	15
7	2	6.8	6.6	6.7	3	22
11	3	17.2	8.7	11.8	46	39
14	2	5.9	2.4	4.1	85	14
20	4	9.0	2.3	4.4	57	15
21	3	10.4	5.6	7.8	36	26
Annual Av				6.4	13	21

^aSee Figs. 4 and 5 for sampling locations.

^bCG = $3.0E-08$ μ Ci/ml for gross beta activity in water.

Table 17. Tritium in water samples from the Livermore Valley during 1976.

Location ^a	Number of samples	(Units - 10^{-7} $\mu\text{Ci/ml}$)		Average	error (%)	$\%CG^b$	Calculated adult whole body dose (mrem)
		Maximum	Minimum				
11	4	1.4	1.0	1.1	16	3.7E-03	4.4E-03
15	4	1.4	1.1	1.2	12	4.0E-03	4.8E-03
16	4	4.0	1.7	2.8	42	9.3E-03	1.1E-02
19	4	3.2	0.8	1.8	65	6.0E-03	7.2E-03
20	6	90.7	3.7	26.3	100	8.8E-02	1.1E-01
24	4	28.0	1.4	13.5	82	4.5E-02	5.4E-02
26	4	3.6	2.6	3.0	15	1.0E-02	1.2E-02
Annual Av				7.10	86	2.4E-02	2.8E-02

^aSee Figs. 2 and 3 for sampling locations.^b $CG = 3.0E-03 \mu\text{Ci/ml}$ for tritium in water.

Table 18. Tritium in water samples from Site 300 during 1976.

Location ^a	Number of samples	(Units - 10^{-8} $\mu\text{Ci/ml}$)		Average	error (%)	$\%CG^b$	Calculated adult whole body dose (mrem)
		Maximum	Minimum				
1	12	3.4	0.6	1.7	31	5.7E-04	6.8E-04
2	2	2.0	1.0	1.5	67	5.0E-04	6.0E-04
3	2	1.4	0.9	1.1	41	3.7E-04	4.4E-04
4	2	2.0	1.3	1.6	43	5.3E-04	6.4E-04
5	2	1.1	1.0	1.0	2	3.3E-04	4.0E-04
6	12	3.4	0.6	1.6	28	5.3E-04	6.4E-04
7	2	1.9	0.8	1.3	81	4.3E-04	5.2E-04
11	3	10.1	0.5	3.8	170	1.3E-03	1.5E-03
14	2	11.1	10.3	10.7	7	3.6E-03	4.3E-03
20	5	11.8	3.9	7.8	37	2.6E-03	3.1E-03
21	3	3.3	1.7	2.3	25	7.6E-04	9.2E-04
Annual Av				3.1	17	1.0E-03	1.2E-03

^aSee Figs. 4 and 5 for sampling locations.^b $CG = 3.0E-03 \mu\text{Ci/ml}$ for tritium in water.

Table 19. Tritium in water samples from the Niles Cone area.

Location ^a	HTO activity (10 ⁻⁶ µCi/ml)
1	2.2 ± 2%
2	0.91 ± 3%
3	0.75 ± 5%
4	0.12 ± 8%
5	0.95 ± 3%
6	0.12 ± 7%
7	1.13 ± 5%
8	0.39 ± 4%
9	0.01 ± 44%
10	0.21 ± 5%
11	0.02 ± 5%
12	0.03 ± 21%
13	0.007 ± 88%
14A	0.03 ± 5%
14B ^b	0.01 ± 8%

^aSee Fig. 12 for locations.

^bReplicate samples.

Table 20. Tritium in water samples from tributaries of Alameda Creek.

Location ^a	HTO activity (10 ⁻⁶ µCi/ml)
1	1.31 ± 3%
2	0.54 ± 3%
3	0.22 ± 2%
4	0.51 ± 3%
5 ^b	54.5 ± 1%
6	2.35 ± 2%
7	0.40 ± 2%
8	0.30 ± 3%
9	0.29 ± 3%
10	0.33 ± 2%
11	0.34 ± 3%
12	0.10 ± 3%
13	0.15 ± 5%
14	0.48 ± 2%

^aSee Fig. 13 for locations.

^bLocation resampled in October at which time the tritium activity was found to be 9.4×10^{-6} µCi/ml.

Table 21. Tritium (HTO) activity in Livermore Valley vegetation during 1976.

Location ^a	(Units - 10 ⁻⁶ µCi/ml water recovered)												Av	error (%)	Calculated adult whole body dose (mrem)
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec			
4	—	0.25	0.35	0.66	0.49	1.32	0.30	0.21	0.87	0.98	0.28	0.42	0.56	39	9.0E-03
15	1.99	0.96	0.90	2.15	1.55	—	0.66	0.91	0.90	1.15	1.05	0.74	1.18	26	1.9E-02
16	1.65	0.20	0.50	1.91	0.33	0.96	0.26	0.17	0.43	0.14	0.27	0.39	0.60	57	9.6E-03
20	—	—	1.58	2.81	2.31	3.19	2.06	5.43	2.44	1.36	1.11	1.64	2.39	33	3.8E-02
21	0.64	0.49	0.90	1.86	0.79	2.21	0.82	0.61	0.54	0.49	0.52	0.30	0.85	40	1.4E-02
22	2.71	0.63	1.91	5.34	0.97	0.58	0.26	14.20	0.20	5.61	1.14	1.50	2.92	79	4.7E-02
23	8.51	2.75	3.03	11.40	1.89	0.86	0.89	4.40	1.65	11.80	3.60	18.40	5.77	55	9.2E-02
29	6.50	1.23	4.97	8.15	1.19	3.39	2.08	2.11	1.90	4.76	1.95	3.39	3.47	38	5.6E-02
30	1.98	0.33	1.83	3.84	2.74	0.95	0.68	2.22	1.37	2.15	0.57	1.46	1.68	35	2.7E-02
31	12.90	1.55	2.25	9.53	1.10	0.84	0.77	1.52	1.08	5.35	2.86	8.82	3.68	68	5.9E-02
Annual av													2.30	23	3.7E-02

^aSee Fig. 3 for sampling locations.

Table 22. Tritium (HTO) activity in grape samples collected in 1976.

Location ^a	Number of samples	(Units - 10 ⁻⁶ μ Ci/ml, water recovered)			
		Maximum	Minimum	Average	± error (%)
51	4	0.31	0.09	0.19	50
52	3	0.12	0.11	0.12	6
53	3	0.18	0.12	0.14	29
54	4	0.20	0.12	0.17	21
55	3	1.90	0.27	0.98	98

^aThe three samples from 55 were collected in the Livermore Valley. The other samples were collected from the following areas (in alphabetical order): Lodi, Modesto, Napa, and San Jose.

Table 23. Tritium (HTO) activity in Site 300 vegetation during 1976.

Location ^a	(Units - 10 ⁻⁶ μ Ci/pl water recovered)												Av	error (%)	Calculated adult whole body dose (mrem)
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec			
1	—	—	0.34	0.16	0.49	0.15	0.17	0.25	0.36	0.18	0.17	0.12	0.24	32	3.8E-03
2	0.20	0.20	0.24	0.13	0.23	0.15	0.22	0.12	0.39	0.20	0.12	0.12	0.19	22	3.0E-03
3	0.36	0.30	0.20	0.14	0.22	0.12	0.23	0.43	0.19	0.12	0.26	0.12	0.22	26	3.5E-03
5	0.20	0.27	0.25	—	—	0.14	0.17	0.57	0.27	0.38	0.91	0.19	0.34	44	5.4E-03
6	6.20	15.30	2.41	1.43	5.22	0.44	0.44	5.68	2.26	0.64	1.78	0.41	3.52	70	5.6E-02
11	0.20	0.26	0.20	0.14	0.22	0.18	0.29	0.21	0.56	0.18	0.19	0.12	0.23	29	3.7E-03
12	—	—	—	0.14	0.31	0.29	0.36	0.51	—	0.34	0.11	0.17	0.28	34	4.5E-03
13	0.39	0.46	0.99	1.07	1.15	0.21	1.28	0.79	1.21	0.20	0.83	1.31	0.82	29	1.3E-02
Annual av													0.73	15	1.2E-02

^aSee Figs. 4 and 5 for sampling locations.

Table 24. Concentration of various radionuclides in milk samples during 1976.

Month	(Units - $\mu\text{Ci/ml} \pm 2\sigma$)		
	(10^{-7}) HTO	(10^{-6}) ^{40}K	(10^{-10}) ^{137}Cs
Jan	$1.9 \pm 100\%$	$1.3 \pm 3\%$	$<2.6 \pm 100\%$
Feb	$1.9 \pm 100\%$	$1.3 \pm 4\%$	$<2.5 \pm 100\%$
Mar	$1.3 \pm 20\%$	$1.3 \pm 4\%$	$5.0 \pm 65\%$
Apr	$1.2 \pm 100\%$	$1.3 \pm 3\%$	$<2.0 \pm 100\%$
May	$1.1 \pm 17\%$	$1.3 \pm 3\%$	$5.4 \pm 70\%$
June	$0.9 \pm 100\%$	$1.4 \pm 3\%$	$<3.5 \pm 100\%$
July	$1.2 \pm 81\%$	$1.1 \pm 2\%$	$14.0 \pm 24\%$
Aug	$1.2 \pm 100\%$	$1.4 \pm 5\%$	$5.2 \pm 72\%$
Sept	$1.2 \pm 100\%$	$2.4 \pm 3\%$	$11.0 \pm 70\%$
Oct	$0.9 \pm 100\%$	$1.3 \pm 3\%$	$11.0 \pm 32\%$
Nov	$1.0 \pm 100\%$	$1.4 \pm 5\%$	$8.8 \pm 76\%$
Dec	$1.1 \pm 88\%$	$1.4 \pm 3\%$	$6.1 \pm 70\%$
Annual Av	1.3	1.4	<6.4
$\pm$ error (%)	16	13	35
Annual adult ^a dose (mrem)	4.1E-04	6.3	3.9E-03

^aCritical organ in all cases is the whole body.

Table 25. Environmental radiation measurements at the Lawrence Livermore Laboratory perimeter during 1976.

Location ^a	(Units - mrem)				Annual ^b
	January-March	April-June	July-September	October-December	
1	16 ± 4.0	18 ± 2.2	15 ± 4.2	13 ± 2.4	62
2	16 ± 4.1	16 ± 1.9	15 ± 3.7	13 ± 1.1	60
3	16 ± 3.5	17 ± 1.5	16 ± 2.6	13 ± 0.7	62
4	15 ± 3.7	16 ± 1.8	16 ± 4.7	14 ± 1.0	61
5	26 ± 5.3	27 ± 2.4	33 ± 8.4	25 ± 2.7	111
5a	87 ± 14	87 ± 14	52 ± 8	67 ± 11	293 ^c
6	15 ± 3.9	17 ± 1.4	17 ± 1.8	Lost	65
7	16 ± 3.6	17 ± 1.8	16 ± 3.6	13 ± 1.1	62
8	14 ± 3.7	15 ± 2.0	15 ± 2.0	13 ± 0.9	57
9	15 ± 3.6	16 ± 1.6	15 ± 1.6	13 ± 1.2	57
10	17 ± 3.6	17 ± 2.1	17 ± 2.1	15 ± 1.1	66
11	16 ± 4.0	18 ± 2.6	19 ± 3.9	15 ± 1.4	68
12	17 ± 3.9	18 ± 2.2	16 ± 2.4	15 ± 1.3	66
Average	22.0	23.0	20.2	19.1	84

^a See Fig. 14 for dosimeter locations.

^b TLD measurements in the off-site vicinity of the Laboratory (Fig. 14) show a median annual background of 60 mrem. However, subtracting this number from the data above to estimate the contribution from Laboratory operations yields several "negative" contributions, which demonstrates that the background at the various perimeter locations cannot be represented by a single value.

^c Neutron dose measurements at Location 5a indicate an additional annual dose of approximately 600 mrem.

Table 26. Concentration of beryllium in LLL perimeter air filters during 1976.

Location ^a	(Units - $10^{-5} \mu\text{g}/\text{m}^3$)												Av	error (%)
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec		
1	<0.05 ^b	1.2	2.5	3.2	3.2	2.1	2.7	3.1	2.7	1.3	8.4	2.2	<2.7	43
2	<0.05	0.5	1.7	2.1	2.4	1.5	2.6	2.9	<0.05	7.6	2.1	4.5	<2.3	52
12	0.8	2.2	3.2	3.8	5.3	7.4	6.9	6.2	3.9	5.4	3.9	4.8	4.5	25
13	<0.05	1.1	0.6	3.1	5.1	2.9	3.1	4.0	0.7	4.0	2.7	1.7	<2.4	38
14	<0.05	5.2	2.6	3.3	4.2	6.9	9.7	8.2	4.1	1.6	10.0	7.2	<5.3	35
15	<0.05	1.0	1.7	2.7	3.8	2.8	3.5	2.2	18.0	1.8	14.0	4.9	<4.7	67
Monthly														
Av	<0.2	1.9	2.0	3.0	4.0	4.5	4.8	4.4	4.9	3.6	6.9	4.2	<3.7	21
%standard ^c	1.0E-04	1.0E-03	1.0E-03	1.0E-03	2.0E-03	2.3E-03	2.4E-03	2.2E-03	2.5E-03	1.8E-03	3.5E-03	2.1E-03	1.8E-03	

^aSee Fig. 2 for sampling locations.

^bLimit of sensitivity is $5.0\text{E-}07 \mu\text{g}/\text{m}^3$.

^cEmission standard is $2 \mu\text{g}/\text{m}^3$ as reported in the Federal Register, April 6, 1973.

Table 27. Concentration of beryllium in Site 300 air filters during 1976.

Location ^a	(Units -- $10^{-5} \mu\text{g}/\text{m}^3$)												Av	±error (%)
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec		
1	<0.05 ^b	0.6	0.8	1.2	2.0	2.2	<0.05	2.2	1.1	<0.05	1.4	0.6	<1.0	46
2	<0.05	0.5	0.8	1.2	2.6	2.1	0.5	2.1	2.0	0.7	1.7	4.7	<1.6	46
3	<0.05	0.9	2.6	2.3	4.4	2.7	<0.05	4.5	4.4	4.1	9.0	10.0	<3.8	48
4	<0.05	0.9	0.7	1.9	3.9	3.9	0.8	2.7	4.6	1.3	3.7	1.8	<2.2	41
5	0.9	1.8	0.6	3.0	4.1	3.0	2.4	3.9	2.6	4.8	5.8	4.2	3.1	29
7	<0.05	0.4	1.4	4.2	2.1	1.9	2.3	1.7	3.4	2.4	8.1	0.8	<2.4	52
8	<0.05	0.9	1.1	3.4	3.7	3.2	2.9	1.9	3.8	2.2	7.0	2.9	<2.8	38
9	<0.05	0.3	<0.05	2.6	3.7	2.7	<0.05	3.7	<0.05	2.0	15.3	10.0	<3.4	81
10	<0.05	0.5	3.6	2.9	3.9	1.5	<0.05	11.0	0.6	2.2	5.9	8.7	<3.4	59
11	<0.05	0.5	2.2	3.3	2.4	1.1	0.5	2.2	1.7	5.7	3.2	4.2	<2.2	41
Monthly Av	<0.1	0.7	<1.4	2.6	3.3	2.4	<1.0	3.6	<2.4	<2.5	6.1	4.8	<2.6	19
%standard ^c	5.5E-05	3.5E-04	7.0E-04	1.3E-03	1.7E-03	1.2E-03	5.0E-04	1.8E-03	1.2E-03	1.3E-03	3.1E-03	2.4E-03	1.3E-03	

^aSee Fig. 4 for sampling locations.

^bLimit of sensitivity is $5.0\text{E-}07 \mu\text{g}/\text{m}^3$.

^cEmission standard is $2 \mu\text{g}/\text{m}^3$ as reported in the Federal Register, April 6, 1973.

Table 28. Monthly average concentrations of various elements in LLL sewage effluent during 1976.

Month	(Units - mg/l)								
	Cd	Cr	Cu	Fe	Pb	Ni	Ag	Zn	F
January	0.01	0.53	2.80	4.83	0.19	0.18	0.18	0.89	0.34
February	0.06	2.19	5.65	27.00	0.56	0.61	0.08	16.70	0.22
March	0.01	0.23	1.40	1.40	0.04	0.11	0.03	0.35	0.20
April	0.01	0.24	6.00	2.30	0.30	0.08	0.02	0.70	0.20
May	0.01	0.20	0.82	0.91	0.09	0.07	0.05	0.40	0.20
June	0.01	0.28	2.00	1.38	0.15	0.10	0.03	0.62	0.09
July	0.01	0.28	1.85	1.00	0.11	0.06	0.02	0.54	0.20
August	0.01	0.23	0.92	1.15	0.07	0.05	0.05	0.46	0.26
September	0.04	0.40	4.35	1.04	0.36	0.07	0.02	0.54	0.17
October	0.01	0.33	0.96	1.60	0.06	0.06	0.00	0.54	0.17
November	0.01	0.30	0.45	1.33	0.06	0.04	0.00	0.40	0.21
December	0.02	0.26	0.90	1.36	0.02	0.08	0.001	0.56	0.26
Annual Av	0.02	0.46	2.34	3.78	0.17	0.13	0.04	1.89	0.21
±error (%)	56	70	48	100	56	72	72	100	17

Table 29. Physical and chemical examination of LLL sewage effluent during 1976.

Analysis	Sewage, 24-hr composite (mg/l)				Annual av	±error (%)
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
BOD	59	42	118	43	66	55
COD	130	72	263	120	146	56
Total nitrogen	23	18	30	26	24	21
Ammonia nitrogen	19	18	18	20	19	5
Nitrate nitrogen	0.38	32	0.15	0.18	8.10	100
Oil and grease (FEM)	22	<5	<5	<5	<10	92
Sulfate	23	67	18	43	38	59
Arsenic	0.0027	<0.0001	0.13	0.020	<0.039	100
Boron	0.3	0.7	0.4	0.4	0.5	38
Cyanide	0.13	0.057	0.10	<0.002	<0.043	100
Mercury	0.0010	0.0008	0.0030	0.0020	0.002	60
Selenium	<0.0009	<0.00001	0.021	<0.0001	<0.006	100
Settleable matter (ml/l/hr)	<0.1	0.4	2.5	<0.1	<0.8	100
Total solids	158	479	295	—	311	60
Solids, dissolved	190	431	168	160	237	55
Solids, suspended	24.7	14	137	34	52	100
Solids, volatile	89	87	153	34	91	54
Total alkalinity	82	97.4	105.4	92	94	10
Total phosphorus	1.25	2.9	4.4	5.0	3.4	49
Hardness	19	28.2	26.5	32	26.4	21

Table 30. Physical and chemical examination of Site 300 sewage settling pond during 1976.

Analysis	Sewage, 24-hr composite (mg/l)				Annual av	±error (%)
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
BOD	72	34	36	35	44	42
COD	540	460	369	444	453	15
Total nitrogen	22	18	21	20	20	8
Ammonia nitrogen	1.1	0.28	1.7	0.39	0.87	76
Nitrate nitrogen	0.19	0.04	0.02	0.04	0.07	100
Oil and grease (FEM)	29	<5	6.6	<5	<12	100
Sulfate	420	549	609	471	512	16
Arsenic	0.0014	0.00015	<0.0001	0.005	0.002	100
Boron	5.2	5.6	6.3	5.0	5.5	10
Cyanide	<0.001	<0.001	0.002	0.10	<0.026	100
Mercury	0.0001	0.0003	0.083	0.005	0.021	100
Selenium	<0.0009	<0.00001	0.029	<0.0001	<0.008	100
Settleable matter (ml/l/hr)	<0.1	0.5	1.2	<0.1	<0.5	100
Total solids	3816	3197	2750	—	3254	19
Solids, dissolved	3563	2960	2660	2700	2971	14
Solids, suspended	169	121	122	156	142	17
Solids, volatile	518	425	540	156	410	43
Total alkalinity	1421	1131	1000	1128	1170	15
Total phosphorus	11	12	9	22	14	43
Hardness	104	52	61	70	72	32

Table 31. Estimated radiation dose to the public from LLL radioactive airborne effluents during 1976.

Nuclide	Facility	Curies released	Dose at site boundary (mrem)	Dose to nearest resident (mrem)	Season	Dose within 80 km radius of LLL (man-rem)
^{41}Ar	Livermore Pool Type Reactor -- Building 281	470	4.0	0.53	wet dry annual	1.7 0.9 2.6
$^3\text{H}_2$	Gaseous Chemistry -- Building 331	2818	0.26	0.022	wet dry annual	0.18 0.09 0.27
$^3\text{H}_2$	Insulating core transfer accelerator --	1173	1.7	0.021	wet dry annual	0.11 0.07 0.18
$^{13}\text{N}_2$ - $^{15}\text{O}_2$	Electron positron linear accelerator -- Building 194	1035	4.5	1.1	wet dry annual	0.16 0.09 0.25

Table 32. Percent of concentration guide of radionuclides detected in discharges to Livermore City sewers.

Radionuclide ^a	CG ^b (μCi/ml)	% CG
^{134}Cs	9E-06	2.1E-01
^{137}Cs	2E-05	9.5E-02
^{110}Ag	3E-05	6.3E-02
^{125}Sb	1E-04	1.9E-02
^{95}Nb	1E-04	1.9E-02
^{56}Mn	1E-04	1.9E-02
^{65}Zn	1E-04	1.9E-04
^{95}Zr	8E-04	2.4E-03
^{60}Co	3E-03	6.3E-04

^a Assuming each of the radionuclides was the sole source of the 1.9E-08 μCi/ml annual average gross beta activity in the discharge.

^b ERDAM 0524, Annex A, Table II.

Table 33. Comparison of plutonium content of jackrabbits collected at LLL and Susanville in 1976.

Organ	<u>wet weight</u> <u>dry weight</u>	²³⁹ Pu (pCi/kg, wet weight)		
		LLL	Susanville	LLL/Susanville
Muscle	4.1	0.010 ± 26	0.007 ± 39	1.4
Lung	4.0	0.14 ± 25	0.03 ± 63	4.7
Kidney	4.4	0.20 ± 31	0.03 ± 100	6.7
Bone	2.1	0.24 ± 17	0.03 ± 43	8.0
Liver	3.9	3.84 ± 4	0.112 ± 18	34
Gut and contents	5.0	1.12 ± 6	0.21 ± 9	5.3

Appendix B

Discharge Limits to the Sanitary Sewer Systems of the City of Livermore

The Code of the City of Livermore (1959) states the discharge requirements to its sanitary sewer system in Section 18.63. These limits are as follows:

Sec. 18.63.

No person shall discharge, or cause to be discharged, except for salt waste discharge from water softener units of any kind or description installed and in operation on or before January 31, 1966, which are regenerated by the owner thereof at the place of use of such units, any of the following described water or wastes to any public sewer unless the customer obtains a permit from the city in accordance with section 18.65.

(a) Any liquor or vapor having a temperature higher than one hundred fifty degrees Fahrenheit.

(b) Any waters or wastes which contain more than two hundred ppm of fat, oil or grease that is petroleum ether soluble.

(c) Any gasoline, benzene, naphtha, fuel oil or other inflammable or explosive liquid, solid or gas.

(d) Any garbage, except properly ground with a mechanical garbage grinder. Specifically excluded from the sewers are waste products resulting from the handling, storage and sale of fruits and vegetables from other than retail produce establishments, or other foods not intended primarily for immediate consumption.

(e) Any ashes, cinders, sand, mud, straw, shavings, metal, glass, rags, feathers, tar, coal tar, asphalt, cement, plastics, woods, paunch manure or any other solid viscous substance capable of causing obstruction to the flow in sewers or other interferences with the proper economical operation of the sewage works.

(f) Any wastes or water with a pH lower than six and eight-tenths or higher than eight.

(g) Any waters or wastes containing total dissolved solids increments greater than three hundred and twenty-five ppm, nor chloride increment greater than seventy-five ppm, increase during a single cycle use of the water supply.

(h) Any water or wastes having a B.O.D. greater than three hundred ppm (the average B.O.D. for residential users).

(i) Any waters or wastes containing more than three hundred ppm of suspended solids (the average suspended solids for residential users).

(j) Any waters intended to be used or used to dilute waste discharge to avoid violation of the above limitation. (Ord. No. 586. par 1.)

Sec. 18.66

No person shall discharge or cause to be discharged any radioactive wastes into any public sewers, except where:

A. The waste is discharged in strict conformity with current atomic energy commission recommendations for safe disposal of radioactive wastes.

B. The discharging of radioactive waste will not cause injury to personnel or damage to the sewage works. Any person discharging a radioactive waste to a public sewer in accordance with the provisions of the preceding paragraph shall submit to the council such report as the council may deem necessary.

In the event of any accidental spill of any radioactive material into the public sewer, the person responsible shall (a) immediately notify the plant superintendent, and (b) render such technical or other assistance to the department of public works within his power to prevent the sewage works from becoming contaminated with radioactivity. (Ord. No. 586, par 1.)

Appendix C

Environmental Activity Concentration Guide Levels

The Standards for Radiation Protection (AEC Manual Chapter 0524, issued 11/8/68) state that if there is a mixture in air and water of radionuclides whose identity and concentrations are unknown, the average activity should not exceed the following values:

1. Air (controlled area)	6×10^{-12} $\mu\text{Ci/ml}$
2. Air (uncontrolled area)	2×10^{-14} $\mu\text{Ci/ml}$
3. Water (controlled area)	4×10^{-7} $\mu\text{Ci/ml}$
4. Water (uncontrolled area)	3×10^{-8} $\mu\text{Ci/ml}$

If it is known that alpha emitters and ^{227}Ac are not present, the following guide values may be used to determine the permissible average activity:

5. Air (controlled area)	3×10^{-11} $\mu\text{Ci/ml}$
6. Air (uncontrolled area)	1×10^{-12} $\mu\text{Ci/ml}$

If it is known that ^{129}I , ^{226}Ra , and ^{228}Ra are not present, the following values may be used:

7. Water (controlled area)	3×10^{-6} $\mu\text{Ci/ml}$
8. Water (uncontrolled area)	1×10^{-7} $\mu\text{Ci/ml}$

The air and water samples are subjected to gross alpha and gross beta measurements. The average annual alpha activities may not exceed those listed under points 1 through 4 above. Since the alpha emitters have been accounted for in the gross alpha measurements, and the assumption is made that ^{129}I , ^{227}Ac , ^{226}Ra , and ^{228}Ra are not present in the samples, and annual average gross beta activities of the samples may not exceed the activities listed under points 5 through 8 above. The assumption that ^{129}I , ^{227}Ac , ^{226}Ra , and ^{228}Ra are not present in air and water samples is reasonable in view of the minute quantities of these radionuclides available at the Laboratory. AEC Manual Chapter 0524 also states that the average tritium activities in off-site water samples may not exceed 3×10^{-3} $\mu\text{Ci/ml}$.

Since analysis for ^{129}I , ^{226}Ra , and ^{228}Ra activities is made on samples collected from the Laboratory's sewage effluent at the point of discharge into the Livermore city sanitary sewer system, the gross alpha and beta activities

in the samples collected from the effluent discharged from the Livermore sewage treatment plant should not exceed the 1×10^{-7} $\mu\text{Ci}/\text{ml}$ listed under point 8 above.

The annual external whole-body radiation dose to workers in controlled areas may not exceed 5 rem; while that to an individual in an uncontrolled area may not exceed 500 mrem. An average annual dose of 170 mrem may not be exceeded for a group of individuals in an uncontrolled area.