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Nonradioactive Ambient Air Monitoring
at Los Alamos National Laboratory
2001–2002

Edited by Hector Hinojosa, Group IM-1

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Nonradioactive Ambient Air Monitoring
at Los Alamos National Laboratory
2001–2002

Ernest Gladney
Craig Eberhart
Jean Dewart
Joseph Lochamy*

*Lochamy Associates, 205 Wealdon Road, Clinton, TN 37716



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List of Acronyms

ACGIH American Conference of Governmental Industrial Hygienists
ACIS Automated Chemical Inventory System
AIHA American Industrial Hygiene Association
ATSDR Agency for Toxic Substances and Disease Registry
CAS Chemical Abstract Service
DQO Data Quality Objective
EPA Environmental Protection Agency
EPCRA Emergency Planning and Community Right-to-Know Act
ESH-17 former designation for the Meteorology and Air Quality Group
HAP Hazardous Air Pollutant
ICPES inductively coupled plasma emission spectrometry
ICPMS inductively coupled plasma mass spectrometry
LANL Los Alamos National Laboratory
LCS laboratory control standards
LMS laboratory matrix spikes
 $\mu\text{g}/\text{m}^3$ micrograms per cubic meter
MAQ Meteorology and Air Quality Group
MSDS Material Safety Data Sheet
NATA National Air Toxics Assessment
 ng/m^3 nanograms per cubic meter
OSHA Occupational Safety and Health Administration
PAMS Photochemical Assessment Monitoring Station
PM_{2.5} particulate matter with an aerodynamic diameter of 2.5 micrometers or less
PM₁₀ particulate matter with an aerodynamic diameter of 10 micrometers or less
ppbv parts per billion by volume
SOW Statement of Work
STL Severn-Trent Laboratories
TA Technical Area
TEOM tapered element oscillating microbalance
TSP total suspended particulate
TWA time weighted average
UATMP Urban Air Toxics Monitoring Program
VOCs volatile organic compounds

Executive Summary

During the spring of 2000, the Cerro Grande forest fire reached Los Alamos National Laboratory (LANL) and ignited both above-ground vegetation and disposed materials in several landfills. During and after the fire, there was concern about the potential human health impacts from chemicals emitted by the combustion of these Laboratory materials. Consequently, short-term, intensive air-monitoring studies were performed during and shortly after the fire. Unlike the radiological data from many years of AIRNET sampling, LANL did not have an adequate database of nonradiological species under baseline conditions with which to compare data collected during the fire. Therefore, during 2001 the Meteorology and Air Quality Group designed and implemented a new air-monitoring program, entitled NonRadNET, to provide nonradiological background data under normal conditions. The objectives of NonRadNET were to

- develop the capability for collecting nonradiological air-monitoring data,
- conduct monitoring to develop a database of typical background levels of selected nonradiological species in the communities nearest the Laboratory, and
- determine LANL's potential contribution to nonradiological air pollution in the surrounding communities.

NonRadNET ended in late December 2002 with five quarters of data. The purpose of this paper is to organize and describe the NonRadNET data that was collected over 2001–2002 to facilitate future use as baseline data, either for monitoring during a fire, some other abnormal event, or routine use. To achieve that purpose, in this paper we will

- document the NonRadNET program procedures, methods, and quality management,
- describe the usual origins and uses of the species measured,
- compare the species measured to LANL and other area emissions,
- present the five quarters of data,
- compare the data to known typical environmental values, and
- evaluate the data against exposure standards.

Three samplers were operated according to a documented quality assurance plan during the five-quarter sampling period. The three samplers were located at

White Rock Fire Station (site #15)

Los Alamos Medical Center (site #61)

Intersection of Diamond Drive and East Jemez Road (site #81)

As part of the program, the samplers collected total suspended particulate matter, particulate matter less than 10 microns, and particulate matter less than 2.5 microns. Concentrations were typical for the nation and region.

Air samples were also collected and analyzed for 20 inorganic elements. The concentrations of these elemental species were also observed generally to be typical for the region and nation with barium, beryllium, iron, and vanadium concentrations being somewhat higher, but still less than values from urban areas.

Finally, we measured approximately 160 volatile organic compounds (VOCs) in our air samples. We determined that about half of the 160 VOCs measured are common components of vehicle fuels and exhausts. We also determined that virtually all of the rest of the VOCs are also components of everyday consumer or industrial processes. Furthermore, we determined that the concentrations for nearly all of the measured species, for which there were comparison data, were less than or within typical national concentration ranges.

We did observe that the concentrations for benzaldehyde, butyraldehyde, acetone, and acetaldehyde appear to be higher than the few national values we found for comparison with them. Our review of the very low LANL emissions of these four VOCs indicated that their airborne concentrations cannot reasonably be attributed to LANL. However, we conservatively concluded that 2, 4, 4-trimethyl-1-pentene and Freon 22 (chlorodifluoromethane) *may* have measurable LANL influence or may have LANL as their primary origin. Additionally, we observed that normal commuter vehicle use, by far, emits more VOCs than LANL.

Based on our measurements, our evaluation of LANL and other emission sources, and a comparison of our results with typical national values, we conclude that the Laboratory is not a significant contributor to the large number of species we measured. Furthermore, the ambient air concentrations around LANL tend to be significantly *lower* than in major urban areas, roughly typical of rural areas, and are many orders of magnitude below regulatory standards considered safe for occupational exposure (since environmental exposure standards do not exist for most of these species).

**NONRADIOACTIVE AMBIENT AIR MONITORING
AT LOS ALAMOS NATIONAL LABORATORY
2001–2002**

by

Ernest Gladney, Craig Eberhart, Jean Dewart, and Joseph Lochamy

Abstract

During the spring of 2000, the Cerro Grande forest fire reached Los Alamos National Laboratory (LANL) and ignited both above-ground vegetation and disposed materials in several landfills. During and after the fire, there was concern about the potential human health impacts from chemicals emitted by the combustion of these Laboratory materials. Consequently, short-term, intensive air-monitoring studies were performed during and shortly after the fire. Unlike the radiological data from many years of AIRNET sampling, LANL did not have an adequate database of nonradiological species under baseline conditions with which to compare data collected during the fire. Therefore, during 2001 the Meteorology and Air Quality Group designed and implemented a new air-monitoring program, entitled NonRadNET, to provide nonradiological background data under normal conditions. The objectives of NonRadNET were to

- develop the capability for collecting nonradiological air-monitoring data,
- conduct monitoring to develop a database of typical background levels of selected nonradiological species in the communities nearest the Laboratory, and
- determine LANL's potential contribution to nonradiological air pollution in the surrounding communities.

NonRadNET ended in late December 2002 with five quarters of data. The purpose of this paper is to organize and describe the NonRadNET data collected over 2001–2002 to use as baseline data, either for monitoring during a fire, some other abnormal event, or routine use. To achieve that purpose, in this paper we will

- document the NonRadNET program procedures, methods, and quality management,
- describe the usual origins and uses of the species measured,
- compare the species measured to LANL and other area emissions,
- present the five quarters of data,
- compare the data to known typical environmental values, and
- evaluate the data against exposure standards.

1.0 Introduction

This paper provides a description of a short-term nonradiological air-monitoring program, “NonRadNET,” at Los Alamos National Laboratory (LANL) that operated for 15 months from the fourth quarter of 2001 through the end of 2002. It also provides the entire data set for the sampled period and consists of results for 183 nonradioactive species, including particulate matter in three size ranges, 20 inorganic elements, and 160 volatile organic compounds (VOCs). The results of this program were first published in the LANL Environmental Surveillance Reports for 2001 and 2002 [LANL2002, LANL2003]. The VOC data reported in the Environmental Surveillance Reports are in units of parts per billion by volume (ppbv), a convenient analytical unit. In this report, we will use the more conventional air concentration units of micrograms per cubic meter ($\mu\text{g}/\text{m}^3$).

The purpose of this paper is to organize and describe the NonRadNET data that was collected over 2001–2002 for future use as baseline data, either for monitoring during a fire, some other abnormal event, or routine use. To achieve that purpose, in this paper we will

- document the NonRadNET program procedures, methods, and quality management,
- describe the usual origins and uses of the species measured,
- compare the species measured to LANL and other area emissions,
- present the five quarters of data,
- compare the data to known typical environmental values, and
- evaluate the data against exposure standards.

Besides the Executive Summary, this paper is divided into 10 major technical sections, plus a references section, and two appendices.

Section 1, Introduction, is intended to provide information on the purpose and structure of the paper and a very general overview. **Section 2, Background**, provides a historical perspective on why the program was begun and gives the objectives of the program. **Section 3, NonRadNET Air Monitoring Network**, provides a general description and overview of the NonRadNET program. **Section 4, Sampling Procedures, Analytical Methods, Data Management, and Quality Assurance**, provides a more detailed description of the specific program components. **Section 5, Origins and Uses of Nonradioactive Species in Ambient Air**, describes where many of the measured species originate and some of their common uses. **Section 6, Comparison with LANL and Other Emission Sources**, cross tabulates the measured species with those used at LANL. **Section 7, Summary of Ambient Air Measurements**, discusses the measured results in terms of averages and ranges. **Section 8, Comparison with National Values**, puts the LANL measurements into perspective by comparing them to typical national concentrations. **Section 9, Comparison with Exposure Standards**, further adds perspective by comparing the measurements with exposure standards, most of which are occupational rather than environmental, since environment exposure standards generally do not exist for the measured species. **Section 10, Conclusion**, makes a final statement regarding achievement of the program objectives. **Section 11, References**, provides the references, many of which are web sites, used in the paper or recommended for further information. References are indicated in square brackets “[Reference]” in the document body.

Appendix A provides a listing of the 160 VOCs included in this project. **Appendix B** contains the details of several special calculations, the results of which are used in the main text of this document.

2.0 Background

During the spring of 2000, the Cerro Grande forest fire reached LANL and ignited both above-ground vegetation and disposed materials in several landfills. During and after the fire, there was concern about the potential human health impacts from chemicals emitted by the combustion of these Laboratory materials. Consequently, short-term, intensive air-monitoring studies were performed during and shortly after the fire. Unlike the radiological data from many years of AIRNET sampling, LANL did not have an adequate database of nonradiological species under baseline conditions with which to compare data collected during the fire. Therefore, during 2001, the Meteorology and Air Quality Group (MAQ, formerly ESH-17) designed and implemented a new air-monitoring program, entitled NonRadNET, to provide nonradiological background data under normal conditions. The objectives of NonRadNET were to

- develop the capability for collecting nonradiological air-monitoring data,
- conduct monitoring to develop a database of typical background levels of selected nonradiological species in the communities nearest the Laboratory, and
- determine LANL's potential contribution to nonradiological air pollution in the surrounding communities.

These objectives will be addressed in this paper. The next section describes how the capability for collecting nonradiological air-monitoring data was developed.

3.0 NonRadNET Air Monitoring Network

This section provides a brief overview of the NonRadNET Air Monitoring Network.

3.1 Monitored Constituents

NonRadNET was designed to sample and analyze environmental levels of airborne nonradiological constituents in Los Alamos County. The species monitored included

- total suspended particulates (TSP),
- particulate matter with an aerodynamic diameter of 10 micrometers or less (PM₁₀),
- particulate matter with an aerodynamic diameter of 2.5 micrometers or less (PM_{2.5}),
- 20 inorganic elements of particulate matter, and
- 160 VOCs.

The 20 monitored inorganic elements are given in Table 3-1 below.

Table 3-1. NonRadNET Inorganic Elements

Name	Symbol
Antimony	Sb
Arsenic	As
Barium	Ba
Beryllium	Be
Cadmium	Cd
Cerium	Ce
Chromium	Cr
Cobalt	Co
Copper	Cu
Iron	Fe
Lead	Pb
Manganese	Mn
Neodymium	Nd
Nickel	Ni
Selenium	Se
Silver	Ag
Strontium	Sr
Thallium	Tl
Vanadium	V
Zinc	Zn

Because the list of VOCs is rather long, two complete lists of the approximately 160 monitored VOCs, ordered alphabetically and by Chemical Abstract Service (CAS) number, are provided in Appendix A and are not reproduced here.

3.2 Sampling Locations

NonRadNET sampling locations were chosen using siting criteria based on Environmental Protection Agency (EPA) specifications in 40 CFR Part 58 [EPA1999] and the MAQ air sampler siting procedure [LANL2000]. Monitoring stations were designed to collect samples in the breathing zone: two meters above the ground surface. Uniform application of these criteria assured consistency, comparability, and representativeness among all air sampling locations. In addition to the site-specific criteria cited above, good scientific judgment was always employed as the final criterion in selecting the optimal sampling locations.

Simultaneous monitoring took place at three different locations—two in Los Alamos and one in White Rock, NM. The White Rock NonRadNET sampling (site #15) was co-located with the existing AIRNET station at the White Rock Fire Station. One of the Los Alamos stations (site #61) was co-located with the existing AIRNET station at the Los Alamos Medical Center. The third NonRadNET station (site #81) was located near the intersection of Diamond Drive and East Jemez Road between the main technical area of the Laboratory and the population center of the Los Alamos town.

3.3 Sampling Frequency and Duration

PM₁₀ and PM_{2.5} concentrations were measured continuously and averaged over 1-hour, 3-hour, and 24-hour time periods. VOC, TSP, and inorganic sampling was done every twelfth day to coincide with the EPA national ambient air monitoring schedule, with each sampling period lasting 24 hours. All sites commenced operation on September 22, 2001. Sampling ended five quarters later on December 23, 2002. Meteorological data were collected through the LANL meteorological monitoring network and used to aid in data interpretation and impact evaluation.

4.0 Sampling Procedures, Analytical Methods, Data Management, and Quality Assurance

This section describes the procedures used for NonRadNET sampling, the methods used to determine the constituents, how the data were handled, and the quality assurance features of NonRadNET.

4.1 Total Suspended Particulate Sampling/Analysis Procedures

The total suspended particulate sampling was done using high-volume particulate samplers. These samplers operate on the same principle as a vacuum cleaner. A calibrated volume of air is drawn through a pre-weighed filter for exactly 24 hours. Particles are trapped on the filter. After the 24-hour period the filter is collected and weighed. The change in weight of the filter pad is recorded as micrograms of particulate per cubic meter of air sampled. For the NonRadNET study, samples for 24-hour time-integrated TSP were collected on either Dynaweb polypropylene or Whatman cellulose 8- by 10-inch filters using Anderson GV-2360 volumetric-flow-controlled high-volume samplers. All filters were placed in the sampler less than 48 hours prior to the start of a sampling run and were recovered from the samplers within 24 hours of the end of each sampling period. All filters were weighed prior to deployment and again after collection to determine net particulate weight gain. All weighing activities took place in a humidity-conditioned chamber. Filters were equilibrated for at least 24 hours prior to each weighing to achieve consistent absorbed-water levels.

4.2 Inorganic Element Sampling/Analysis Procedures

After determining the TSP on the filters, they were then sent to a commercial environmental analytical chemistry laboratory in glassine envelopes under chain of custody for chemical analysis of 20 inorganic elements via both inductively coupled plasma emission spectrometry (ICPES) using EPA Method SW6010 and inductively coupled plasma mass spectrometry (ICPMS) using EPA Method SW6020.

4.3 PM₁₀ and PM_{2.5} Sampling/Analysis Procedures

PM₁₀ and PM_{2.5} can be sampled using traditional filter-based sampling techniques as described in Section 4.1 for TSP or by continuous *in-situ* monitors. The benefits of continuous *in-situ* monitors are as follows: (1) reduced site visits and monitoring network operating costs, (2) collection of real-time data to assist in decision making, such as air quality alerts, or temporary control measures, such as no-burn days, and (3) identification of diurnal variations or variations due to temporary, site-specific activities.

For the NonRadNET study, continuous PM₁₀ and PM_{2.5} concentrations in micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) were collected using a Rupprecht & Patashnick tapered element oscillating microbalance (TEOM) Series 1400a ambient particulate monitor fitted with either PM₁₀ or PM_{2.5} sample inlets. Figure 4-1 shows a photograph of the TEOM sampling equipment inside an enclosure at Site #61 near the medical center.

The Rupprecht and Patashnick TEOM has been designated a Federal Equivalent Method by the EPA for compliance monitoring. The TEOM draws air through a hollow tapered tube, with the wide end

of the tube fixed, while the narrow end oscillates in response to an applied electric field. The narrow end of the tube holds a filter cartridge. The sampled air stream passes from the sampling inlet, through the filter and tube, to a flow controller. As particles are collected on the filter, the oscillating mass changes and results in a change in the oscillating frequency. An electronic control system maintains the tapered tube in oscillation and continuously measures the oscillating frequency and its changes. The resonant frequency of the element decreases as mass accumulates on the filter. Temperatures must be maintained at a fairly constant value, typically 50° C, to minimize thermal expansion of the tapered element.

In the NonRadNET study, the collecting instruments automatically recorded and electronically saved the PM_{10/2.5} data for subsequent downloading and transfer to a database maintained by MAQ. These data were used as an indicator of natural dust loading in the atmosphere and to aid in interpreting the inorganic elemental concentration data determined on the large TSP filters.

The data from these TEOMs provide good short-term measurements that can be used to make decisions about protecting sensitive individuals from exposure to high levels of particulate matter. For example, during the 2002 Arizona wildfires these monitors were used to advise New Mexico Department of Health officials about the levels of smoke in the atmosphere.

4.4 Volatile Organic Compound Sampling/Analysis Procedures

A ThermoAnderson[®] Ambient Volatile Organic Collection System was used to collect samples of ambient air in 15-liter Summa canisters owned by LANL. Figure 4-2 shows the sampling equipment for this system at Site #61 near the medical center. Prior to each sampling event, all canisters were pre-cleaned and monitored for residual levels of all VOC to be determined by Severn-Trent Laboratories (STL), located in Austin, TX. Upon completion of an integrated 24-hour sample, taken simultaneously at all sites every twelfth day per EPA procedure, all canisters were returned to STL under chain of custody for VOC determination via EPA Compendium Method TO-15. Up to 160 organic compounds were reported for each sample and these data were stored within the existing AIRNET database for subsequent evaluation and interpretation.

Field sampling data were entered manually on paper forms and returned to MAQ for keyboard entry into an existing database. Net air volumes sampled were calculated using calibration procedures provided by each sampling system's manufacturer. These volumes were used to calculate net ambient air concentrations of TSP, VOC, and inorganic elements.

4.5 Data Management and Quality Assurance

The NonRadNET project was operated according to a formal quality assurance project plan [LANL2002a]. This plan and related procedures describe or prescribe all of the planned and systematic activities believed necessary to provide adequate confidence that NonRadNET processes perform satisfactorily. Current copies of these documents are available on the web at www.airquality.lanl.gov.

The following subsections briefly describe the NonRadNET data management and quality program.



Figure 4-1. TEOM sampling equipment inside an enclosure at Site #61.



Figure 4-2. Ambient Volatile Organic Collection System at Site #61.

4.5.1 Field Sampling Quality Assurance

Overall quality of this portion of the program was maintained through the rigorous use of carefully documented procedures governing all aspects of the sample collection program. Particulate samples were taken on commercially available media of known performance. VOC samples were collected in Summa canisters of known characteristics. All samples were collected under common EPA chain-of-custody procedures using field-portable electronic data systems to minimize the chances of data transcription errors. These samples were prepared for shipment in a secure, clean laboratory. Samples were shipped to external analytical laboratories under full chain of custody by a secure commercial shipper. MAQ tracked samples at all stages of their collection and analysis through the AIRNET relational database. A complete suite of blanks was also included for analysis with each set of samples. These blanks consisted of matrix blanks, trip blanks, and process blanks (where applicable).

Field sampling completeness was determined each sampling period upon receipt of the inorganic or VOC analytical data sets. Chemistry staff in MAQ included all of these calculations in quality assessment memos that were prepared to evaluate every data set received from an analytical laboratory.

4.5.2 Analytical Laboratory Quality Assessment

Specific Statements of Work (SOWs) were written to govern the acquisition and delivery of analytical chemistry services after the Data Quality Objective (DQO) process had identified and quantified our program objectives. These SOWs were sent to potentially qualified suppliers who then underwent pre-award on-site assessment by experienced and trained MAQ quality systems and chemistry laboratory assessors. SOW specifications, professional judgment, and quality system performance at each laboratory (including recent past performance on nationally conducted performance evaluation programs) were primarily used to award contracts for specific types of analyses.

Each laboratory conducted its chain-of-custody and analytical processes under their own quality plans and analytical procedures. Preliminary data were returned to MAQ via e-mail in an electronic data deliverable of specified format and content. Each set of samples contained all of the internal quality assurance/quality control data generated by the analytical laboratory during each phase of analysis. These quality assurance/quality control data included laboratory control standards (LCS), VOC surrogate compounds, process blanks, matrix spikes, duplicates, and replicates, where applicable. All data were electronically uploaded into the AIRNET database and immediately subjected to a variety of quality and consistency checks. Analytical completeness was calculated, and tracking and trending of all blank and control sample data were performed. All results were included in the quality assessment memo mentioned in the field sampling section. All parts of the data management process were tracked electronically, and periodic reports to management were prepared.

4.5.3 Evaluation of Field and Analytical Data Quality Control Results

Field data completeness for NonRadNET was 100%. Sampler run time was greater than 95% at each station. Analytical data completeness was 100% for samples submitted to analytical

laboratories. The Clean Air Act required that an EPA-compliant program of quality control samples be included as an integral part of the sampling and analysis process. Our sample and data management procedures documented the specific evaluations of each type of quality control sample for each analytical measurement. These quality control parameters were tracked and trended as the analytical results were returned from the laboratories. The overall results of this quality program are summarized in the tables in this section.

The analytical laboratory corrected all VOC data for instrument and canister blanks during the gas chromatography/mass spectrometry analysis of the gas recovered from the Summa canisters. Five EPA-specified surrogate compounds, used as indicators of analytical recovery, were added to each analytical sample prior to injection into the spectrometer. EPA considers that VOC surrogate recoveries within the range of 70% to 130% are an indication that the instrument measurement process is under control. The analytical laboratory maintained an excellent surrogate recovery record during the entire program as summarized in Table 4-1.

Table 4-1. VOC Surrogate Recovery Summary for 2001–2002

CAS #	Surrogate Compound Name	Mean % Recovery	% Std Dev of Recovery*
110-56-5	1,4-Dichlorobutane	93.7	6.7
2037-26-5	Toluene-d8	103.6	5.6
421-06-7	2-Bromo-1,1,1-trifluoroethane	94.4	8.5
460-00-4	4-Bromofluorobenzene	98.4	6.2
462-06-6	Fluorobenzene	85.4	12.5

*127 values for each compound

Inorganic analysis quality controls included LCS, matrix blanks, matrix spikes, and process blanks. We also monitored the reported detection limit on each sample to ensure that contract and program requirements were consistently met and compared a number of elements measured by both analytical methods throughout the whole sampling program.

The LCS was a single aqueous solution containing known quantities of all elements of interest. The LCS was analyzed at the beginning of each analytical measurement session. This performance check was intended to alert the analyst to potential instrument problems at the outset of each sample set. The summarized results for both ICPEs and ICPMS are shown in Table 4-2. We considered recoveries of $100 \pm 10\%$ of the known value with a standard deviation of $<10\%$ to represent excellent control. The vast majority of the data shown in Table 4-2 meet this criterion with only a few exceptions. Chromium (Cr) recoveries by both analytical methods remained slightly on the high side with a larger standard deviation than desirable during the entire program. Iron (Fe) evidenced out of control conditions during the first half of the program, as can be seen by its very high mean recovery and large standard deviation. Ultimately we conducted an on-site assessment with the analytical laboratory to correct this situation. The ICPEs antimony (Sb) recovery was slightly low throughout the program, but the ICPMS Sb recovery was under good control. Ultimately, we only reported the ICPMS Sb measurements during the latter portion of the program.

Table 4-2. LCS* Recovery Summary for Inorganics for 2001–2002

Element	ICPES % Recovery (Mean ± StdDev)	ICPES Measurements	ICPMS % Recovery (Mean ± StdDev)	CPMS Measurements
Ag	93.0 ± 3.9	27	99.2 ± 6.6	46
As	95.4 ± 5.8	46	---	---
Ba	104.4 ± 4.5	46	99.3 ± 4.6	46
Be	100.7 ± 7.1	46	---	46
Cd	102.2 ± 6.4	27	96.8 ± 4.5	46
Ce	103.8 ± 4.0	23	98.2 ± 3.0	23
Co	103.6 ± 5.7	27	102.2 ± 7.4	46
Cr	111.3 ± 17.5	46	111.0 ± 14.3	46
Cu	104.3 ± 5.1	46	99.4 ± 6.4	27
Fe	165.9 ± 84.9	24	---	24
Mn	103.8 ± 4.0	28	104.3 ± 8.1	28
Nd	100.1 ± 3.6	22	97.8 ± 3.6	23
Ni	104.4 ± 4.8	27	102.0 ± 7.3	46
Pb	108.0 ± 9.0	27	101.3 ± 7.9	46
Sb	89.9 ± 13.4	27	96.7 ± 9.9	46
Se	90.9 ± 16.5	46	---	---
Sr	104.6 ± 3.5	28	99.1 ± 6.1	28
Tl	98.8 ± 10.0	27	94.9 ± 8.7	46
V	99.3 ± 4.4	46	---	---
Zn	110.7 ± 12.7	46	103.5 ± 5.9	46

*Laboratory Control Standard

Laboratory matrix spikes (LMS), single filters of the same type as samples, were analyzed in each batch of samples. The analyst spiked the LMS with differing portions of an aqueous solution containing known quantities of all elements of interest. These LMS were treated identically with the samples during sample preparation and analysis. This matrix spike was intended to alert the analyst to potential method problems that could be related either to the matrix or to something in the sample preparation process after each sample set had been run. The summarized results for both ICPES and ICPMS are shown in Table 4-3. We considered recoveries of $100 \pm 10\%$ of the known value with a standard deviation of $<10\%$ to represent excellent control. The vast majority of the data shown in Table 4-3 meet this criterion with only a few exceptions. As with the LCS above, chromium (Cr) recoveries in the LMS by both analytical methods remained significantly on the high side with a large standard deviation during the entire program. Iron (Fe) evidenced out of control conditions during the first half of the program, as can be seen by the very high mean recovery and large standard deviation, similar to the situation observed in the LCS. The ICPES antimony (Sb) recovery was slightly low throughout the program while that of the ICPMS was under good control. Finally, the lead (Pb) and zinc (Zn) recoveries by both methods remained slightly high throughout the whole program for undetermined reasons.

Table 4-3. LMS* Recovery Summary for Inorganics for 2001–2002

Element	ICPES % Recovery (Mean ± StdDev)	ICPES Measurements	ICPMS % Recovery (Mean ± StdDev)	ICPMS Measurements
Ag	92.7 ± 18.3	20	100.9 ± 7.8	40
As	95.1 ± 4.8	40	---	---
Ba	102.5 ± 5.2	40	97.7 ± 3.5	40
Be	103.8 ± 6.1	40	---	---
Cd	102.7 ± 4.3	20	98.1 ± 2.8	40
Ce	103.7 ± 3.2	18	99.6 ± 3.7	18
Co	103.2 ± 5.4	20	99.3 ± 8.1	40
Cr	128.4 ± 39.5	40	126.3 ± 16.6	20
Cu	108.2 ± 5.5	40	102.5 ± 7.4	20
Fe	158.3 ± 51.9	21	---	---
Mn	103.8 ± 4.2	24	102.7 ± 8.9	24
Nd	100.9 ± 2.8	17	99.8 ± 3.2	18
Ni	106.5 ± 5.7	20	104.1 ± 7.7	40
Pb	112.0 ± 14.4	20	110.6 ± 17.5	40
Sb	81.9 ± 11.3	20	97.7 ± 7.9	40
Se	97.1 ± 9.7	40	---	---
Sr	103.7 ± 3.5	24	96.9 ± 6.2	24
Tl	96.1 ± 7.0	20	94.9 ± 7.0	40
V	99.6 ± 4.5	40	---	---
Zn	110.9 ± 9.3	40	106.8 ± 11.5	40

*Laboratory Matrix Spike

We monitored the reported detection limit on each sample to ensure that contract requirements and program DQOs were being consistently met. These results are summarized in Table 4-4. The analytical laboratory met all detection limit requirements that were contained in the original SOW. In general, ICPMS proved to be the more sensitive analytical procedure for many elements that it was able to readily measure: Ag, Ce, Co, Cr, Nd, Ni, Pb, Sb, Tl, and Zn. Interestingly, ICPES proved to have modestly superior sensitivity for Ba, Cd, Cu, Mn, and Sr.

We also compared results for a number of elements measured by both analytical methods throughout the whole sampling program. This comparison is shown in Table 4-5, was calculated as the individual ratios of ICPES data to ICPMS data, and then reported as the mean and standard deviation of these individual ratios by element. For most elements the methods delivered very comparable data.

Table 4-4. Detection Limit Summary for Inorganics for 2001–2002

Element	ICPES Mean (ng/sample)	ICPES Measurements	ICPMS Mean (ng/sample)	ICPMS Measurements
Ag	24	156	6.5	276
As	75	276	---	---
Ba	21	276	19	276
Be	5.2	276	---	---
Cd	5.0	156	8.4	276
Ce	107	148	7.4	148
Co	65	156	7.1	276
Cr	35	276	20	156
Cu	33	276	44	156
Fe	106	166	---	---
Mn	5.0	184	18	184
Nd	48	142	7.4	148
Ni	45	156	11	276
Pb	29	156	6.6	276
Sb	25	156	10	276
Se	138	276	---	---
Sr	5.2	184	9.6	184
Tl	57	157	6.3	276
V	17	276	---	---
Zn	93	276	28	276

4.5.4 Analytical Laboratory Assessments

MAQ conducted formal supplier assessments at each external laboratory performing chemical analyses reported for NonRadNET samples. All of these analytical laboratories also participated in national performance evaluation studies during 2001–2002. The detailed results of these performance evaluations are included in each assessment report [Gladney2001, Morgan, and Gladney2003]. Overall the analytical laboratories that participated in these national studies were judged by the study sponsors to have acceptable performance for almost all analytes attempted in all matrices.

Table 4-5. Comparison of ICPES and ICPMS Concentration Results

Element	ICPES/ICPMS Ratio (Mean \pm Std Dev)	Measurements
Ag	2.7 \pm 0.8	44
Ba	1.03 \pm 0.07	110
Cd	1.6 \pm 0.7	33
Ce	1.02 \pm 0.07	54
Co	0.95 \pm 0.09	49
Cr	0.80 \pm 0.12	50
Cu	1.09 \pm 0.08	50
Mn	0.99 \pm 0.11	72
Nd	0.94 \pm 0.15	51
Ni	1.01 \pm 0.07	50
Pb	0.99 \pm 0.04	50
Sb	1.3 \pm 0.3	47
Sr	1.02 \pm 0.08	72
Tl	2.1 \pm 2.2	10
Zn	1.06 \pm 0.09	110

4.5.5 Data Rejection

Inconsistencies in blanks for a few elements (primarily Ag, Cr, Fe, and Ni) ultimately caused the rejection of some of these analytical data. In the cases where the matrix blank for an individual set of samples was so uncharacteristically high that it caused the blank-corrected net air concentration to become negative, we rejected those values from the determination of ambient conditions during this study period.

Although TSP has been routinely reported since the 1960s throughout the world, it is actually a rather difficult determination to do well. Quality control procedures are not straightforward, since the actual water and VOC content of the filter material and the sampled particles can strongly influence the accuracy of the outcome. Simply performing carefully calibrated weighing of the filter before and after sampling is far from adequate quality control to ensure results of known quality. As a result of our experience with the Dynaweb[®] filter material used during 2001, we ultimately rejected all of those TSP data and changed to Whatman[®] 41 filters to better control our TSP data acquisition. During 2002 we were able to use simultaneous PM₁₀ data as an additional check on the accuracy of our reported TSP, and did eliminate a small number of TSP results due to the TSP weight being much greater than the 24-hour PM₁₀ average at the same station.

4.5.6 Inorganic Uncertainty Study

EPA Methods 6010 and 6020 do not provide for determining and reporting analytical uncertainties for inorganic elemental measurements. We made an effort to provide some basis for estimating these uncertainties by commissioning a reproducibility study for spiked samples using our filter matrices. Five replicate spikes that span the actual sample concentration range observed during this entire study were prepared at seven different concentration levels for each element.

5.0 Origins and Uses of Nonradioactive Species in Ambient Air

As described in Sections 3 and 4 above, NonRadNET measured three broad categories of nonradioactive species:

- 3 particulate matter size ranges
- 20 inorganic elements
- 160 VOCs

This section discusses some of the general origins and, where applicable, typical uses of these ambient airborne species. It also labels the various measured species according to regulatory hazard classes. The intended purpose of this section is to provide some practical insight into this large number of measured species, so that they are not just long lists of strange chemical names but, rather, can better be related to our everyday living, health, and the environment. In fact, such insight will be our purpose in subsequent sections as we compare the measured species with LANL and other airborne emission sources in the area, summarize the measured concentrations of these species, compare their measured concentrations with typical national values, and compare the measured concentrations with exposure standards.

5.1 Particulate Matter

Particulate matter is the term for the small particles of solid or semi-solid material found in the atmosphere. Particulates ranging in size from less than 0.1 micrometer to 50 micrometers are called TSP. Particles larger than that range tend to settle out of the air. Particulate matter 10 micrometers in diameter and smaller can be inhaled. This particulate matter is commonly called PM₁₀.

Particles larger than 10 micrometers are usually due to fugitive dust from activities such as sand and dirt blown by winds from roadways, fields, and construction sites. This naturally occurring fugitive dust contains large amounts of silica (sand like) materials. The majority of anthropogenic (human-made) particles are in the 0.1 to 10 micrometer diameter range. These particles are generally created during a burning process and include fly ash from power plants, carbon black from automobiles and diesel engines, and soot from fire places and wood stoves. PM₁₀ particles are typically attributable to both anthropogenic and natural sources. The PM₁₀ particles from these sources contain a large percentage of elemental and organic carbon, which play a major role in the formation of haze and contribute to adverse health effects.

Fine particles with diameters less than 2.5 micrometers are known as PM_{2.5}. These fine particles are primarily from combustion processes as well as particles that are formed in the atmosphere from condensation, chemical reaction, or decay of gases and vapors. Generally, they pose a greater health risk because they can deposit deep in the lungs and contain chemicals that are particularly harmful to health. In addition to health impacts, these fine particles tend to stay in the atmosphere for longer periods of time and are the main contributors to regional haze and reduced visibility.

The NonRadNET program included sampling for TSP, PM₁₀, and PM_{2.5}.

5.2 Inorganic Elements

NonRadNET measured 20 elements (as various inorganic compounds). These elements are shown in Table 5-1. EPA classifies 10 of these elements and their compounds as Hazardous Air Pollutants (HAPs) [EPA-HAP]. Those 10 inorganic HAPs include the pure elements and compounds of

- antimony
- arsenic
- beryllium
- cadmium
- chromium
- cobalt
- lead
- manganese
- nickel
- selenium

All 20 of the monitored elements occur naturally in the earth's crust, and most can be easily detected anywhere in the world. Besides occurring naturally in the ground and air, they are also used in a wide variety of human-made products and processes. Manufacturing and using these products can enhance the presence of these elements in air. Mining the ores of these elements and natural weathering of ore-bearing rock also contribute to airborne emissions of these elements. Table 5-1 provides a summary of some of the human-made sources and uses of these elemental materials. In addition to the uses listed below, trace amounts of arsenic, chromium, manganese, nickel, and lead may be present in vehicle exhausts.

This information was extracted from web sites of the Agency for Toxic Substances and Disease Registry (ATSDR) [ATSDR-TPIS], EPA [EPA-HENHAP], and the WebElements Periodic Table [Winter]. See those web sites for more technical information on these elements, their natural and human-made emission sources, and health effects.

5.3 Volatile Organic Compounds

NonRadNET monitored the ambient air for approximately 160 VOCs. For complete alphabetical and CAS-ordered lists of these VOCs, see Appendix A. Because of the large number of VOCs involved, it is helpful to divide them into manageable groups by source and use. We have chosen to group the VOCs by the following source/use categories:

- Naturally occurring materials
- Mobile fuel and exhaust combustion products
- Tobacco combustion products
- Refrigerants
- Solvents
- Miscellaneous VOCs

Table 5-1. Human-Made Sources/Uses of NonRadNET Inorganic Elements

Name	Symbol	Human-Made Uses*
Antimony	Sb	Metal hardening processes, lead-acid batteries, fire retardant
Arsenic	As	Pressure treated lumber (90% of all use), copper/lead smelting, pesticides
Barium	Ba	Oil/gas drilling, paint, brick/ceramic/tile, rubber, medical procedures
Beryllium	Be	Metal alloys (electrical, cars, golf clubs), nuclear weapons, mirrors, fuels
Cadmium	Cd	Batteries, pigments, metal coatings, byproduct of zinc/lead/copper smelting
Cerium	Ce	Metal alloys, gas lantern mantles, self-cleaning oven surfaces, diesel
Chromium	Cr	Steel alloy, electroplating, dyes, leather/wood preservation, copy machine toner
Cobalt	Co	Metal alloys (grinding tools, artificial joints), vitamin B12, colorant
Copper	Cu	Coins, wiring, water pipe, wood preservative, leather, fabrics, colorant
Iron	Fe	Most commonly used metal
Lead	Pb	Mostly in lead-acid batteries and ammunition, no longer in gasoline/paint
Manganese	Mn	Metal alloys, batteries, matches, fireworks, gasoline, diesel, pesticides
Neodymium	Nd	Metal alloys, magnets, and as a colorant in glass and paint
Nickel	Ni	Electroplating, batteries, coins, stainless steel, high-resistance wire, spark plugs
Selenium	Se	Burning coal, dandruff shampoo, animal food additive, gun bluing
Silver	Ag	Photographic film and processing, coins, jewelry, flatware, medicine/dentistry
Strontium	Sr	Colorant in fireworks, color television tubes, zinc refining
Thallium	Tl	Burning coal, cement factories, smelting, cigarettes, electronics, medical
Vanadium	V	Burning coal/fuel oil, steel making
Zinc	Zn	Metal corrosion inhibitor, coins, paint, rubber, sun block, deodorant, shampoo

*Additionally, all occur naturally in the ground and in ambient air.

Some VOCs will appear in more than one group. However, no attempt has been made to *exhaustively* determine all origins or uses of all species. Instead, the information is intended to provide a general perspective of the more common uses and sources of these materials.

Besides grouping the compounds by origin and uses, those that are classified as one or more of the following hazard categories are also identified:

- EPA 188 HAPs [EPA-HAP],
- 33 National Air Toxics Assessment (NATA) Pollutants (a subset of HAPs) [EPA-NATA],
- Photochemical Assessment Monitoring Station (PAMS) pollutants [EPA-PAMS]

5.3.1 Naturally Occurring Components

Of the approximately 160 VOCs monitored at LANL, 30 are known to exist naturally. These naturally occurring VOCs are identified and discussed at web sites of the ATSDR [ATSDR-TPIS], EPA [EPA-HENHAP], and California Air Resources Board [CARB]. Furthermore, a large fraction of the technical information in this entire Section 5.3 comes from these same three references. To be listed in this “naturally occurring” group, the VOC must be generated by one of the following (or closely related) processes:

- Living plant or animal biological activities

- Biomass decomposition
- Ocean/geochemistry
- Forest fires
- Volcanoes

We decided that compounds existing naturally, *only* as a component of crude oil or natural gas, would **not** be considered here to be “naturally occurring,” although, technically, they are. Table 5-2 lists those NonRadNET VOCs that are classed as “natural.”

We do not intend to discuss every one of these naturally occurring VOCs in any detail. However, it is useful to group some of them into their common natural sources. For example some **plants, foods, and fruits** contain and may, at some point, emit

Benzaldehyde	beta-pinene
4-methyl-2-pentanone	acetone
cyclohexane	chloroform
n-nonane	ethylene
limonene	acetaldehyde
ethanol	isoprene
alpha-pinene	isopropylbenzene

Many of these VOCs are also biomass fermentation and decomposition products.

Forest fires and/or volcanoes emit

1,3 butadiene	acetone
mixed xylenes	benzene
toluene	methyl chloride
cyclohexane	methyl ethyl ketone
ethanol	naphthalene
methanol	

Marine organisms and ocean chemistry emit

ethylene dibromide
bromomethane
methyl chloride (about 99% natural)
bromoform (Marine algae is a major source.)

Ethanol (grain alcohol) is one of the most commonly detected natural VOCs in the air. In this study, it was detected at the *highest* average concentration ($23 \mu\text{g}/\text{m}^3$) of any of the 160 VOCs. Other natural VOCs (acetaldehyde, acetone, and methanol) are closely associated with natural ethanol chemistry and also were detected by NonRadNET at average levels in the range of 8 to $12 \mu\text{g}/\text{m}^3$. The other naturally occurring VOCs above are typically detected at average levels of $1 \mu\text{g}/\text{m}^3$ or less. (See Section 7 for a detailed listing of average NonRadNET concentrations.)

Many of these naturally occurring VOCs are also included and discussed in the other classifications in the following subsections.

Table 5-2. NonRadNET Naturally Occurring VOCs

CAS #	Name	HAPs*	33 [#]	PAMS [†]
100-52-7	Benzaldehyde			
106-42-3	p-Xylene	X		X
106-93-4	Ethylene Dibromide (1,2-Dibromoethane)	X	X	
106-99-0	1,3-Butadiene	X	X	
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)	X		
108-38-3	m-Xylene	X		X
108-88-3	Toluene	X		X
110-82-7	Cyclohexane			X
111-84-2	n-Nonane			X
123-72-8	Butyraldehyde			
127-91-3	beta-Pinene			
138-86-3	Limonene			
64-17-5	Ethanol (Ethyl Alcohol)			
67-56-1	Methanol (Methyl alcohol)	X		
67-64-1	Acetone (2-Propanone)			X
67-66-3	Chloroform	X	X	
71-36-3	1-Butanol			
71-43-2	Benzene	X	X	X
74-83-9	Bromomethane (Methyl Bromide)	X		
74-85-1	Ethylene			X
74-87-3	Freon 40 Chloromethane (Methyl Chloride)	X		
75-05-8	Acetonitrile	X		
75-07-0	Acetaldehyde	X	X	X
75-25-2	Bromoform	X		
78-79-5	Isoprene			X
78-93-3	2-Butanone (Methyl Ethyl Ketone)	X		
80-56-8	alpha-Pinene			
91-20-3	Naphthalene	X	X	
95-47-6	o-Xylene	X		X
98-82-8	Isopropylbenzene (Cumene)	X		X

*HAPs—EPA Hazardous Air Pollutant

[#]33—NATA 33 Monitored Pollutants

[†]PAMS—Photochemical Assessment Monitoring Station Pollutant

5.3.2 Mobile Fuel and Exhaust Components

Gasoline and diesel fuels are, by far, the most used fuels in automobiles and trucks. Jet aircraft use kerosene and other jet fuels (JP-4, JP-8). Of the approximately 160 VOCs monitored at LANL, over 80 are either a component of these fuels, found in the exhaust of these fuels, or found in both the fuel and the exhaust. Table 5-3 provides a list of these VOCs and identifies whether they come from vehicle fuels, their exhaust, or both. Seventeen of these fuel/exhaust components are also naturally occurring. However, for some of these VOCs (given in the bulleted list below), the EPA [EPA2000] estimates that the majority, or a large fraction of the ambient airborne concentrations, are from vehicle emissions.

- ethyl benzene
- styrene
- m, p, o xylene
- 1,3 butadiene
- toluene
- hexane
- methyl tert butyl ether
- benzene
- acetaldehyde

The last column in Table 5-3 gives the EPA estimated percentage of total airborne emissions for these large vehicle fuel emissions.

Table 5-3. NonRadNET Mobile Fuel and Exhaust Components

CAS #	Name	HAPs *	33 [#]	PAMS ⁺	Fuel	Exhaust	% Mobile Emissions
100-41-4	Ethyl Benzene	X		X	X	X	84
100-42-5	Styrene	X		X		X	40
103-65-1	n-Propylbenzene			X	X	X	
104-51-8	n-Butylbenzene				X		
105-05-5	1,4-Diethylbenzene (p-Diethylbenzene)			X	X		
106-42-3	p-Xylene	X		X	X	X	79
106-93-4	Ethylene Dibromide (1,2-Dibromoethane)	X	X		X		
106-97-8	Butane			X	X		
106-99-0	1,3-Butadiene	X	X			X	60
107-06-2	1, 2-Dichloroethane (Ethylene Dichloride)	X			X		
107-13-1	Acrylonitrile	X	X			X	
107-83-5	Isohexane (2-Methylpentane)			X	X		
108-08-7	2,4-Dimethylpentane			X	X		
108-38-3	m-Xylene	X		X	X	X	79
108-67-8	1,3,5-Trimethylbenzene			X	X		
108-87-2	Methylcyclohexane			X	X		
108-88-3	Toluene	X		X	X	X	74
109-66-0	Pentane			X	X		
109-67-1	1-Pentene			X	X		
110-54-3	Hexane	X		X	X	X	44
110-82-7	Cyclohexane			X	X		
110-83-8	Cyclohexene				X		
111-65-9	n-Octane			X	X		
111-84-2	n-Nonane			X	X		
1120-21-4	n-Undecane			X	X		
124-18-5	n-Decane			X	X		
141-93-5	1,3-Diethylbenzene (m-Diethylbenzene)			X	X		
142-29-0	Cyclopentene				X		
142-82-5	Heptane			X	X		

*HAPs—EPA Hazardous Air Pollutant

[#]33—NATA 33 Monitored Pollutants

⁺PAMS—Photochemical Assessment Monitoring Station Pollutant

Table 5-3 (cont.)

CAS #	Name	HAPs *	33 [#]	PAMS [†]	Fuel	Exhaust	% Mobile Emissions
14686-13-6	trans-2-Heptene				X		
1634-04-4	Methyl tert-Butyl Ether	X			X	X	86
287-92-3	Cyclopentane			X	X		
31394-54-4	Isoheptane (2-Methylhexane)			X	X		
3522-94-9	2,2,5-Trimethylhexane				X		
4050-45-7	trans-2-Hexene				X		
463-82-1	Neopentane				X		
496-11-7	Indan				X		
513-35-9	2-Methyl-2-butene				X		
526-73-8	1,2,3-Trimethylbenzene			X	X		
538-93-2	Isobutylbenzene				X		
540-84-1	2,2,4-Trimethylpentane (Isooctane)	X		X	X	X	
563-45-1	3-Methyl-1-butene				X		
564-02-3	2,2,3-Trimethylpentane				X		
565-59-3	2,3-Dimethylpentane			X	X		
565-75-3	2,3,4-Trimethylpentane			X	X		
589-34-4	3-Methylhexane			X	X		
589-81-1	3-Methylheptane			X	X		
590-18-1	cis-2-Butene			X	X		
592-27-8	2-Methylheptane			X	X		
592-41-6	1-Hexene				X		
611-14-3	2-Ethyltoluene (o-Ethyltoluene)			X	X		
620-14-4	3-Ethyltoluene (m-Ethyltoluene)			X	X		
622-96-8	4-Ethyltoluene (p-Ethyltoluene)			X	X		
624-64-6	trans-2-Butene			X	X		
625-27-4	2-Methyl-2-pentene				X		
627-20-3	cis-2-Pentene			X	X		
64-17-5	Ethanol (Ethyl alcohol)				X		
646-04-8	trans-2-Pentene			X	X		
67-56-1	Methanol (Methyl alcohol)	X			X		
67-63-0	2-Propanol (Isopropyl Alcohol)				X		
67-64-1	Acetone (2-Propanone)			X		X	
71-43-2	Benzene	X	X	X	X	X	76
74-98-6	Propane			X	X		
75-05-8	Acetonitrile	X				X	
75-07-0	Acetaldehyde	X	X	X		X	70
75-28-5	Isobutane			X	X		
75-34-3	1,1-Dichloroethane (Ethylidene Dichloride)	X			X		
75-83-2	2,2-Dimethylbutane (Neohexane)			X	X		
760-21-4	2-Ethyl-1-butene				X		
763-29-1	2-Methyl-1-pentene			X	X		
7642-09-3	cis-3-Hexene				X		

*HAPs—EPA Hazardous Air Pollutant

[#]33—NATA 33 Monitored Pollutants

[†]PAMS—Photochemical Assessment Monitoring Station Pollutant

Table 5-3 (cont.)

CAS #	Name	HAPs *	33 [#]	PAMS ⁺	Fuel	Exhaust	% Mobile Emissions
7642-10-6	cis-3-Heptene				X		
7688-21-3	cis-2-Hexene				X		
78-78-4	2-Methylbutane (Isopentane)			X	X		
78-79-5	Isoprene			X	X		
78-93-3	2-Butanone (methyl Ethyl Ketone)	X				X	
79-29-8	2,3-Dimethylbutane			X	X		
91-20-3	Naphthalene	X	X		X	X	
95-47-6	o-Xylene	X		X	X	X	79
95-63-6	1,2,4-Trimethylbenzene			X	X		
96-14-0	3-Methylpentane			X	X		
96-37-7	Methylcyclopentane			X	X		
98-82-8	Isopropylbenzene (Cumene)	X		X	X	X	

*HAPs—EPA Hazardous Air Pollutant

[#]33—NATA 33 Monitored Pollutants⁺PAMS—Photochemical Assessment Monitoring Station Pollutant

5.3.3 Tobacco Smoke Products

Because of its wide prevalence and obvious health effects, we evaluated which of the monitored VOCs are contained in tobacco smoke. Table 5-4 shows these components. All of these tobacco-smoke products, except butyraldehyde, vinyl chloride, and isoprene are also contained in vehicle exhaust. Also, all of these tobacco smoke components occur naturally, except ethyl benzene, styrene, acrylonitrile, and vinyl chloride. According to the ATSDR, even though mobile sources contribute about 76% of the ambient airborne benzene *concentration*, about half of the national population airborne *exposure* to benzene comes from tobacco smoke [ATSDR-PHSB].

Table 5-4. NonRadNET VOCs in Tobacco Smoke

CAS	Name	HAPs *	33 [#]	PAMS ⁺
100-41-4	Ethyl Benzene	X		X
100-42-5	Styrene	X		X
106-99-0	1,3-Butadiene	X	X	
107-13-1	Acrylonitrile	X	X	
108-88-3	Toluene	X		X
123-72-8	Butyraldehyde			
67-64-1	Acetone (2-Propanone)			X
71-43-2	Benzene	X	X	X
75-01-4	Vinyl Chloride	X	X	
75-05-8	Acetonitrile	X		
75-07-0	Acetaldehyde	X	X	X
78-79-5	Isoprene			X
78-93-3	2-Butanone (Methyl Ethyl Ketone)	X		
91-20-3	Naphthalene	X	X	
98-82-8	Isopropylbenzene (Cumene)	X		X

*HAPs—EPA Hazardous Air Pollutant; [#]33—NATA 33 Monitored Pollutants; ⁺PAMS—Photochemical Assessment Monitoring Station Pollutant

5.3.4 Refrigerants

The NonRadNET VOCs in Table 5-5 are or have, until recently, been used as refrigerants. Note that bromomethane and methyl chloride also occur naturally.

Table 5-5. NonRadNET Refrigerants

CAS	Name	HAPs*	33 [#]	PAMS ⁺
106-97-8	Butane			X
124-48-1	Dibromochloromethane			
156-59-2	cis-1,2 Dichloroethene			
156-60-5	trans-1,2-Dichloroethene			
56-23-5	Carbon Tetrachloride	X	X	
71-55-6	1,1,1-Trichloroethane (Methyl Chloroform)	X		
74-83-9	Bromomethane (Methyl Bromide)	X		
74-87-3	Freon 40 Chloromethane (Methyl Chloride)	X		
75-00-3	Chloroethane (Ethyl Chloride) Freon 160	X		
75-01-4	Vinyl Chloride	X	X	
75-28-5	Isobutane			X
75-43-4	Freon 21 (Dichlorofluoromethane)			
75-45-6	Freon 22 (Chlorodifluoromethane)			
75-69-4	Freon 11 (Trichlorofluoromethane)			
75-71-8	Freon 12 (Dichlorodifluoromethane)			
76-13-1	Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)			
76-14-2	Freon 114 (1,2-Dichlorotetrafluoroethane)			
79-01-6	Trichloroethene (Trichloroethylene)	X		
811-97-2	Halocarbon 134A			

*HAPs—EPA Hazardous Air Pollutant; [#]33—NATA 33 Monitored Pollutants; ⁺PAMS—Photochemical Assessment Monitoring Station Pollutant

5.3.5 Solvents

Many of the components of fuels and some refrigerants are also solvents. The NonRadNET VOCs in Table 5-6 are NonRadNET solvents **not** found in the fuels and refrigerants tables above. Note that benzaldehyde, methyl isobutyl ketone, butyraldehyde, chloroform, and 1-butanol also occur naturally.

5.3.6 Miscellaneous VOCs

Some of the NonRadNET VOCs do not fit into any category above. Those VOCs are in Table 5-7. Note that, after significant research, we were unable to find any source or use information on several of these miscellaneous VOCs.

For more technical information on VOCs, their natural and human-made emission sources, and health effects, see the chemical profiles at the web sites of the ATSDR [ATSDR-TPIS], EPA [EPA-HENHAP], and California Air Resources Board [CARB].

Table 5-6. NonRadNET Solvents

CAS	Name	HAPs*	33 [#]	PAMS ⁺
100-52-7	Benzaldehyde			
106-43-4	4-Chlorotoluene			
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)	X		
108-41-8	3-Chlorotoluene			
108-90-7	Chlorobenzene	X		
120-82-1	1,2,4-Trichlorobenzene	X		
123-72-8	Butyraldehyde			
123-91-1	1,4-Dioxane (1,4-Diethyloxy)	X		
127-18-4	Tetrachloroethene/ethylene (Perchloroethylene/hylene)	X	X	
60-29-7	Diethyl ether			
67-66-3	Chloroform	X	X	
71-36-3	1-Butanol			
75-09-2	Methylene Chloride (Dichloromethane)	X	X	
75-27-4	Bromodichloromethane			
78-87-5	1,2-Dichloropropane (Propylene Dichloride)	X	X	
79-00-5	1,1,2-Trichloroethane	X		
79-34-5	1,1,2,2-Tetrachloroethane	X	X	
87-68-3	Hexachlorobutadiene	X		
95-50-1	1,2-Dichlorobenzene			

*HAPs—EPA Hazardous Air Pollutant; [#]33—NATA 33 Monitored Pollutants; ⁺PAMS—Photochemical Assessment Monitoring Station Pollutant

Table 5-7. Miscellaneous NonRadNET VOCs

CAS #	Name	HAPs*	33#	PAMS [†]	Uses
100-44-7	Chlorotoluene (Benzyl Chloride)	X			Perfumes, dyes, flavorings, chemical synthesis
10061-01-5	cis-1,3-Dichloropropene				Soil fumigant
10061-02-6	trans-1,3-Dichloropropene				Soil fumigant for nematodes
106-46-7	1,4-Dichlorobenzene	X			Insecticide/fumigant, dye, moths, deodorant
106-98-9	1-Butene			X	Organic manufacture
107-39-1	2,4,4-Trimethyl-1-pentene				
107-40-4	2,4,4-Trimethyl-2-pentene				
108-05-4	Vinyl Acetate	X			Plastics, chewing gum, hair spray
111-66-0	1-Octene				
111-71-7	Heptanal				Perfumes, flavorings, drugs
115-07-1	Propylene			X	Plastic and organic manufacturing
124-11-8	1-Nonene				
126-99-8	2-Chloro-1,3-butadiene (Chloroprene)	X			Rubber (neoprene) manufacture, food package adhesives
141-32-2	Butyl Acrylate				Manufacture of polymers and resins
14686-14-7	trans-3-Heptene				
2198-23-4	4-Nonene				
541-73-1	1,3-Dichlorobenzene				Fumigant and insecticide
591-49-1	1-Methylcyclohexene				
592-13-2	2,5-Dimethylhexane				
592-76-7	1-Heptene				
593-60-2	Vinyl bromide	X			Mostly a flame retardant
66-25-1	Hexanal				Flame-retarding treatment for acrylics
691-37-2	4-Methyl-1-pentene				
691-38-3	cis/trans-4-Methyl-2-pentene				
693-89-0	1-Methylcyclopentene				
71-23-8	1-Propanol				Flame retardant for plastics and synthetic fibers
74-86-2	Acetylene			X	Welding gas
74-97-5	Bromochloromethane				Chemical intermediate, fire extinguishing
75-35-4	1,1-Dichloroethene (Vinylidene Chloride)	X			Used in synthetic fiber manufacture, organic synthesis, and in making plastic food wraps
7642-04-8	cis-2-Octene				
821-95-4	1-Undecene				
872-05-9	1-Decene				
922-62-3	cis-3-Methyl-2-pentene				
95-13-6	Indene				Plastic resin manufacturing
95-49-8	2-Chlorotoluene				
98-06-6	tert-Butylbenzene				
99-87-6	4-Isopropyltoluene (p-Cymene)				

*HAPs—EPA Hazardous Air Pollutant; #33—NATA 33 Monitored Pollutants; †PAMS—Photochemical Assessment Monitoring Station Pollutant

6.0 Comparison with LANL and Other Emission Sources

This section provides an overview of the particulate matter, inorganic elements, and NonRadNET VOCs emitted by various sources in the Los Alamos area, particularly the Laboratory. No attempt has been made to fully inventory all possible sources of these materials. However, the Laboratory is required to document its use and emissions of many of the monitored species. Thus, very good emissions information, much better than for other local sources, is available for LANL.

Los Alamos has both rural and metropolitan characteristics. While the town is remote from large commercial, industrialized areas and small by national standards, traffic into and out of the town each day is relatively significant. Additionally, there are a number of commercial refueling stations, businesses of various types, large numbers of residences, and, of course, the Laboratory.

Our focus in this section is on emissions at the Laboratory related to this study, but we also consider **non**-Laboratory sources of such emissions. It is instructive to note that LANL is one of over 200 “major stationary sources” in New Mexico, as defined by EPA [EPA-TVPIS]. Furthermore, New Mexico has one of the lowest annual regulated airborne emissions rates of any state in the entire country [EPA-TRI].

The primary resources for determining Laboratory emissions of the 188 EPA HAPs during 2001 and 2002 were the Emissions Inventory Reports for those years [LANL2003a, LANL2003b]. For those chemicals that are not classified as HAPs, we used the 2001 and 2002 Toxic Chemicals Release Inventory Reports (also known as the Emergency Planning and Community Right-to-Know Act [EPCRA] Reports) [LANL2001, LANL2002b]. As a cross check and for those chemicals that did not fall within the criteria of the above references, we used the Laboratory Automated Chemical Inventory System (ACIS) database, which typically has about 40,000 entries of purchased chemicals each year.

6.1 Particulate Emissions

As stated in Section 5, significant contributors to airborne particulate matter in the air around Los Alamos include Laboratory operations, private and commercial vehicle traffic, residential fireplaces, natural wind-blown dust, plant pollens and other normal plant particulate emissions, forest fires, and, likely, other sources. The LANL Emissions Inventory Reports [LANL2003a, LANL2003b] state that LANL emitted 5.5 tons of *total* particulate matter in 2001 and 15.42 tons in 2002. Smaller quantities of PM₁₀ and PM_{2.5} were emitted. In 2001 most of these Laboratory particulate emissions came from the Technical Area (TA) 3 steam power plant with secondary amounts from air curtain destructors used to burn wood and brush thinned from the nearby forests for fire mitigation. In 2002 the air curtain destructors contributed most of the airborne particulate emissions with secondary amounts from the TA-3 steam plant. In each case, there were also other smaller Laboratory particulate sources.

By comparison, PM₁₀ from commuter traffic in Los Alamos County is in the range of approximately 21 tons each year. (See Appendix B for the details of this estimate.) Residential fireplaces in the area also contribute substantially to airborne particles, in the range of 29 tons/yr (Appendix B). Additionally, an unquantified, but very likely, large amount of natural wind-blown dust is emitted into the air. Regional forest fires are another obviously significant, although unquantified, source of

airborne particles. All of these particulate sources and, no doubt, many others contribute to the airborne particulate load in the Los Alamos area. Because of the relatively small Laboratory particulate emissions, compared to all others, it would **not** be likely that LANL particulate emissions could easily be distinguished from other regional particulate emissions, except, perhaps, if a sampler were located very close to and downwind of a large Laboratory particulate source, such as the air curtain destructors.

6.2 Inorganic Elements

All of the 20 inorganic elements NonRadNET measured are present naturally in wind-blown dust. Some also occur in vehicle emissions and other combustion processes, especially coal burning, which is **not** a large source in the immediate area. In 2001 and 2002 [LANL2003a, LANL2003b], the Laboratory reported emissions of HAPs inorganic elements that were included in the NonRadNET program as shown in Table 6-1. The more significant chemicals (by weight) are shaded in the table. Note that these emissions are conservative estimates of actual emissions. In many cases, for **conservative** HAPs reporting, it was *assumed* that the entire inventories of these HAPs materials purchased each year were emitted in the year purchased.

Table 6-1. NonRadNET HAPs Inorganic Elements Used at LANL

Element	Symbol	2001 Usage (tons)	2002 Usage (tons)
Antimony	Sb	0.0	0.0015
Arsenic	As	0.002	0.003
Beryllium	Be	9.6 E-6	0.0003
Cadmium	Cd	0.003	0.0007
Chromium	Cr	0.056	0.021
Cobalt	Co	0.001	0.003
Manganese	Mn	0.275	0.844
Nickel	Ni	0.002	0.038
Lead	Pb	0.006	0.01
Selenium	Se	0.0	0.0004

The following inorganic elements are **not** classed as HAPs and, thus, were not reported in the emissions reports. However, if used, they were reported in the LANL ACIS databases or the EPCRA Reports for 2001 and 2002 [LANL2001, LANL2002b] in the quantities stated in Table 6-2. The more significant uses of these chemicals (by weight) are shaded in the table.

Table 6-2. Other NonRadNET Inorganic Elemental Chemicals Used at LANL

Element	Symbol	2001 EPCRA (tons)	2002 EPCRA (tons)
Barium	Ba	1.1	0.002
Cerium	Ce	0.002	0.003
Copper	Cu	0.27	0.08
Iron	Fe	0.012	0.006
Neodymium	Nd	0.002	0.0
Silver	Ag	0.016	0.023
Strontium	Sr	0.001	0.0
Thallium	Tl	0.0015	0.0
Vanadium	V	0.0005	<0.0005
Zinc	Zn	0.62	0.93

6.3 VOCs

Reporting of HAPs VOC emissions at the Laboratory is also done conservatively. That is, conservative emission factors are used to estimate emissions from larger operations and facilities such as the steam plants and air curtain destructors. Emissions from laboratories and similar smaller-scale operations are typically conservatively estimated by assuming the entire quantity of chemicals purchased during the year is emitted. LANL emitted approximately 19 tons of total VOCs in 2001 [LANL2003a] and 15 tons in 2002 [LANL2003b].

Of the 46 NonRadNET HAPs VOCs, 41 are specifically used at LANL [LANL2003a, LANL2003b]. Table 6-3 lists those LANL HAPs VOCs and their conservatively estimated emissions, in tons, for 2001 and 2002. The more significant emissions (by weight) are shaded in the table.

Table 6-3. NonRadNET HAPs VOC Chemicals Used at LANL

CAS #	Name	2001 (tons)	2002 (tons)
100-41-4	Ethyl Benzene	0.02	0.018
100-42-5	Styrene	0.007	0.101
100-44-7	Chlorotoluene (Benzyl Chloride)	0	0
106-42-3	p-Xylene*	0	0.001
106-46-7	1,4-Dichlorobenzene	0	0.0005
106-93-4	Ethylene Dibromide (1,2-Dibromoethane)	0	0.0005
106-99-0	1,3-Butadiene	0	0.0001
107-06-2	1, 2-Dichloroethane (Ethylene Dichloride)	0.017	0.077
107-13-1	Acrylonitrile	0	0.0005
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)	0.003	0
108-38-3	m-Xylene*	0.001	0.0002
108-88-3	Toluene	0.34	0.281
108-90-7	Chlorobenzene	0.025	0.018
110-54-3	Hexane	0.398	1.03
120-82-1	1,2,4-Trichlorobenzene	0	0.0002
123-91-1	1,4-Dioxane (1,4-Diethyloxyde)	0.087	0.092
127-18-4	Tetrachloroethene (Perchloroethylene, Tetrachloroethylene)	0	0.016
1634-04-4	Methyl tert-Butyl Ether	0.004	0
540-84-1	2,2,4-Trimethylpentane (Isooctane)	0.234	0.188
56-23-5	Carbon Tetrachloride	0.012	0.008
67-56-1	Methanol (Methyl alcohol)	0.91	0.854
67-66-3	Chloroform	0.094	0.204
71-43-2	Benzene	0.012	0.234
71-55-6	1,1,1-Trichloroethane (Methyl Chloroform)	0.031	0.003
74-83-9	Bromomethane (Methyl Bromide)	0	0.0008
74-85-1	Ethylene	0.009	0.009
74-87-3	Freon 40 Chloromethane (Methyl Chloride)	0.116	0.015
75-01-4	Vinyl Chloride	0	0.001
75-05-8	Acetonitrile	0.66	0.954

Table 6-3 (cont.)

CAS	Name	2001 (tons)	2002 (tons)
75-07-0	Acetaldehyde	0	0.047
75-09-2	Methylene Chloride (Dichloromethane)	0.436	1.45
75-25-2	Bromoform	0	0
75-34-3	1,1-Dichloroethane (Ethylidene Dichloride)	0	0.000001
75-35-4	1,1-Dichloroethene (Vinylidene Chloride)	0	0.0000006
78-87-5	1,2-Dichloropropane (Propylene Dichloride)	0	0.002
78-93-3	2-Butanone (Methyl Ethyl Ketone)	0.297	0.166
79-00-5	1,1,2-Trichloroethane	0.002	0.0006
79-01-6	Trichloroethene (Trichloroethylene)	0.51	0.025
91-20-3	Naphthalene	0	0.0006
95-47-6	o-Xylene*	0.004	0.006
95-63-6	1,2,4-Trimethylbenzene	0.013	0.013

*Besides specific m,p, and o xylene, LANL also reported emissions of "mixed" xylenes (CAS # 1330-20-7) of 0.069 and 0.064 tons for 2001 and 2002, respectively.

For **non-HAPs** LANL emissions monitored by NonRadNET, the 2001/2002 EPCRA Reports [LANL2001, LANL2002b] and the 2001/2002 ACIS Database were used to estimate emissions. Table 6-4 gives the quantities, in tons, of these NonRadNET VOCs purchased at LANL during 2001 and 2002. They *could* be used as a conservative estimate of the emissions of these materials. The more significant uses (by weight) are shaded in the table.

Table 6-4. Other NonRadNET VOC Chemicals Used at LANL

CAS	Name	2001 (tons)	2002 (tons)
107-39-1	2,4,4-Trimethyl-1-pentene	0.32	0
115-07-1	Propylene	2.4	1.05
60-29-7	Diethyl ether	0.28	0.13
64-17-5	Ethanol (Ethyl alcohol)	1.2	2.05
67-63-0	2-Propanol (Isopropyl Alcohol)	0.41	0.53
67-64-1	Acetone (2-Propanone)	1.26	1.37
74-85-1	Ethylene	0.05	0
74-86-2	Acetylene	0.65	0.89
74-98-6	Propane	36.3	19.8
75-45-6	Freon 22 (Chlorodifluoromethane)	2.54	1.25
75-69-4	Freon 11 (Trichlorofluoromethane)	0.06	0
76-13-1	Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	0.03	0
811-97-2	Halocarbon 134A	0.14	0.04
95-63-6	1,2,4-Trimethylbenzene	0.01	0

It is important to observe that acetylene and propane are not normally emitted unburned. So listing their entire inventories as "emitted" is not reasonable. Instead, a very small fraction of these unburned material inventories would be emitted.

Other sources of VOCs, besides LANL, include evaporative emissions from commercial fueling stations, non-Laboratory vehicles, normal building construction materials, natural sources, private and commercial chemical use, and other sources. To put the LANL VOC emissions into perspective, the annual VOC emissions from commuter traffic in Los Alamos County are roughly 400 tons per year, greatly overshadowing total LANL VOC emissions. Emissions of VOCs from fireplaces in Los Alamos County are approximately 41 tons per year. (See Appendix B for the details of these two estimates.)

Thus, except for “large” emissions of VOCs foreign to vehicle emissions and other combustion sources, LANL contributions to airborne VOC emissions are not likely to be discernable in ambient air. Such nonvehicle and noncombustion emissions at LANL could include those VOCs in Table 6-5. These LANL VOCs were detected in at least 50% of the NonRadNET measurements. The more significant chemicals (by weight) are shaded in the table. See Section 7 for a summary of these measurements.

Table 6-5. Frequently Detected* LANL VOC Chemical Usage Not Found in Vehicle Emissions

CAS	Name	2001-2002 Usage (tons)	% Detection Frequency
107-39-1	2,4,4-Trimethyl-1-pentene	0.32	61
115-07-1	Propylene	3.4	100
56-23-5	Carbon Tetrachloride	0.018	100
67-66-3	Chloroform	0.29	76
71-55-6	1,1,1-Trichloroethane (Methyl Chloroform)	0.033	99
74-85-1	Ethylene	0.05	100
74-83-9	Bromomethane (Methyl Bromide)	8 E-4	62
74-86-2	Acetylene	1.54	100
74-87-3	Freon 40 Chloromethane (Methyl Chloride)	0.14	100
75-09-2	Methylene Chloride (Dichloromethane)	1.9	99
75-45-6	Freon 22 (Chlorodifluoromethane)	3.8	100
75-69-4	Freon 11 (Trichlorofluoromethane)	0.06	100
76-13-1	Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	0.03	100
811-97-2	Halocarbon 134A	0.18	99

*->50% detects

Each of the VOCs in Table 6-5 above is discussed in the following paragraphs, with the intent of trying to determine if sufficient evidence exists to conclude that the NonRadNET results for the VOC are attributable to LANL.

To our knowledge the compound, **2,4,4-trimethyl-1-pentene**, is not commonly used in New Mexico outside of the Laboratory. This compound is **not** classified as a HAP. Although during the two years of interest, LANL purchased and used much less than a ton of this material, we are not aware of any other local sources of this compound. Oddly, it was detected much more frequently in samples taken at the White Rock location than at the other two locations nearer the center of the

Laboratory. However, the average concentration at the Diamond Drive location was higher than the other two locations. Section 8 of this paper compares NonRadNET results to national values, but we were unable to find a national value with which to compare this chemical.

Propylene, which is **not** a HAP, is a very common component of many plastics (e.g., polypropylene). The Laboratory used several tons of propylene during the two years of interest. The average concentration at the Diamond Drive location was two to three times the averages at the other two locations. A comparable national value in Section 8 is higher than the average at Diamond Drive.

Carbon tetrachloride is a HAP. It was historically used as a refrigerant, an aerosol propellant, solvent, grain fumigant, and extensively in dry cleaning. It is primarily used in industrial processes now. The Laboratory used very little, about 36 pounds, during 2001–2002. The average values at all three NonRadNET locations were similar and split the two national values (below one, above the other) given in Section 8.

Chloroform is a HAP. It is used to make some refrigerants but also occurs naturally as a plant volatile. LANL used substantially less than a ton of chloroform during 2001–2002. The three NonRadNET locations measured essentially the same average concentration. That value was significantly less than the national values in Section 8.

1,1,1-Trichloroethane is a HAP. It is used as a solvent/degreaser and is used in home cleaners, glues, aerosols, and similar consumer products. It is a substitute for carbon tetrachloride. The Laboratory used about 66 pounds of the material in 2001–2002. The highest average for the three NonRadNET stations was the same as one national value and about 20 times less than a second national value in Section 8.

Ethylene is **not** a HAP, occurs naturally in plants, and is used as a ripener. LANL used about 100 pounds in 2001–2002. The highest NonRadNET average was at the Diamond Drive location and was just less than half of the national value in Section 8. The other two stations were substantially lower.

Bromomethane is a HAP, occurs naturally in marine organisms, and is used as a fumigant. LANL used less than 10 pounds in 2001–2002. The highest NonRadNET average was at the White Rock location and was less than the national value in Section 8. The other two stations were substantially lower.

Acetylene is **not** a HAP. It is primarily used as welding gas. Although LANL used more than a ton of it during 2001–2002, it was mostly burned with only a small fraction escaping unburned. The average concentrations at Diamond Drive and at the medical center were about five times the White Rock average. The average value measured was less than half of the national value in Section 8.

Chloromethane (Freon 40), although classed as a HAP, is about 99% natural. Therefore, the small LANL emissions of this compound are not likely to be detectable above the natural levels. The comparable national value for Freon 40 in Section 8 is higher than the averages measured by NonRadNET.

Methylene chloride, a HAP, occurs naturally. It is the active ingredient in many paint strippers. It is also used as an aerosol propellant for paint, a fumigant, and a degreener for fruit. LANL used almost 4000 pounds in 2001–2002. However, the largest NonRadNET average was significantly less than the national values in Section 8.

Freon 22 is a non-HAP refrigerant. LANL used about 7600 pounds of it during 2001–2002. It is present in consumer and commercial refrigeration systems. The average value at the medical center was about 3.5 times the average at the other two stations. We do not know if the medical center uses Freon 22 in large quantities, and we do not have any national values with which to compare.

Freon 11, **Freon 113**, and **Halocarbon 134A** are all non-HAP refrigerants. LANL used very little of these materials in 2001–2002. The averages are relatively consistent between NonRadNET sites. We do not have any national values with which to compare them.

7.0 Summary of Ambient Air Measurements

This section summarizes the *quantitative* results of NonRadNET. It includes summary tables of averages and ranges for the entire program. Tables 7-1 through 7-5 summarize the NonRadNET ambient air concentrations for particulate matter, inorganic elements, and VOCs.

7.1 Particulate Matter

Summary results for the three measured particle types: TSP, PM₁₀, and PM_{2.5} are given in Table 7-1.

Table 7-1. Average Concentrations of NonRadNET Particulate Matter

Particle	Measurements*	Range (µg/m ³)	Mean Conc. (µg/m ³)	Std Dev
TSP	77/120	9.7–299.6	52.1	43.6
PM ₁₀	29,711/31,158	0–983.6	18.8	21.6
PM _{2.5}	62,612/66,650	0–92.8	7.9	4.9

*Number of valid (unrejected) measurements/total measurements

The TSP measurements were made for 24 hours once every 12 days as described in subsections 3.3 and 4.1 above. Therefore, the TSP range is expressed as 24-hour averages. The TSP mean concentration is the program-wide (three stations) and program-term (5 quarters) average of those data. The TSP results for the first quarter of data (fourth quarter of 2001) were all rejected as probably invalid. See the 2001 Environmental Surveillance Report for discussion on this issue [LANL2002].

The PM₁₀ and PM_{2.5} measurements were made continuously. The ranges in Table 7-1 are for 30-minute averages. The mean concentrations for PM₁₀ and PM_{2.5} are the program-wide (three stations) and program-term (5 quarters) averages of those data.

7.2 Inorganic Elements

Summary results for the 20 inorganic elemental data are given in Table 7-2. Note that these results are given in **nanograms** per cubic meter (ng/m³) and not in µg/m³. Other concentration units in this paper are normally in µg/m³. HAPs are shown in **bold**, and average concentrations equal to or exceeding 20 ng/m³ are shaded.

In decreasing concentration order, iron, copper, manganese, and barium had the highest average concentrations. The average iron concentration was 16 times higher than the next highest average, copper.

A common interpretive technique for inorganic elements is to calculate elemental ratios to the element measured that has the minimum uncertainty and is not likely to have any source besides resuspended local soil materials. Commonly selected elements used for this comparison purpose include silicon (Si), aluminum (Al), iron (Fe), manganese (Mn), and rare earth elements such as cerium (Ce). These elemental ratios are then compared to corresponding ones taken from chemical analysis of local soils or to average terrestrial crustal abundance data. See the 2001 and 2002

Environmental Surveillance Reports [LANL2002, LANL2003] for an analysis of elemental ratios. The 2002 Environmental Surveillance Report [LANL2003] concludes that there is some evidence for enhancement to the soil background levels for copper, iron, manganese, antimony, and zinc. Possible explanations for these enhancements are given in the 2002 Report.

Table 7-2. Average Concentrations of NonRadNET Inorganic Elements

Element	Symbol	Measurements*	Range (ng/m ³)	Mean Conc. (ng/m ³)	Std Dev
Antimony	Sb	158	0.1–1.4	0.46	0.25
Arsenic	As	107	-0.01–2.15	0.42	0.30
Barium	Ba	238	2.9–110	21	15
Beryllium	Be	117	0.0008–0.51	0.06	0.06
Cadmium	Cd	153	0.004–0.38	0.08	0.05
Cerium	Ce	108	0.20–6.2	2.0	1.3
Chromium	Cr	161	0.10–10	1.9	1.6
Cobalt	Co	162	0.02–1.8	0.33	0.28
Copper	Cu	152	11–235	47	28
Iron	Fe	63	68–2190	760	520
Lead	Pb	154	0.61–16	2.7	2.2
Manganese	Mn	142	2.1–122	21	18
Neodymium	Nd	105	0.08–2.3	0.76	0.51
Nickel	Ni	155	0.14–4.2	1.1	0.8
Selenium	Se	90	0.10–0.84	0.36	0.18
Silver	Ag	160	0.009–1.14	0.10	0.12
Strontium	Sr	144	0.93–41	8.1	6.5
Thallium	Tl	113	0.004–0.11	0.02	0.02
Vanadium	V	112	0.30–12	2.0	1.6
Zinc	Zn	219	5.2–53	19	10

*Number of measurements from all analytical methods.

HAPs are shown in **bold**.

Concentrations over 20 ng/m³ are shaded.

7.3 Volatile Organic Compounds

This subsection summarizes the measurements of the 160 VOCs for 129 combined samples at the three sampling locations. Because so many VOCs were included in our analyses, we have divided the summary results into several groups, based on detection frequency, in an attempt to avoid overwhelming readers with so much data at once.

Table 7-3 provides a summary of those VOCs that were detected above the detection limit in at least 50% of all samples. Referring back to Section 5, note that 72% (62 out of 86) of these *frequently* detected VOCs are components of vehicle fuels or their exhausts. Thirty-eight percent (33) of these 86 VOCs are used at LANL, and 14 of those 33 VOCs used at LANL are **not** fuel related. (See Section 6.) Twenty-one of the 86 VOCs in Table 7-3 also occur naturally. Of those, benzaldehyde, butyraldehyde, and alpha-pinene are primarily natural and are **not** used at LANL in any significant quantity. Entries shown in **bold** are on the EPA list of 188 HAPs.

Ethyl alcohol (ethanol, “grain alcohol”), not a HAP, had the highest average concentration ($23 \mu\text{g}/\text{m}^3$) of any of the 160 measured VOCs. As discussed in Section 5, it has multiple natural and human-made sources and uses: biological decay, fires, volcanoes, vehicle fuels, consumer and industrial solvent use, and other commercial uses. Section 6 shows that LANL used one to two tons of ethyl alcohol each year during 2001–2002, a relatively small quantity.

Other VOC materials used at LANL in near-ton or larger quantities during 2001–2002 included methyl alcohol, acetone, hexane, toluene, propylene, propane, acetonitrile, and Freon 22. Of these LANL larger-use VOCs, only methyl alcohol, acetone, toluene, and propane were detected in greater than $2 \mu\text{g}/\text{m}^3$ quantities. Although not used in significant quantities at LANL, acetaldehyde (primarily natural), butane (refinery/fuel gas), ethane (refinery gas), isobutane (common aerosol propellant), 2-methylbutane, pentane (refinery gas), and Freon 12 (refrigerant) were detected at average levels over $2 \mu\text{g}/\text{m}^3$. All 12 VOCs in Table 7-3 averaging over $2 \mu\text{g}/\text{m}^3$ are shaded.

All other detected VOCs averaged less than $2 \mu\text{g}/\text{m}^3$. If further analysis of the origins, hazard categories, or emission sources of these frequently detected VOCs is of interest, see Sections 5 and 6. Sections 8 and 9 compare these average results with national values and with exposure limits.

Table 7-4 provides a summary of those VOCs that were detected between 10% and 50% of the time in samples. Again, using Section 5 for reference, a significant fraction, 30% (8 of 27), of these *less frequently* detected VOCs are fuel related. Five (19%) of these 27 less frequently detected VOCs are used at LANL, four of which are *not* fuel related. (See Section 6.)

Six of the 27 VOCs in Table 7-4 also occur naturally. Limonene and beta-pinene are almost exclusively natural and are **not** used in any significant quantity at LANL.

Table 7-5 provides a summary of those VOCs that were detected less than 10% of the time in samples. As in the previous discussions, a significant fraction, 27% (13 out of 48), of these *infrequently* detected VOCs, is fuel related. Eleven (23%) of these 48 infrequently detected VOCs are used at LANL, six of which are *not* fuel related. (See Section 6.) Two of the 48 VOCs in Table 7-5 also occur naturally.

Note that in Tables 7-3 through 7-5 only the “detects” were used in the average and standard deviation calculations. *Thus, those calculations for the less frequently detected VOCs are biased, very likely on the high side.* Furthermore, some ranges that contain “less-than” results begin with a value other than a “less-than” result. This condition results when the lowest detected result was actually lower than the “less-than” for other samples in the set.

Table 7-3. Average Concentrations of VOCs Detected in >50% of NonRadNET Samples

CAS #	Name	LANL	Detect %	Range ($\mu\text{g}/\text{m}^3$)	Mean Conc. ($\mu\text{g}/\text{m}^3$)	Std Dev
100-41-4	Ethyl Benzene	X	98.4%	<0.018–1.38	0.35	0.23
100-42-5	Styrene	X	63.6%	0.016–0.23	0.07	0.04
100-52-7	Benzaldehyde		95.3%	0.070–4.58	1.1	0.8
103-65-1	n-Propylbenzene		56.6%	0.042–0.26	0.09	0.04
106-42-3	p-Xylene (including 108-38-3 m-Xylene)	X	100.0%	0.083–4.3	1.1	0.8
106-97-8	Butane		100.0%	0.20–312	12	37
106-98-9	1-Butene		99.2%	<0.015–5.4	0.4	0.5
106-99-0	1,3-Butadiene	X	93.8%	0.009–0.36	0.1	0.06
107-39-1	2,4,4-Trimethyl-1-pentene	X	61.2%	0.015–0.19	0.07	0.03
107-83-5	Isohexane (2-Methylpentane)		99.2%	<0.08–24	1.3	2.6
108-08-7	2,4-Dimethylpentane		94.6%	0.02–2.6	0.2	0.27
108-67-8	1,3,5-Trimethylbenzene		82.2%	0.022–0.40	0.11	0.06
108-87-2	Methylcyclohexane		89.9%	0.021–1.56	0.16	0.21
108-88-3	Toluene	X	100.0%	0.20–13	2.5	1.9
109-66-0	Pentane		100.0%	0.14–69	3.1	7.6
109-67-1	1-Pentene		93.8%	<0.025–4.9	0.29	0.62
110-54-3	Hexane	X	99.2%	0.046–13.5	0.81	1.44
110-82-7	Cyclohexane		96.1%	0.032–3.5	0.26	0.4
111-65-9	n-Octane		93.8%	0.05–0.56	0.15	0.09
111-84-2	n-Nonane		93.8%	0.023–2.4	0.12	0.22
1120-21-4	n-Undecane		68.2%	0.016–0.27	0.07	0.04
115-07-1	Propylene	X	100.0%	0.05–1.7	0.48	0.32
123-72-8	Butyraldehyde		89.1%	<0.08–12.6	1.2	1.6
124-18-5	n-Decane		89.1%	0.015–0.19	0.07	0.03
142-82-5	Heptane		94.6%	0.028–2.4	0.25	0.28
287-92-3	Cyclopentane		84.5%	0.023–4.2	0.22	0.49
31394-54-4	Isoheptane (2-Methylhexane)		96.9%	0.028–7.2	0.5	0.82
4050-45-7	trans-2-Hexene		57.4%	0.01–0.97	0.09	0.15

HAPs are shown in **bold**.

Concentrations over $2 \mu\text{g}/\text{m}^3$ are shaded.

Table 7-3 (cont.)

CAS #	Name	LANL	Detect %	Range ($\mu\text{g}/\text{m}^3$)	Mean Conc. ($\mu\text{g}/\text{m}^3$)	Std Dev
463-82-1	Neopentane		54.3%	0.005–1.4	0.1	0.21
513-35-9	2-Methyl-2-butene		92.2%	<0.015–14.3	0.58	1.77
526-73-8	1,2,3-Trimethylbenzene		62.8%	0.018–0.32	0.08	0.05
540-84-1	2,2,4-Trimethylpentane (Isooctane)	X	99.2%	0.032–4.3	0.42	0.57
56-23-5	Carbon Tetrachloride	X	100.0%	0.17–1.0	0.73	0.1
564-02-3	2,2,3-Trimethylpentane		69.8%	0.01–0.31	0.05	0.04
565-59-3	2,3-Dimethylpentane		93.0%	0.032–3.8	0.35	0.44
565-75-3	2,3,4-Trimethylpentane		72.9%	<0.02–1.0	0.34	0.14
589-34-4	3-Methylhexane		95.3%	<0.08–4.2	0.49	0.49
589-81-1	3-Methylheptane		58.9%	0.02–0.41	0.09	0.07
590-18-1	cis-2-Butene		76.0%	<0.01–6.7	0.26	0.74
592-13-2	2,5-Dimethylhexane		66.7%	0.01–0.34	0.06	0.04
592-27-8	2-Methylheptane		78.3%	0.06–2.0	0.2	0.21
592-41-6	1-Hexene		65.9%	0.027–0.81	0.1	0.11
592-76-7	1-Heptene		74.4%	0.02–1.7	0.2	0.22
611-14-3	2-Ethyltoluene (o-Ethyltoluene)		71.3%	0.023–0.34	0.09	0.05
620-14-4	3-Ethyltoluene (m-Ethyltoluene)		96.1%	0.04–0.95	0.23	0.14
622-96-8	4-Ethyltoluene (p-Ethyltoluene)		78.3%	0.03–0.42	0.12	0.06
624-64-6	trans-2-Butene		79.8%	0.02–6.7	0.26	0.71
625-27-4	2-Methyl-2-pentene		68.2%	0.01–1.18	0.1	0.17
627-20-3	cis-2-Pentene		74.4%	0.016–5.53	0.29	0.78
64-17-5	Ethanol (Ethyl alcohol)	X	100.0%	1.96–89.8	23	16
646-04-8	trans-2-Pentene		92.2%	0.02–10.9	0.5	1.4
66-25-1	Hexanal		75.2%	0.15–12.1	1	1.4
67-56-1	Methanol (Methyl alcohol)	X	100.0%	0.83–69.6	10.8	7.6
67-63-0	2-Propanol (Isopropyl Alcohol)	X	74.4%	<0.03–2.3	0.42	0.3
67-64-1	Acetone (2-Propanone)	X	100.0%	1.65–64.6	12	10
67-66-3	Chloroform	X	76.0%	0.024–0.49	0.04	0.04
71-43-2	Benzene	X	100.0%	0.13–10.3	1.3	1.2

HAPs are shown in bold.

Concentrations over $2 \mu\text{g}/\text{m}^3$ are shaded.

Table 7-3 (cont.)

CAS #	Name	LANL	Detect %	Range ($\mu\text{g}/\text{m}^3$)	Mean Conc. ($\mu\text{g}/\text{m}^3$)	Std Dev
71-55-6	1,1,1-Trichloroethane (Methyl Chloroform)	X	99.2%	<0.07–0.80	0.21	0.08
74-83-9	Bromomethane (Methyl Bromide)	X	62.0%	0.017–0.24	0.04	0.03
74-84-0	Ethane		100.0%	1.4–26.2	5.4	4.2
74-85-1	Ethylene	X	100.0%	0.24–4.2	1.3	0.7
74-86-2	Acetylene	X	100.0%	0.20–4.9	1.1	0.7
74-87-3	Freon 40 Chloromethane (Methyl Chloride)	X	100.0%	0.31–1.7	1.1	0.3
74-98-6	Propane	X	100.0%	0.51–27.3	3.4	3.8
75-05-8	Acetonitrile	X	60.5%	<0.05–1.1	0.37	0.2
75-07-0	Acetaldehyde	X	100.0%	0.26–40.4	8.1	6.1
75-09-2	Methylene Chloride (Dichloromethane)	X	99.2%	<0.06–2.3	0.25	0.27
75-28-5	Isobutane		100.0%	0.082–107	3.7	12
75-45-6	Freon 22 (Chlorodifluoromethane)	X	100.0%	0.41–34.7	1.4	3.5
75-69-4	Freon 11 (Trichlorofluoromethane)	X	100.0%	0.44–1.98	1.65	0.17
75-71-8	Freon 12 (Dichlorodifluoromethane)		100.0%	0.79–3.8	2.96	0.33
75-83-2	2,2-Dimethylbutane (Neohexane)		83.7%	0.023–4.2	0.22	0.48
76-13-1	Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	X	100.0%	0.11–1.13	0.66	0.14
76-14-2	Freon 114 (1,2-Dichlorotetrafluoroethane)		99.2%	<0.04–0.18	0.1	0.02
763-29-1	2-Methyl-1-pentene		54.3%	0.0084–0.82	0.08	0.13
78-78-4	2-Methylbutane (Isopentane)		100.0%	0.22–210	9	24
78-79-5	Isoprene		83.7%	0.011–1.0	0.2	0.23
78-93-3	2-Butanone (Methyl Ethyl Ketone)	X	90.7%	<0.11–8.2	1.1	1.2
79-29-8	2,3-Dimethylbutane		98.4%	0.02–6.8	0.33	0.74
80-56-8	alpha-Pinene		89.9%	0.027–9.7	1	1.7
811-97-2	Halocarbon 134A	X	99.2%	<0.02–1.08	0.24	0.16
95-47-6	o-Xylene	X	99.2%	0.064–1.7	0.43	0.29
95-63-6	1,2,4-Trimethylbenzene	X	99.2%	0.041–1.37	0.31	0.21
96-14-0	3-Methylpentane		99.2%	<0.04–14	0.7	1.5
96-37-7	Methylcyclopentane		99.2%	<0.02–8.2	0.4	0.9

HAPs are shown in bold.

Concentrations over $2 \mu\text{g}/\text{m}^3$ are shaded.

Table 7-4. Average Concentrations of VOCs Detected in 10% to 50% of NonRadNET Samples

CAS	Name	LANL	Detect %	Range ($\mu\text{g}/\text{m}^3$)	Mean Conc. ($\mu\text{g}/\text{m}^3$)	Std Dev
106-46-7	1,4-Dichlorobenzene	X	22.5%	0.02–0.40	0.1	0.09
108-05-4	Vinyl Acetate		31.0%	0.63–4.5	1.7	0.9
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)		39.5%	0.047–2.4	0.27	0.4
108-90-7	Chlorobenzene	X	26.4%	0.022–0.088	0.04	0.01
111-66-0	1-Octene		31.0%	0.021–0.27	0.08	0.06
111-71-7	Heptanal		28.7%	0.19–5.7	0.95	0.97
120-82-1	1,2,4-Trichlorobenzene	X	17.1%	0.023–1.18	0.22	0.32
124-11-8	1-Nonene		14.0%	0.041–0.18	0.08	0.03
127-18-4	Tetrachloroethene (Perchloroethylene, Tetrachloroethylene)	X	28.7%	0.018–0.56	0.13	0.1
127-91-3	beta-Pinene		47.3%	0.017–0.60	0.15	0.12
138-86-3	Limonene		33.3%	0.027–0.61	0.12	0.1
142-29-0	Cyclopentene		43.4%	0.010–1.07	0.09	0.17
3522-94-9	2,2,5-Trimethylhexane		45.0%	0.016–0.15	0.04	0.02
496-11-7	Indan		34.1%	0.018–0.13	0.04	0.02
563-45-1	3-Methyl-1-butene		34.1%	<0.02–2.6	0.27	0.53
691-38-3	cis/trans-4-Methyl-2-pentene		31.8%	0.01–0.81	0.11	0.16
693-89-0	1-Methylcyclopentene		31.8%	0.024–0.84	0.11	0.15
71-36-3	1-Butanol (n-Butyl Alcohol)		14.0%	0.08–4.6	0.8	1
75-00-3	Chloroethane (Ethyl Chloride) Freon 160		27.9%	<0.02–0.28	0.12	0.05
75-43-4	Freon 21 (Dichlorofluoromethane)		10.1%	0.020–0.055	0.03	0.01
7642-09-3	cis-3-Hexene		38.0%	0.010–0.76	0.09	0.12
7688-21-3	cis-2-Hexene		28.7%	0.014–0.49	0.07	0.1
821-95-4	1-Undecene		14.7%	<0.05–0.95	0.27	0.21
87-68-3	Hexachlorobutadiene		10.9%	<0.026–1.6	0.35	0.42
91-20-3	Naphthalene	X	14.0%	0.081–0.17	0.11	0.02
922-62-3	cis-3-Methyl-2-pentene		27.9%	0.01–0.63	0.1	0.12
99-87-6	4-Isopropyltoluene (p-Cymene)		28.7%	0.031–0.18	0.08	0.02

HAPs are shown in bold.

Table 7-5. Average Concentrations of VOCs Detected in <10% of NonRadNET Samples

CAS	Name	LANL	% Detected	Range ($\mu\text{g}/\text{m}^3$)	Mean Conc. ($\mu\text{g}/\text{m}^3$)	Std Dev
100-44-7	Chlorotoluene (Benzyl Chloride)		0.8%	<0.047–<0.31		
10061-01-5	cis-1,3-Dichloropropene		0.0%	<0.036–<0.19		
10061-02-6	trans-1,3-Dichloropropene		0.0%	<0.08–<0.18		
104-51-8	n-Butylbenzene		7.8%	0.02–0.17	0.05	0.04
105-05-5	1,4-Diethylbenzene (p-Diethylbenzene)		4.7%	0.01–0.089	0.04	0.03
106-43-4	4-Chlorotoluene		0.0%	<0.24–<1.8		
106-93-4	Ethylene Dibromide (1,2-Dibromoethane)	X	1.6%	<0.03–0.13	0.08	
107-06-2	1, 2-Dichloroethane (Ethylene Dichloride)	X	7.0%	0.016–0.10	0.03	0.02
107-13-1	Acrylonitrile	X	0.0%	<0.05–<0.14		
107-40-4	2,4,4-Trimethyl-2-pentene		0.8%	<0.04–<0.33		
108-41-8	3-Chlorotoluene (measured as 2- and 3-Chlorotoluene)		0.0%	<0.34–<3.2		
110-83-8	Cyclohexene		3.1%	0.023–0.08	0.04	0.02
123-91-1	1,4-Dioxane (1,4-Diethyloxyde)	X	0.0%	<0.16–<0.59		
124-48-1	Dibromochloromethane		0.0%	<0.07–<0.56		
126-99-8	2-Chloro-1,3-butadiene (Chloroprene)		0.0%	<0.04–<0.14		
141-32-2	Butyl Acrylate		0.8%	<0.34–<1.23		
141-93-5	1,3-Diethylbenzene (m-Diethylbenzene)		7.0%	0.012–0.077	0.03	0.02
14686-13-6	trans-2-Heptene		4.7%	0.026–0.14	0.07	0.05
14686-14-7	trans-3-Heptene		7.0%	0.036–0.43	0.15	0.14
156-59-2	cis-1,2 Dichloroethene		0.0%	<0.066–<0.17		
156-60-5	trans-1,2-Dichloroethene		0.0%	<0.038–<0.15		
1634-04-4	Methyl tert-Butyl Ether		7.8%	0.012–0.16	0.05	0.04
2198-23-4	4-Nonene		0.0%	<0.11–<0.32		
538-93-2	Isobutylbenzene		0.8%	<0.27–<1.9		
541-73-1	1,3-Dichlorobenzene		6.2%	0.022–0.30	0.14	0.1
591-49-1	1-Methylcyclohexene		0.0%	<0.07–<0.28		
593-60-2	Vinyl bromide		0.0%	<0.037–<0.41		

HAPs are shown in bold.

Table 7-5 (cont.)

CAS	Name	LANL	% Detected	Range ($\mu\text{g}/\text{m}^3$)	Mean Conc. ($\mu\text{g}/\text{m}^3$)	Std Dev
60-29-7	Diethyl ether	X	0.0%	<0.05–<0.38		
691-37-2	4-Methyl-1-pentene		6.2%	<0.017–0.52	0.17	0.18
71-23-8	1-Propanol		5.4%	<0.18–2.7	1.5	0.8
74-97-5	Bromochloromethane		0.0%	<0.02–<0.11		
75-01-4	Vinyl Chloride	X	1.6%	<0.02–0.083	0.08	
75-25-2	Bromoform		0.0%	<0.032–<0.89		
75-27-4	Bromodichloromethane		0.0%	<0.06–<0.39		
75-34-3	1,1-Dichloroethane (Ethylidene Dichloride)	X	0.0%	<0.035–<0.08		
75-35-4	1,1-Dichloroethene (Vinylidene Chloride)	X	0.8%	<0.02–<0.09*		
760-21-4	2-Ethyl-1-butene		8.5%	0.038–0.17	0.09	0.03
7642-04-8	cis-2-Octene		1.6%	<0.083–<0.3		
7642-10-6	cis-3-Heptene		6.2%	0.076–0.62	0.19	0.19
78-87-5	1,2-Dichloropropane (Propylene Dichloride)	X	0.0%	<0.057–<0.11		
79-00-5	1,1,2-Trichloroethane	X	0.8%	<0.07–<0.12		
79-01-6	Trichloroethene (Trichloroethylene)	X	8.5%	0.02–0.23	0.08	0.07
79-34-5	1,1,2,2-Tetrachloroethane		5.4%	0.036–0.15	0.08	0.04
872-05-9	1-Decene		0.8%	<0.19–<1.9		
95-13-6	Indene		3.9%	0.015–0.047	0.02	0.01
95-49-8	2-Chlorotoluene (measured as 2- and 3-Chlorotoluene)		0.0%	<0.34–<3.2		
95-50-1	1,2-Dichlorobenzene		6.2%	0.027–0.35	0.17	0.12
98-82-8	Isopropylbenzene (Cumene)		9.3%	0.02–0.07	0.04	0.01
98-06-6	tert-Butylbenzene		0.0%	<0.29–<2.2		

HAPs are shown in bold.

8.0 Comparison with National Values

To gain a perspective of the significance of our measurements, it is instructive to compare our measurements with available typical national values. This section provides that information in three subsections for particles, inorganic elements, and VOCs. Much of the information on typical concentrations came from the ATSDR [ATSDR-TPIS], EPA [EPA-HENHAP], the California Air Resources Board [CARB], and the 1999/2000 Urban Air Toxics Monitoring Program Report (UATMP) [EPA2001]. Other references for such information are provided in the individual sections below.

8.1 Particulate Matter

The EPA “Air Trends” web site for particles [EPA-ATPM] and a closely related site [EPA-ATPMMD] provide a wealth of information about airborne particulate matter. Those web sites provide a number of comparisons for particulate matter that can provide a point of reference for our particulate measurements. For example, the annual average PM_{10} at 770 sites around the US has declined from about $28 \mu\text{g}/\text{m}^3$ in 1992 to about $23 \mu\text{g}/\text{m}^3$ in 2001. As of 2001 about 90% of those 770 stations had annual averages less than about $34 \mu\text{g}/\text{m}^3$, and about 10% had annual averages less than $15 \mu\text{g}/\text{m}^3$. The long-term average PM_{10} we measured was $18.8 \mu\text{g}/\text{m}^3$. Thus, the Los Alamos area is lower than the national average.

The EPA data show that $PM_{2.5}$ measurements average about $11 \mu\text{g}/\text{m}^3$ in the *rural* Eastern US and about $4 \mu\text{g}/\text{m}^3$ in the *rural* Western US. *Urban* $PM_{2.5}$ is substantially higher. For example, the San Joaquin Valley (Sacramento, CA) averages a $PM_{2.5}$ of about $32 \mu\text{g}/\text{m}^3$. Phoenix and Dallas have annual averages of about $13 \mu\text{g}/\text{m}^3$, while El Paso has an average over $22 \mu\text{g}/\text{m}^3$. Our $PM_{2.5}$ measurements at LANL averaged $7.9 \mu\text{g}/\text{m}^3$, low for a metropolitan area and a little higher than for the typical rural Western US.

Thus, we conclude that, since Los Alamos is a rural area with some urban characteristics, our particulate measurements are consistent with what we would expect, based on national averages.

8.2 Inorganic Elements

Table 8-1 compares our inorganic elemental measurements to some national values. HAPs are shown in **bold**. Again, note that these inorganic results are in ng/m^3 . Generally, our inorganic elemental results appear to be typical to low, sometimes very low (antimony, arsenic, cadmium, chromium, lead, nickel, and selenium). Los Alamos appears to be a little higher than the typical average for barium, beryllium, iron, and vanadium. However, these four elements are low compared to urban areas.

Table 8-1. LANL Inorganic Measurements Compared to Typical National Values

Symbol	Name	Typical National Value (ng/m ³)	LANL Avg (ng/m ³)
Sb	Antimony	1–170 (1–500 range)	0.46
As	Arsenic	20–30 urban (0.4–30 range)	0.42
Ba	Barium	9 (1.5–950 range)	21
Be	Beryllium	0.03 typically, 0.2 urban (<5)	0.06
Cd	Cadmium	<1–40, urban higher	0.08
Ce	Cerium	No data found	2.0
Cr	Chromium	10–30	1.9
Co	Cobalt	<1–2, 0.4 typically	0.33
Cu	Copper	1–200 (in some cases, 3–7000)	47
Fe	Iron	50–90 rural, urban 1300	760
Pb	Lead	<50 typically, (100–300 range)	2.7
Mn	Manganese	20 (5–33 range)	21
Nd	Neodymium	No data found	0.76
Ni	Nickel	7–12 (1–3 remote areas, 5–35 urban)	1.1
Se	Selenium	<10 (0.1–10 range)	0.36
Ag	Silver	<1	0.10
Sr	Strontium	No data found	8.1
Tl	Thallium	<1	0.02
V	Vanadium	0.1–1, 64 where hi-V fuels used	2.0
Zn	Zinc	10–100 rural, 100–500 urban	19

HAPs are shown in **bold**.

8.3 Volatile Organic Compounds

Tables 8-2, 8-3, and 8-4 compare our VOC measurements to some national values. Table 8-2 provides information for those VOCs that we frequently detected, that is, in greater than 50% of the samples. Table 8-3 is for those VOCs we detected in 10% to 50% of the samples. Table 8-4 is for those VOCs that we detected in less than 10% of the samples. In Table 8-4, “ND” means “none detected.” In all three tables, HAPs are shown in **bold**.

As shown in these tables, the NonRadNET average concentrations are generally lower to much lower than the comparable national values. It is notable that benzene, toluene, and the xylenes, the primary components of gasoline, are well below typical national values. Those few NonRadNET averages that seem to be higher than national values are

- benzaldehyde
- butyraldehyde
- acetone
- acetaldehyde (HAP)

All four of these VOCs have a naturally occurring component. Acetone and acetaldehyde are also found in fuel exhausts. Benzaldehyde and butyraldehyde are solvents. Benzaldehyde, acetone, and acetaldehyde appear to be roughly three times the few comparable national values

we were able to find. Butyraldehyde is just slightly higher than the comparable national value. Neither benzaldehyde nor butyraldehyde is used at the Laboratory. Acetone is used at the Laboratory in just over one-ton quantities each year. Less than 100 pounds of acetaldehyde was used at the Laboratory in 2002. None was used in 2001.

Table 8-2. Comparison of National Values With VOCs Detected In >50% of NonRadNET Samples

CAS #	Name	LANL ($\mu\text{g}/\text{m}^3$)	Typical Airborne Levels ($\mu\text{g}/\text{m}^3$)			
			General	Urban	Rural	UATMP
100-41-4	Ethyl Benzene	0.35		1.7	0.6	1
100-42-5	Styrene	0.07	0.8	0.3–3.8	0.3–0.34	0.8
100-52-7	Benzaldehyde	1.1				0.4
103-65-1	n-Propylbenzene	0.09				3.9
106-42-3	p-Xylene (including 108-38-3 m-Xylene)	1.1	8.7	3–380		2.7
106-97-8	Butane	12				26
106-98-9	1-Butene	0.4				4.6
106-99-0	1,3-Butadiene	0.1	0.7			0.3
107-39-1	2,4,4-Trimethyl-1-pentene	0.07	no data	no data	no data	no data
107-83-5	Isohexane (2-Methylpentane)	1.3				12.3
108-08-7	2,4-Dimethylpentane	0.2				5.2
108-67-8	1,3,5-Trimethylbenzene	0.11				6.5
108-87-2	Methylcyclohexane	0.16				6.2
108-88-3	Toluene	2.5	10	11	1.3	5.6
109-66-0	Pentane	3.1				35
109-67-1	1-Pentene	0.29				1.8
110-54-3	Hexane	0.81	13			50
110-82-7	Cyclohexane	0.26				27
111-65-9	n-Octane	0.15				0.5
111-84-2	n-Nonane	0.12				6
1120-21-4	n-Undecane	0.07				19.5
115-07-1	Propylene	0.48				1.7
123-72-8	Butyraldehyde	1.2				0.8
124-18-5	n-Decane	0.07				8.3
142-82-5	Heptane	0.25				5.6
287-92-3	Cyclopentane	0.22				2
31394-54-4	Isoheptane (2-Methylhexane)	0.5				5.4
4050-45-7	trans-2-Hexene	0.09				1.2

HAPs are shown in **bold**.

Table 8-2 (cont.)

CAS #	Name	LANL ($\mu\text{g}/\text{m}^3$)	Typical Airborne Levels ($\mu\text{g}/\text{m}^3$)			
			General	Urban	Rural	UATMP
463-82-1	Neopentane	0.1	no data	no data	no data	no data
513-35-9	2-Methyl-2-butene	0.58				3.4
526-73-8	1,2,3-Trimethylbenzene	0.08				7.3
540-84-1	2,2,4-Trimethylpentane (Isooctane)	0.42		22.5		10
56-23-5	Carbon Tetrachloride	0.73	1.2		1	0.4
564-02-3	2,2,3-Trimethylpentane	0.05				3.9
565-59-3	2,3-Dimethylpentane	0.35				7
565-75-3	2,3,4-Trimethylpentane	0.34				5.4
589-34-4	3-Methylhexane	0.49				9.3
589-81-1	3-Methylheptane	0.09				3.2
590-18-1	cis-2-Butene	0.26				1.9
592-13-2	2,5-Dimethylhexane	0.06	no data	no data	no data	no data
592-27-8	2-Methylheptane	0.2				3.2
592-41-6	1-Hexene	0.1				2.3
592-76-7	1-Heptene	0.2				1.8
611-14-3	2-Ethyltoluene (o-Ethyltoluene)	0.09				5.8
620-14-4	3-Ethyltoluene (m-Ethyltoluene)	0.23				10.9
622-96-8	4-Ethyltoluene (p-Ethyltoluene)	0.12				5.9
624-64-6	trans-2-Butene	0.26				1.5
625-27-4	2-Methyl-2-pentene	0.1	no data	no data	no data	no data
627-20-3	cis-2-Pentene	0.29				2
64-17-5	Ethanol (Ethyl alcohol)	23	no data	no data	no data	no data
646-04-8	trans-2-Pentene	0.5				2.4
66-25-1	Hexanal	1	no data	no data	no data	no data
67-56-1	Methanol (Methyl alcohol)	10.8	23.1			
67-63-0	2-Propanol (Isopropyl Alcohol)	0.42	no data	no data	no data	no data
67-64-1	Acetone (2-Propanone)	12				4.4
67-66-3	Chloroform	0.04	0.2	2.7		0.1
71-43-2	Benzene	1.3	2	50	0.3-54	2

HAPs are shown in bold.

Table 8-2 (cont.)

CAS #	Name	LANL ($\mu\text{g}/\text{m}^3$)	Typical Airborne Levels ($\mu\text{g}/\text{m}^3$)			
			General	Urban	Rural	UATMP
71-55-6	1,1,1-Trichloroethane (Methyl Chloroform)	0.21	5.6			0.2
74-83-9	Bromomethane (Methyl Bromide)	0.04	<0.1	9		0.3
74-84-0	Ethane	5.4				13
74-85-1	Ethylene	1.3				6.5
74-86-2	Acetylene	1.1				2.5
74-87-3	Freon 40 Chloromethane (Methyl Chloride)	1.1	1.6			1.4
74-98-6	Propane	3.4				20
75-05-8	Acetonitrile	0.37		0.05		0.8
75-07-0	Acetaldehyde	8.1	2.5		<1	2.6
75-09-2	Methylene Chloride (Dichloromethane)	0.25	5.6			10
75-28-5	Isobutane	3.7				9.6
75-45-6	Freon 22 (Chlorodifluoromethane)	1.4	no data	no data	no data	no data
75-69-4	Freon 11 (Trichlorofluoromethane)	1.65				1.9
75-71-8	Freon 12 (Dichlorodifluoromethane)	2.96				3.4
75-83-2	2,2-Dimethylbutane (Neohexane)	0.22				3.4
76-13-1	Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	0.66				0.6
76-14-2	Freon 114 (1,2-Dichlorotetrafluoroethane)	0.1	no data	no data	no data	no data
763-29-1	2-Methyl-1-pentene	0.08				1.3
78-78-4	2-Methylbutane (Isopentane)	9				48
78-79-5	Isoprene	0.2				2.3
78-93-3	2-Butanone (Methyl Ethyl Ketone)	1.1	1.4			6
79-29-8	2,3-Dimethylbutane	0.33				5.2
80-56-8	alpha-Pinene	1				5-26
811-97-2	Halocarbon 134A	0.24	no data	no data	no data	no data
95-47-6	o-Xylene	0.43	2.6	3-380		1.2
95-63-6	1,2,4-Trimethylbenzene	0.31				16.7
96-14-0	3-Methylpentane	0.7				9
96-37-7	Methylcyclopentane	0.4				5.6

HAPs are shown in bold.

Table 8-3. Comparison of National Values With VOCs Detected in 10% to 50% of NonRadNET Samples

CAS	Name	LANL ($\mu\text{g}/\text{m}^3$)	Typical Airborne Levels ($\mu\text{g}/\text{m}^3$)			
			General	Urban	Rural	UATMP
106-46-7	1,4-Dichlorobenzene (p-Dichlorobenzene)	0.1	1			0.4
108-05-4	Vinyl Acetate	1.7	no data	no data	no data	no data
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)	0.27				0.8
108-90-7	Chlorobenzene	0.04	0.14			0.1
111-66-0	1-Octene	0.08				1.2
111-71-7	Heptanal	0.95	no data	no data	no data	no data
120-82-1	1,2,4-Trichlorobenzene	0.22		1.3	0.8	0.2
124-11-8	1-Nonene	0.08				2.2
127-18-4	Tetrachloroethene (Perchloroethylene, Tetrachloroethylene)	0.13	4	5.4	1	0.4
127-91-3	beta-Pinene	0.15				12.3
138-86-3	Limonene	0.12	no data	no data	no data	no data
142-29-0	Cyclopentene	0.09				1.5
3522-94-9	2,2,5-Trimethylhexane	0.04	no data	no data	no data	no data
496-11-7	Indan	0.04	no data	no data	no data	no data
563-45-1	3-Methyl-1-butene	0.27	1.2			0.4
691-38-3	cis/trans-4-Methyl-2-pentene	0.11	no data	no data	no data	no data
693-89-0	1-Methylcyclopentene	0.11	no data	no data	no data	no data
71-36-3	1-Butanol (n-Butyl Alcohol)	0.8	no data	no data	no data	no data
75-00-3	Chloroethane (Ethyl Chloride) Freon 160	0.12	55			0.1
75-43-4	Freon 21 (Dichlorofluoromethane)	0.03				2.9
7642-09-3	cis-3-Hexene	0.09	no data	no data	no data	no data
7688-21-3	cis-2-Hexene	0.07				1.7
821-95-4	1-Undecene	0.27				4.2
87-68-3	Hexachlorobutadiene	0.35	0.3			0.3
91-20-3	Naphthalene	0.11	1	0.5-1		
922-62-3	cis-3-Methyl-2-pentene	0.1	no data	no data	no data	no data
99-87-6	4-Isopropyltoluene (p-Cymene)	0.08	no data	no data	no data	no data

HAPs are shown in bold.

Table 8-4. Comparison of National Values With VOCs Detected in <10% of NonRadNET Samples

CAS	Name	LANL ($\mu\text{g}/\text{m}^3$)	Typical Airborne Levels ($\mu\text{g}/\text{m}^3$)			
			General	Urban	Rural	UATMP
100-44-7	Chlorotoluene (Benzyl Chloride)	ND*	no data	no data	no data	no data
10061-01-5	cis-1,3-Dichloropropene	ND				ND
10061-02-6	trans-1,3-Dichloropropene	ND				ND
104-51-8	n-Butylbenzene	0.05	no data	no data	no data	no data
105-05-5	1,4-Diethylbenzene (p-Diethylbenzene ^o)	0.04				6.3
106-43-4	4-Chlorotoluene	ND	no data	no data	no data	no data
106-93-4	Ethylene Dibromide (1,2-Dibromoethane)	0.08	1.8			
107-06-2	1, 2-Dichloroethane (Ethylene Dichloride)	0.03		0.4–6		0.1
107-13-1	Acrylonitrile	ND		0.7		0.4
107-40-4	2,4,4-Trimethyl-2-pentene	ND	no data	no data	no data	no data
108-41-8	3-Chlorotoluene (measured as 2- and 3-Chlorotoluene)	ND	no data	no data	no data	no data
110-83-8	Cyclohexene	0.04	no data	no data	no data	no data
123-91-1	1,4-Dioxane (1,4-Diethyloxide)	ND	0.4			
124-48-1	Dibromochloromethane	ND				0.2
126-99-8	2-Chloro-1,3-butadiene (Chloroprene)	ND		0.3		0.2
141-32-2	Butyl Acrylate	ND	no data	no data	no data	no data
141-93-5	1,3-Diethylbenzene (m-Diethylbenzene)	0.03				8.9
14686-13-6	trans-2-Heptene	0.07	no data	no data	no data	no data
14686-14-7	trans-3-Heptene	0.15	no data	no data	no data	no data
156-59-2	cis-1,2 Dichloroethene	ND				0.1
156-60-5	trans-1,2-Dichloroethene	ND	no data	no data	no data	no data
1634-04-4	Methyl tert-Butyl Ether	0.05	1	6		1
2198-23-4	4-Nonene	ND	no data	no data	no data	no data
538-93-2	Isobutylbenzene	ND	no data	no data	no data	no data
541-73-1	1,3-Dichlorobenzene	0.14	1.2			0.4
591-49-1	1-Methylcyclohexene	ND	no data	no data	no data	no data
593-60-2	Vinyl bromide	ND	no data	no data	no data	no data
60-29-7	Diethyl ether	ND	no data	no data	no data	no data
691-37-2	4-Methyl-1-pentene	0.17				ND

HAPS shown in **bold**

Table 8-4 (cont.)

CAS #	Name	LANL ($\mu\text{g}/\text{m}^3$)	Typical Airborne Levels ($\mu\text{g}/\text{m}^3$)			
			General	Urban	Rural	UATMP
71-23-8	1-Propanol	1.5	no data	no data	no data	no data
74-97-5	Bromochloromethane	ND				25.2
75-01-4	Vinyl Chloride	0.08	1			0.07
75-25-2	Bromoform	ND		2.3		0.4
75-27-4	Bromodichloromethane	ND				0.2
75-34-3	1,1-Dichloroethane (Ethylidene Dichloride)	ND	0.2	0.4–6		0.14
75-35-4	1,1-Dichloroethene (Vinylidene Chloride)	ND	<0.4			0.15
760-21-4	2-Ethyl-1-butene	0.09				ND
7642-04-8	cis-2-Octene	ND	no data	no data	no data	no data
7642-10-6	cis-3-Heptene	0.19	no data	no data	no data	no data
78-87-5	1,2-Dichloropropane (Propylene Dichloride)	ND		0.75		0.17
79-00-5	1,1,2-Trichloroethane	ND	0.06–0.3	0.3		0.16
79-01-6	Trichloroethene (Trichloroethylene)	0.08	0.01–4			2
79-34-5	1,1,2,2-Tetrachloroethane	0.08	0.03	1–60	0.4–1	0.2
872-05-9	1-Decene	ND				2.4
95-13-6	Indene	0.02	no data	no data	no data	no data
95-49-8	2-Chlorotoluene (measured as 2- and 3-Chlorotoluene)	ND	no data	no data	no data	no data
95-50-1	1,2-Dichlorobenzene	0.17				0.2
98-06-6	tert-Butylbenzene	ND	no data	no data	no data	no data
98-82-8	Isopropylbenzene (Cumene)	0.04	1.3			2

*ND = None Detected
HAPS shown in **bold**

9.0 Comparison with Exposure Standards

Unlike radioactive materials, nonradioactive airborne environmental pollutants traditionally have been regulated at the **source**; that is, emission rates are regulated instead of ambient air concentrations. Consequently, ambient airborne limits for most nonradioactive pollutants do not exist. Therefore, in the absence of ambient airborne standards, we have chosen to compare our measurements with limits for *occupational* airborne exposure, which do exist for many of these pollutants. We recognize that occupational limits do not apply directly to public exposures; however, we believe the comparison is still instructive. Wherever an Occupational Safety and Health Administration (OSHA) 29CFR1910.1000 [OSHA1910] 8-hour time weighted average (TWA) exists, we have used it. In some cases OSHA has vacated (eliminated) a limit, but we have chosen to use it in the absence of other limits. If there was no known OSHA limit, we used American Conference of Governmental Industrial Hygienists (ACGIH) recommendations listed in some Material Safety Data Sheets (MSDSs). If neither OSHA nor ACGIH listed a value, we used American Industrial Hygiene Association (AIHA) or other standards (such as those of Du Pont) given in some of the MSDS. Finally, in the absence of any known US standard or recommendation, we used any limits specified in foreign standards from 16 countries [IPCS].

9.1 Particulate Matter

The EPA has established National Ambient Air Quality Standards [EPA] for PM₁₀ and PM_{2.5}. Additionally, the New Mexico Administrative Code has an ambient air quality standard for TSP. These standards are shown in Table 9-1. Although EPA and New Mexico 24-hour limits exist (150 µg/m³), the values in the table are the lower **annual average** limits, since the LANL mean is a long-term average. These EPA and New Mexico particulate limits are among the few ambient environmental (nonoccupational) limits that exist. The table shows that, even though northern New Mexico could be classed as “dry and dusty,” the NonRadNET particulate measurements are below the EPA and New Mexico particulate standards.

Table 9-1. Comparison of NonRadNET Particulate Measurements to EPA and New Mexico Ambient Air Quality Standards

Particle Type	LANL Mean (µg/m³)	New Mexico Standard* (µg/m³)	EPA Standard# (µg/m³)
TSP	52.1	60	None
PM ₁₀	21.6	None	50
PM _{2.5}	7.9	None	15

*Annual geometric mean for TSP as specified in 20 NMAC 2.03

#Annual average

9.2 Inorganic Elements

This section discusses the 20 inorganic elements with reference to OSHA occupational limits and the one EPA ambient air quality standard for lead. Table 9.2 shows the average and maximum values for each of the 20 NonRadNET elements. Recall that we have been expressing these

measurements in ng/m^3 . The table shows that the measured concentrations are generally many orders of magnitude below the OSHA 8-hour TWA occupational limits. EPA has an ambient air quality standard for lead, and the measured values are very low by comparison, about 1% of the limit for the highest lead value measured during the entire NonRadNET program. The ratio of the OSHA occupational lead value to the EPA ambient air quality standard is 33. If we were to create artificial “environmental” limits by reducing all of the OSHA values by a factor of 33, or even by a factor of 100, the measured concentrations for the remaining elements still would be a very small fraction of these artificial “environmental” limits.

Table 9-2. Comparison of NonRadNET Elemental Measurements to Limits

Symbol	Name	LANL Mean (ng/m^3)	LANL Max (ng/m^3)	OSHA* (ng/m^3)	EPA# (ng/m^3)
Sb	Antimony	0.46	1.4	500,000	None
As	Arsenic	0.42	2.15	10,000	None
Ba	Barium	21	110	500,000	None
Be	Beryllium	0.06	0.51	2,000	None
Cd	Cadmium	0.08	0.38	5,000	None
Ce	Cerium	2.0	6.2	None	None
Cr	Chromium	1.9	10	500,000	None
Co	Cobalt	0.33	1.8	100,000	None
Cu	Copper	47	235	1,000,000	None
Fe	Iron	760	2190	10,000,000	None
Pb	Lead	2.7	16	50,000	1,500
Mn	Manganese	21	122	1,000,000	None
Nd	Neodymium	0.76	2.3	None	None
Ni	Nickel	1.1	4.2	1,000,000	None
Se	Selenium	0.36	0.84	200,000	None
Ag	Silver	0.10	1.14	10,000	None
Sr	Strontium	8.1	41	None	None
Tl	Thallium	0.02	0.11	100,000	None
V	Vanadium	2.0	12	500,000	None
Zn	Zinc	19	53	5,000,000	None

*8-hour time weighted average (TWA)

#Annual average

9.3 Volatile Organic Compounds

This section discusses the 160 VOCs with reference to their OSHA (or other) occupational limits, wherever such exist. If OSHA has no current or historical limit, we have used ACGIH, AIHA, and foreign standards. Again, we fully recognize that occupational limits do not apply to ambient environmental exposures. However, in the absence of any such ambient exposure standards, we believe a comparison with occupational standards can be useful.

Using the previous format of dividing the VOCs by their detection frequencies, Tables 9-3 through 9-5 compare the average and maximum measurements with the occupational limits. The most obvious conclusion from scanning through these tables is that the measured values are **very** small when compared to the occupational limits. In fact, hexachlorobutadiene (CAS # 87-68-3) in Table 9-4 comes the closest of any of these measurements to its limit. If we divide our *maximum* measurement for hexachlorobutadiene into its occupational limit (which is foreign; there is no US limit), our maximum is 0.007 of the limit, less than 1%. All of the others are smaller. For those VOCS in Table 9-3 (detected >50% of the time), benzaldehyde (CAS # 100-52-7) comes closest to its limit (which OSHA has dropped from the regulations) at 0.0005 of the old limit.

Table 9-3. Occupational TWAs for NonRadNET VOCs Detected With > 50% Frequency

CAS #	Name	LANL Mean ($\mu\text{g}/\text{m}^3$)	LANL Max ($\mu\text{g}/\text{m}^3$)	TWA* ($\mu\text{g}/\text{m}^3$)
100-41-4	Ethyl Benzene	0.35	1.38	442,000
100-42-5	Styrene	0.07	0.23	433,000
100-52-7	Benzaldehyde	1.1	4.58	8,820
103-65-1	n-Propylbenzene	0.09	0.26	None
106-42-3	p-Xylene (including 108-38-3 m-Xylene)	1.1	4.3	442,000
106-97-8	Butane	12	312	1,940,000
106-98-9	1-Butene	0.4	5.4	None
106-99-0	1,3-Butadiene	0.1	0.36	2,250
107-39-1	2,4,4-Trimethyl-1-pentene	0.07	0.19	None
107-83-5	Isohexane (2-Methylpentane)	1.3	24	1,790,000
108-08-7	2,4-Dimethylpentane	0.2	2.6	None
108-67-8	1,3,5-Trimethylbenzene	0.11	0.40	125,000
108-87-2	Methylcyclohexane	0.16	1.56	2,000,000
108-88-3	Toluene	2.5	13	766,000
109-66-0	Pentane	3.1	69	2,950,000
109-67-1	1-Pentene	0.29	4.9	None
110-54-3	Hexane	0.81	13.5	180,000
110-82-7	Cyclohexane	0.26	3.5	1,050,000
111-65-9	n-Octane	0.15	0.56	2,350,000
111-84-2	n-Nonane	0.12	2.4	1,066,000
1120-21-4	n-Undecane	0.07	0.27	None
115-07-1	Propylene	0.48	1.7	17,500,000
123-72-8	Butyraldehyde	1.2	12.6	64,000
124-18-5	n-Decane	0.07	0.19	350,000
142-82-5	Heptane	0.25	2.4	1,668,000
287-92-3	Cyclopentane	0.22	4.2	1,746,000
31394-54-4	Isoheptane (2-Methylhexane)	0.5	7.2	None
4050-45-7	trans-2-Hexene	0.09	0.97	None

HAPs are shown in **bold**.

Table 9-3 (cont.)

CAS #	Name	LANL Mean ($\mu\text{g}/\text{m}^3$)	LANL Max ($\mu\text{g}/\text{m}^3$)	TWA* ($\mu\text{g}/\text{m}^3$)
463-82-1	Neopentane	0.1	1.4	1,800,000
526-73-8	1,2,3-Trimethylbenzene	0.08	0.32	125,000
540-84-1	2,2,4-Trimethylpentane (Isooctane)	0.42	4.3	1,425,000
56-23-5	Carbon Tetrachloride	0.73	1.0	154,000
564-02-3	2,2,3-Trimethylpentane	0.05	0.31	None
565-59-3	2,3-Dimethylpentane	0.35	3.8	None
565-75-3	2,3,4-Trimethylpentane	0.34	1.0	None
589-34-4	3-Methylhexane	0.49	4.2	None
589-81-1	3-Methylheptane	0.09	0.41	None
590-18-1	cis-2-Butene	0.26	6.7	None
592-13-2	2,5-Dimethylhexane	0.06	0.34	None
592-27-8	2-Methylheptane	0.2	2.0	None
592-41-6	1-Hexene	0.1	0.81	175,000
592-76-7	1-Heptene	0.2	1.7	None
611-14-3	2-Ethyltoluene (o-Ethyltoluene)	0.09	0.34	None
620-14-4	3-Ethyltoluene (m-Ethyltoluene)	0.23	0.95	None
622-96-8	4-Ethyltoluene (p-Ethyltoluene)	0.12	0.42	None
624-64-6	trans-2-Butene	0.26	6.7	None
625-27-4	2-Methyl-2-pentene	0.1	1.18	None
627-20-3	cis-2-Pentene	0.29	5.53	None
64-17-5	Ethanol (Ethyl alcohol)	23	89.8	1,900,000
646-04-8	trans-2-Pentene	0.5	10.9	None
66-25-1	Hexanal	1	12.1	None
67-56-1	Methanol (Methyl alcohol)	10.8	69.6	260,000
67-63-0	2-Propanol (Isopropyl Alcohol)	0.42	2.3	980,000
67-64-1	Acetone (2-Propanone)	12	64.6	2,400,000
67-66-3	Chloroform	0.04	0.49	240,000
71-43-2	Benzene	1.3	10.3	33,000
71-55-6	1,1,1-Trichloroethane (Methyl Chloroform)	0.21	0.80	1,900,000

HAPs are shown in bold.

Table 9-3 (cont.)

CAS #	Name	LANL Mean (µg/m ³)	LANL Max (µg/m ³)	TWA* (µg/m ³)
74-83-9	Bromomethane (Methyl Bromide)	0.04	0.24	80,000
74-84-0	Ethane	5.4	26.2	12,500,000
74-87-3	Freon 40 Chloromethane (Methyl Chloride)	1.1	1.7	420,000
74-98-6	Propane	3.4	27.3	1,800,000
75-05-8	Acetonitrile	0.37	1.1	70,000
75-07-0	Acetaldehyde	8.1	40.4	360,000
75-09-2	Methylene Chloride (Dichloromethane)	0.25	2.3	88,000
75-28-5	Isobutane	3.7	107	1,936,000
75-45-6	Freon 22 (Chlorodifluoromethane)	1.4	34.7	3,600,000
75-69-4	Freon 11 (Trichlorofluoromethane)	1.65	1.98	5,600,000
75-71-8	Freon 12 (Dichlorodifluoromethane)	2.96	3.8	4,950,000
75-83-2	2,2-Dimethylbutane (Neohexane)	0.22	4.2	1,790,000
76-13-1	Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	0.66	1.13	7,600,000
76-14-2	Freon 114 (1,2-Dichlorotetrafluoroethane)	0.1	0.18	7,000,000
763-29-1	2-Methyl-1-pentene	0.08	0.82	None
78-78-4	2-Methylbutane (Isopentane)	9	210	1,800,000
78-79-5	Isoprene	0.2	1.0	100,000
78-93-3	2-Butanone (Methyl Ethyl Ketone)	1.1	8.2	590,000
79-29-8	2,3-Dimethylbutane	0.33	6.8	1,790,000
80-56-8	alpha-Pinene	1	9.7	None
811-97-2	Halocarbon 134A	0.24	1.08	4,240,000
95-47-6	o-Xylene	0.43	1.7	435,000
95-63-6	1,2,4-Trimethylbenzene	0.31	1.37	125,000
96-14-0	3-Methylpentane	0.7	14	1,790,000
96-37-7	Methylcyclopentane	0.4	8.2	None

*8-hour time weighted average (TWA)
HAPs are in **bold**

Table 9-4. Occupational TWAs for NonRadNET VOCs Detected With 10% to 50% Frequency

CAS	Name	LANL Mean ($\mu\text{g}/\text{m}^3$)	LANL Max ($\mu\text{g}/\text{m}^3$)	TWA* ($\mu\text{g}/\text{m}^3$)
106-46-7	1,4-Dichlorobenzene (p-Dichlorobenzene)	0.1	0.40	458,000
108-05-4	Vinyl Acetate	1.7	4.5	35,800
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)	0.27	2.4	417,000
108-90-7	Chlorobenzene	0.04	0.088	350,000
111-66-0	1-Octene	0.08	0.27	None
111-71-7	Heptanal	0.95	5.7	None
120-82-1	1,2,4-Trichlorobenzene	0.22	1.18	37,000
124-11-8	1-Nonene	0.08	0.18	None
127-18-4	Tetrachloroethene (Perchloroethylene, Tetrachloroethylene)	0.13	0.56	690,000
127-91-3	beta-Pinene	0.15	0.60	None
138-86-3	Limonene	0.12	0.61	None
142-29-0	Cyclopentene	0.09	1.07	None
3522-94-9	2,2,5-Trimethylhexane	0.04	0.15	None
496-11-7	Indan	0.04	0.13	None
563-45-1	3-Methyl-1-butene	0.27	2.6	None
691-38-3	cis/trans-4-Methyl-2-pentene	0.11	0.81	None
693-89-0	1-Methylcyclopentene	0.11	0.84	None
71-36-3	1-Butanol (n-Butyl Alcohol)	0.8	4.6	300,000
75-00-3	Chloroethane (Ethyl Chloride) Freon 160	0.12	0.28	2,600,000
75-43-4	Freon 21 (Dichlorofluoromethane)	0.03	0.055	4,200,000
7642-09-3	cis-3-Hexene	0.09	0.76	None
7688-21-3	cis-2-Hexene	0.07	0.49	None
821-95-4	1-Undecene	0.27	0.95	None
87-68-3	Hexachlorobutadiene	0.35	1.6	240
91-20-3	Naphthalene	0.11	0.17	50,000
922-62-3	cis-3-Methyl-2-pentene	0.1	0.63	None
99-87-6	4-Isopropyltoluene (p-Cymeme)	0.08	0.18	140,000

*8-hour time weighted average (TWA)

HAPs are in **bold**

Table 9-5. Occupational TWAs for NonRadNET VOCs Detected With <10% Frequency

CAS	Name	LANL Mean (µg/m ³)	LANL Max (µg/m ³)	TWA* (µg/m ³)
100-44-7	Chlorotoluene (Benzyl Chloride)	ND	<0.31	5,260
10061-01-5	cis-1,3-Dichloropropene	ND	<0.19	4,610
10061-02-6	trans-1,3-Dichloropropene	ND	<0.18	4,610
104-51-8	n-Butylbenzene	0.05	0.17	None
105-05-5	1,4-Diethylbenzene (p-Diethylbenzene)	0.04	0.089	None
106-43-4	4-Chlorotoluene	ND	<1.8	None
106-93-4	Ethylene Dibromide (1,2-Dibromoethane)	0.08	0.13	156,000
107-06-2	1, 2-Dichloroethane (Ethylene Dichloride)	0.03	0.10	206,000
107-13-1	Acrylonitrile	ND	<0.14	4,400
107-40-4	2,4,4-Trimethyl-2-pentene	ND	<0.33	None
108-41-8	3-Chlorotoluene (measured as 2- and 3-Chlorotoluene)	ND	<3.2	None
110-83-8	Cyclohexene	0.04	0.08	1,015,000
123-91-1	1,4-Dioxane (1,4-Diethyloxiide)	ND	<0.59	360,000
124-48-1	Dibromochloromethane	ND	<0.56	None
126-99-8	2-Chloro-1,3-butadiene (Chloroprene)	ND	<0.14	90,000
141-32-2	Butyl Acrylate	ND	<1.23	11,000
141-93-5	1,3-Diethylbenzene (m-Diethylbenzene)	0.03	0.077	None
14686-13-6	trans-2-Heptene	0.07	0.14	None
14686-14-7	trans-3-Heptene	0.15	0.43	None
156-59-2	cis-1,2 Dichloroethene	ND	<0.17	806,000
156-60-5	trans-1,2-Dichloroethene	ND	<0.15	806,000
1634-04-4	Methyl tert-Butyl Ether	0.05	0.16	146,000
2198-23-4	4-Nonene	ND	<0.32	None
538-93-2	Isobutylbenzene	ND	<1.9	558,000
541-73-1	1,3-Dichlorobenzene	0.14	0.30	None
591-49-1	1-Methylcyclohexene	ND	<0.28	None
593-60-2	Vinyl bromide	ND	<0.41	2,000

Table 9-5 (cont.)

CAS	Name	LANL Mean ($\mu\text{g}/\text{m}^3$)	LANL Max ($\mu\text{g}/\text{m}^3$)	TWA* ($\mu\text{g}/\text{m}^3$)
691-37-2	4-Methyl-1-pentene	0.17	0.52	None
71-23-8	1-Propanol	1.5	2.7	500,000
74-97-5	Bromochloromethane	ND	<0.11	1,050,000
75-01-4	Vinyl Chloride	0.08	0.083	2,600
75-25-2	Bromoform	ND	<0.89	5,000
75-27-4	Bromodichloromethane	ND	<0.39	None
75-34-3	1,1-Dichloroethane (Ethylidene Dichloride)	ND	<0.08	400,000
75-35-4	1,1-Dichloroethene (Vinylidene Chloride)	ND	<0.09	4,000
760-21-4	2-Ethyl-1-butene	0.09	0.17	None
7642-04-8	cis-2-Octene	ND	<0.3	None
7642-10-6	cis-3-Heptene	0.19	0.62	None
78-87-5	1,2-Dichloropropane (Propylene Dichloride)	ND	<0.11	350,000
79-00-5	1,1,2-Trichloroethane	ND	<0.12	45,000
79-01-6	Trichloroethene (Trichloroethylene)	0.08	0.23	546,000
79-34-5	1,1,2,2-Tetrachloroethane	0.08	0.15	35,000
872-05-9	1-Decene	ND	<1.9	None
95-13-6	Indene	0.02	0.047	48,000
95-49-8	2-Chlorotoluene (measured as 2- and 3-Chlorotoluene)	ND	<3.2	250,000
95-50-1	1,2-Dichlorobenzene	0.17	0.35	300,000
98-06-6	tert-Butylbenzene	ND	<2.2	None
98-82-8	Isopropylbenzene (Cumene)	0.04	0.07	245,000

*8-hour time weighted average (TWA)

HAPs are in **bold**

10.0 Conclusion

The purpose of this paper was to organize and describe the NonRadNET data collected over 2001–2002 for future use as baseline data, either for monitoring during a fire, some other abnormal event, or routine use. To achieve that purpose, in this paper we

- documented the NonRadNET program procedures, methods, and quality management,
- described the usual origins and uses of the species measured,
- compared the species measured to LANL and other area emissions,
- presented the data,
- compared the data to typical environmental values, and
- evaluated the data against exposure standards.

The airborne particle (TSP, PM₁₀, and PM_{2.5}) concentrations measured were well within normal ranges. Furthermore, when compared to vehicle, natural, and other particulate emission sources, LANL does not significantly affect the particulate concentration in the ambient atmosphere, except perhaps in the immediate vicinity of air curtain destructors used to dispose of large quantities of waste wood generated by the Cerro Grande fire recovery effort.

Of the 20 inorganic elements measured, most were very low compared to national values. Our measurements for barium, beryllium, iron, and vanadium *may* be slightly higher than typical national values.

For the 160 VOCs measured, we generally observed that the results were low to much lower than typical national concentrations. However, we observed that the concentrations for benzaldehyde, butyraldehyde, acetone, and acetaldehyde appear to be higher than the few national values we found for comparison with them. We did *conservatively* conclude that LANL *may* contribute measurably to the airborne concentrations of 2, 4, 4-trimethyl-1-pentene and Freon 22 (chlorodifluoromethane).

Based on our measurements, the ambient air concentrations around LANL tend to be significantly *lower* than in major urban areas, roughly typical of rural areas, and are many orders of magnitude below regulatory standards considered safe for occupational exposure (since environmental exposure standards do not exist for most of these species).

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APPENDIX A
Comprehensive NonRadNET VOC Data

This appendix contains a listing of the 160 volatile organic compounds (VOCs) monitored as part of NonRadNET. Two comprehensive lists of the monitored VOCs, one ordered by Chemical Abstract Service (CAS) number and one ordered alphabetically, are provided.

NonRadNET Volatile Organic Compounds Ordered By CAS Number

CAS #	Name
100-41-4	Ethyl Benzene
100-42-5	Styrene
100-44-7	Chlorotoluene (Benzyl Chloride)
100-52-7	Benzaldehyde
10061-01-5	cis-1,3-Dichloropropene
10061-02-6	trans-1,3-Dichloropropene
103-65-1	n-Propylbenzene
104-51-8	n-Butylbenzene
105-05-5	1,4-Diethylbenzene (p-Diethylbenzene)
106-42-3	p-Xylene
106-43-4	4-Chlorotoluene
106-46-7	1,4-Dichlorobenzene
106-93-4	Ethylene Dibromide (1,2-Dibromoethane)
106-97-8	Butane
106-98-9	1-Butene
106-99-0	1,3-Butadiene
107-06-2	1, 2-Dichloroethane (Ethylene Dichloride)
107-13-1	Acrylonitrile
107-39-1	2,4,4-Trimethyl-1-pentene
107-40-4	2,4,4-Trimethyl-2-pentene
107-83-5	Isohexane (2-Methylpentane)
108-05-4	Vinyl Acetate
108-08-7	2,4-Dimethylpentane
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)
108-38-3	m-Xylene
108-41-8	3-Chlorotoluene
108-67-8	1,3,5-Trimethylbenzene
108-87-2	Methylcyclohexane
108-88-3	Toluene
108-90-7	Chlorobenzene
109-66-0	Pentane
109-67-1	1-Pentene
110-54-3	Hexane
110-82-7	Cyclohexane
110-83-8	Cyclohexene
111-65-9	n-Octane
111-66-0	1-Octene

CAS #	Name
111-71-7	Heptanal
111-84-2	n-Nonane
1120-21-4	n-Undecane
115-07-1	Propylene
120-82-1	1,2,4-Trichlorobenzene
123-72-8	Butyraldehyde
123-91-1	1,4-Dioxane (1,4-Diethyloxide)
124-11-8	1-Nonene
124-18-5	n-Decane
124-48-1	Dibromochloromethane
126-99-8	2-Chloro-1,3-butadiene (Chloroprene)
127-18-4	Tetrachloroethene (Perchloroethylene, Tetrachloroethylene)
127-91-3	beta-Pinene
1330-20-7	mixed Xylenes
138-86-3	Limonene
141-32-2	Butyl Acrylate
141-93-5	1,3-Diethylbenzene (m-Diethylbenzene)
142-29-0	Cyclopentene
142-82-5	Heptane
14686-13-6	trans-2-Heptene
14686-14-7	trans-3-Heptene
156-59-2	cis-1,2 Dichloroethene
156-60-5	trans-1,2-Dichloroethene
1634-04-4	Methyl tert-Butyl Ether
2198-23-4	4-Nonene
287-92-3	Cyclopentane
31394-54-4	Isoheptane (2-Methylhexane)
3522-94-9	2,2,5-Trimethylhexane
4050-45-7	trans-2-Hexene
463-82-1	Neopentane
496-11-7	Indan
513-35-9	2-Methyl-2-butene
526-73-8	1,2,3-Trimethylbenzene
538-93-2	Isobutylbenzene
540-84-1	2,2,4-Trimethylpentane (Isooctane)
541-73-1	1,3-Dichlorobenzene
56-23-5	Carbon Tetrachloride
563-45-1	3-Methyl-1-butene
564-02-3	2,2,3-Trimethylpentane
565-59-3	2,3-Dimethylpentane
565-75-3	2,3,4-Trimethylpentane
589-34-4	3-Methylhexane
589-81-1	3-Methylheptane
590-18-1	cis-2-Butene
591-49-1	1-Methylcyclohexene

CAS #	Name
592-13-2	2,5-Dimethylhexane
592-27-8	2-Methylheptane
592-41-6	1-Hexene
592-76-7	1-Heptene
593-60-2	Vinyl bromide
60-29-7	Diethyl ether
611-14-3	2-Ethyltoluene (o-Ethyltoluene)
620-14-4	3-Ethyltoluene (m-Ethyltoluene)
622-96-8	4-Ethyltoluene (p-Ethyltoluene)
624-64-6	trans-2-Butene
625-27-4	2-Methyl-2-pentene
627-20-3	cis-2-Pentene
64-17-5	Ethanol (Ethyl alcohol)
646-04-8	trans-2-Pentene
66-25-1	Hexanal
67-56-1	Methanol (Methyl alcohol)
67-63-0	2-Propanol (Isopropyl Alcohol)
67-64-1	Acetone (2-Propanone)
67-66-3	Chloroform
691-37-2	4-Methyl-1-pentene
691-38-3	cis/trans-4-Methyl-2-pentene
693-89-0	1-Methylcyclopentene
71-23-8	1-Propanol
71-36-3	1-Butanol (n-Butyl Alcohol)
71-43-2	Benzene
71-55-6	1,1,1-Trichloroethane (Methyl Chloroform)
74-83-9	Bromomethane (Methyl Bromide)
74-84-0	Ethane
74-85-1	Ethylene
74-86-2	Acetylene
74-87-3	Freon 40 Chloromethane (Methyl Chloride)
74-97-5	Bromochloromethane
74-98-6	Propane
75-00-3	Chloroethane (Ethyl Chloride) Freon 160
75-01-4	Vinyl Chloride
75-05-8	Acetonitrile
75-07-0	Acetaldehyde
75-09-2	Methylene Chloride (Dichloromethane)
75-25-2	Bromoform
75-27-4	Bromodichloromethane
75-28-5	Isobutane
75-34-3	1,1-Dichloroethane (Ethylidene Dichloride)
75-35-4	1,1-Dichloroethene (Vinylidene Chloride)
75-43-4	Freon 21 (Dichlorofluoromethane)
75-45-6	Freon 22 (Chlorodifluoromethane)

CAS #	Name
75-69-4	Freon 11 (Trichlorofluoromethane)
75-71-8	Freon 12 (Dichlorodifluoromethane)
75-83-2	2,2-Dimethylbutane (Neohexane)
760-21-4	2-Ethyl-1-butene
76-13-1	Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)
76-14-2	Freon 114 (1,2-Dichlorotetrafluoroethane)
763-29-1	2-Methyl-1-pentene
7642-04-8	cis-2-Octene
7642-09-3	cis-3-Hexene
7642-10-6	cis-3-Heptene
7688-21-3	cis-2-Hexene
78-78-4	2-Methylbutane (Isopentane)
78-79-5	Isoprene
78-87-5	1,2-Dichloropropane (Propylene Dichloride)
78-93-3	2-Butanone (Methyl Ethyl Ketone)
79-00-5	1,1,2-Trichloroethane
79-01-6	Trichloroethene (Trichloroethylene)
79-29-8	2,3-Dimethylbutane
79-34-5	1,1,2,2-Tetrachloroethane
80-56-8	alpha-Pinene
811-97-2	Halocarbon 134A
821-95-4	1-Undecene
872-05-9	1-Decene
87-68-3	Hexachlorobutadiene
91-20-3	Naphthalene
922-62-3	cis-3-Methyl-2-pentene
95-13-6	Indene
95-47-6	o-Xylene
95-49-8	2-Chlorotoluene
95-50-1	1,2-Dichlorobenzene
95-63-6	1,2,4-Trimethylbenzene
96-14-0	3-Methylpentane
96-37-7	Methylcyclopentane
98-06-6	tert-Butylbenzene
98-82-8	Isopropylbenzene (Cumene)
99-87-6	4-Isopropyltoluene (p-Cymene)

NonRadNET Volatile Organic Compounds Ordered Alphabetically

CAS #	Name
107-06-2	1, 2-Dichloroethane (Ethylene Dichloride)
71-55-6	1,1,1-Trichloroethane (Methyl Chloroform)
79-34-5	1,1,2,2-Tetrachloroethane
79-00-5	1,1,2-Trichloroethane
75-34-3	1,1-Dichloroethane (Ethylidene Dichloride)
75-35-4	1,1-Dichloroethene (Vinylidene Chloride)
526-73-8	1,2,3-Trimethylbenzene
120-82-1	1,2,4-Trichlorobenzene
95-63-6	1,2,4-Trimethylbenzene
95-50-1	1,2-Dichlorobenzene
78-87-5	1,2-Dichloropropane (Propylene Dichloride)
108-67-8	1,3,5-Trimethylbenzene
106-99-0	1,3-Butadiene
541-73-1	1,3-Dichlorobenzene
141-93-5	1,3-Diethylbenzene (m-Diethylbenzene)
106-46-7	1,4-Dichlorobenzene
105-05-5	1,4-Diethylbenzene (p-Diethylbenzene)
123-91-1	1,4-Dioxane (1,4-Diethyloxy)
71-36-3	1-Butanol (n-Butyl Alcohol)
106-98-9	1-Butene
872-05-9	1-Decene
592-76-7	1-Heptene
592-41-6	1-Hexene
591-49-1	1-Methylcyclohexene
693-89-0	1-Methylcyclopentene
124-11-8	1-Nonene
111-66-0	1-Octene
109-67-1	1-Pentene
71-23-8	1-Propanol
821-95-4	1-Undecene
564-02-3	2,2,3-Trimethylpentane
540-84-1	2,2,4-Trimethylpentane (Isooctane)
3522-94-9	2,2,5-Trimethylhexane
75-83-2	2,2-Dimethylbutane (Neohexane)
565-75-3	2,3,4-Trimethylpentane
79-29-8	2,3-Dimethylbutane
565-59-3	2,3-Dimethylpentane
107-39-1	2,4,4-Trimethyl-1-pentene
107-40-4	2,4,4-Trimethyl-2-pentene
108-08-7	2,4-Dimethylpentane
592-13-2	2,5-Dimethylhexane
78-93-3	2-Butanone (Methyl Ethyl Ketone)
126-99-8	2-Chloro-1,3-butadiene (Chloroprene)

CAS #	Name
95-49-8	2-Chlorotoluene
760-21-4	2-Ethyl-1-butene
611-14-3	2-Ethyltoluene (o-Ethyltoluene)
763-29-1	2-Methyl-1-pentene
513-35-9	2-Methyl-2-butene
625-27-4	2-Methyl-2-pentene
78-78-4	2-Methylbutane (Isopentane)
592-27-8	2-Methylheptane
67-63-0	2-Propanol (Isopropyl Alcohol)
108-41-8	3-Chlorotoluene
620-14-4	3-Ethyltoluene (m-Ethyltoluene)
563-45-1	3-Methyl-1-butene
589-81-1	3-Methylheptane
589-34-4	3-Methylhexane
96-14-0	3-Methylpentane
106-43-4	4-Chlorotoluene
622-96-8	4-Ethyltoluene (p-Ethyltoluene)
99-87-6	4-Isopropyltoluene (p-Cymene)
691-37-2	4-Methyl-1-pentene
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)
2198-23-4	4-Nonene
75-07-0	Acetaldehyde
67-64-1	Acetone (2-Propanone)
75-05-8	Acetonitrile
74-86-2	Acetylene
107-13-1	Acrylonitrile
80-56-8	alpha-Pinene
100-52-7	Benzaldehyde
71-43-2	Benzene
127-91-3	beta-Pinene
74-97-5	Bromochloromethane
75-27-4	Bromodichloromethane
75-25-2	Bromoform
74-83-9	Bromomethane (Methyl Bromide)
106-97-8	Butane
141-32-2	Butyl Acrylate
123-72-8	Butyraldehyde
56-23-5	Carbon Tetrachloride
108-90-7	Chlorobenzene
75-00-3	Chloroethane (Ethyl Chloride) Freon 160
67-66-3	Chloroform
100-44-7	Chlorotoluene (Benzyl Chloride)
691-38-3	cis/trans-4-Methyl-2-pentene
156-59-2	cis-1,2 Dichloroethene
10061-01-5	cis-1,3-Dichloropropene
590-18-1	cis-2-Butene

CAS #	Name
7688-21-3	cis-2-Hexene
7642-04-8	cis-2-Octene
627-20-3	cis-2-Pentene
7642-10-6	cis-3-Heptene
7642-09-3	cis-3-Hexene
922-62-3	cis-3-Methyl-2-pentene
110-82-7	Cyclohexane
110-83-8	Cyclohexene
287-92-3	Cyclopentane
142-29-0	Cyclopentene
124-48-1	Dibromochloromethane
60-29-7	Diethyl ether
74-84-0	Ethane
64-17-5	Ethanol (Ethyl alcohol)
100-41-4	Ethyl Benzene
74-85-1	Ethylene
106-93-4	Ethylene Dibromide (1,2-Dibromoethane)
75-69-4	Freon 11 (Trichlorofluoromethane)
76-13-1	Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)
76-14-2	Freon 114 (1,2-Dichlorotetrafluoroethane)
75-71-8	Freon 12 (Dichlorodifluoromethane)
75-43-4	Freon 21 (Dichlorofluoromethane)
75-45-6	Freon 22 (Chlorodifluoromethane)
74-87-3	Freon 40 Chloromethane (Methyl Chloride)
811-97-2	Halocarbon 134A
111-71-7	Heptanal
142-82-5	Heptane
87-68-3	Hexachlorobutadiene
66-25-1	Hexanal
110-54-3	Hexane
496-11-7	Indan
95-13-6	Indene
75-28-5	Isobutane
538-93-2	Isobutylbenzene
31394-54-4	Isoheptane (2-Methylhexane)
107-83-5	Isohexane (2-Methylpentane)
78-79-5	Isoprene
98-82-8	Isopropylbenzene (Cumene)
138-86-3	Limonene
67-56-1	Methanol (Methyl alcohol)
1634-04-4	Methyl tert-Butyl Ether
108-87-2	Methylcyclohexane
96-37-7	Methylcyclopentane
75-09-2	Methylene Chloride (Dichloromethane)
108-38-3	m-Xylene
1330-20-7	mixed Xylenes

CAS #	Name
91-20-3	Naphthalene
104-51-8	n-Butylbenzene
124-18-5	n-Decane
463-82-1	Neopentane
111-84-2	n-Nonane
111-65-9	n-Octane
103-65-1	n-Propylbenzene
1120-21-4	n-Undecane
95-47-6	o-Xylene
109-66-0	Pentane
74-98-6	Propane
115-07-1	Propylene
106-42-3	p-Xylene
100-42-5	Styrene
98-06-6	tert-Butylbenzene
127-18-4	Tetrachloroethene (Perchloroethylene, Tetrachloroethylene)
108-88-3	Toluene
156-60-5	trans-1,2-Dichloroethene
10061-02-6	trans-1,3-Dichloropropene
624-64-6	trans-2-Butene
14686-13-6	trans-2-Heptene
4050-45-7	trans-2-Hexene
646-04-8	trans-2-Pentene
14686-14-7	trans-3-Heptene
79-01-6	Trichloroethene (Trichloroethylene)
108-05-4	Vinyl Acetate
593-60-2	Vinyl bromide
75-01-4	Vinyl Chloride
	Xylene—see mixed, m-, o-, or p-Xylene

APPENDIX B Special Calculations

This appendix contains several calculations to support statements made in the body of this paper. The special calculations include

- Conversion Factors for Parts Per Billion by Volume (ppbv) to $\mu\text{g}/\text{m}^3$
- Estimate of Particulate Emissions from On-Road Vehicles in the Los Alamos Area
- Estimate of Particulate Emissions from Fireplaces in the Los Alamos Area
- Estimate of VOC Emissions from On-Road Vehicles in the Los Alamos Area
- Estimate of VOC Emissions from Fireplaces in the Los Alamos Area

Conversion Factors for Parts Per Billion by Volume (ppbv) to $\mu\text{g}/\text{m}^3$

The VOC results published in the 2001 and 2002 Environmental Surveillance Reports are in units of parts per billion by volume (ppbv). The VOC units in this paper are in $\mu\text{g}/\text{m}^3$. To convert from ppbv to $\mu\text{g}/\text{m}^3$, use the conversion factors below. For example, if you have 2 ppbv of ethyl benzene, multiply it by 4.42 to get 8.84 $\mu\text{g}/\text{m}^3$. To convert $\mu\text{g}/\text{m}^3$ to ppbv, divide ppbv by the factor.

CAS #	Name	ppbv to $\mu\text{g}/\text{m}^3$
100-41-4	Ethyl Benzene	4.42
100-42-5	Styrene	4.33
100-44-7	Chlorotoluene (Benzyl Chloride)	5.26
100-52-7	Benzaldehyde	4.41
10061-01-5	cis-1,3-Dichloropropene	4.61
10061-02-6	trans-1,3-Dichloropropene	4.61
103-65-1	n-Propylbenzene	5
104-51-8	n-Butylbenzene	5.58
105-05-5	1,4-Diethylbenzene (p-Diethylbenzene)	5.58
106-42-3	p-Xylene (including 108-38-3 m-Xylene)	4.42
106-43-4	4-Chlorotoluene	5.26
106-46-7	1,4-Dichlorobenzene	6.11
106-93-4	Ethylene Dibromide (1,2-Dibromoethane)	7.81
106-97-8	Butane	2.42
106-98-9	1-Butene	2.33
106-99-0	1,3-Butadiene	2.25
107-06-2	1, 2-Dichloroethane (Ethylene Dichloride)	4.12
107-13-1	Acrylonitrile	2.21
107-39-1	2,4,4-Trimethyl-1-pentene	4.66
107-40-4	2,4,4-Trimethyl-2-pentene	4.66
107-83-5	Isohexane (2-Methylpentane)	3.58
108-05-4	Vinyl Acetate	3.58
108-08-7	2,4-Dimethylpentane	4.17
108-10-1	4-Methyl-2-pentanone (Methyl isobutyl ketone)	4.17
108-38-3	m-Xylene (including 106-42-3 p-Xylene)	4.42

CAS #	Name	ppbv to $\mu\text{g}/\text{m}^3$
108-41-8	3-Chlorotoluene (measured as 2- and 3-Chlorotoluene)	5.26
108-67-8	1,3,5-Trimethylbenzene	5
108-87-2	Methylcyclohexane	4.08
108-88-3	Toluene	3.83
108-90-7	Chlorobenzene	4.68
109-66-0	Pentane	3
109-67-1	1-Pentene	2.91
110-54-3	Hexane	3.58
110-82-7	Cyclohexane	3.5
110-83-8	Cyclohexene	3.41
111-65-9	n-Octane	4.75
111-66-0	1-Octene	4.66
111-71-7	Heptanal	4.75
111-84-2	n-Nonane	5.33
1120-21-4	n-Undecane	6.5
115-07-1	Propylene	1.75
120-82-1	1,2,4-Trichlorobenzene	7.54
123-72-8	Butyraldehyde	3
123-91-1	1,4-Dioxane (1,4-Diethyloxide)	3.66
124-11-8	1-Nonene	5.25
124-18-5	n-Decane	5.92
124-48-1	Dibromochloromethane	8.66
126-99-8	2-Chloro-1,3-butadiene (Chloroprene)	3.68
127-18-4	Tetrachloroethene (Perchloroethylene, Tetrachloroethylene)	6.89
127-91-3	beta-Pinene	5.66
1330-20-7	mixed Xylenes (see specific m,o, p -xylenes)	4.42
138-86-3	Limonene	5.66
141-32-2	Butyl Acrylate	5.33
141-93-5	1,3-Diethylbenzene (m-Diethylbenzene)	5.58
142-29-0	Cyclopentene	2.83
142-82-5	Heptane	4.17
14686-13-6	trans-2-Heptene	4.08
14686-14-7	trans-3-Heptene	4.08
156-59-2	cis-1,2 Dichloroethene	4.03
156-60-5	trans-1,2-Dichloroethene	4.03
1634-04-4	Methyl tert-Butyl Ether	3.66
2037-26-5	Toluene-d8 (Surrogate)	NA
2198-23-4	4-Nonene	5.25
287-92-3	Cyclopentane	2.91
31394-54-4	Isoheptane (2-Methylhexane)	4.17
3522-94-9	2,2,5-Trimethylhexane	5.33
4050-45-7	trans-2-Hexene	3.5
463-82-1	Neopentane	3
496-11-7	Indan	4.91

CAS #	Name	ppbv to $\mu\text{g}/\text{m}^3$
513-35-9	2-Methyl-2-butene	2.91
526-73-8	1,2,3-Trimethylbenzene	5
538-93-2	Isobutylbenzene	5.58
540-84-1	2,2,4-Trimethylpentane (Isooctane)	4.75
541-73-1	1,3-Dichlorobenzene	6.11
56-23-5	Carbon Tetrachloride	6.39
563-45-1	3-Methyl-1-butene	2.91
564-02-3	2,2,3-Trimethylpentane	4.75
565-59-3	2,3-Dimethylpentane	4.17
565-75-3	2,3,4-Trimethylpentane	4.75
589-34-4	3-Methylhexane	4.17
589-81-1	3-Methylheptane	4.75
590-18-1	cis-2-Butene	2.33
591-49-1	1-Methylcyclohexene	4.17
592-13-2	2,5-Dimethylhexane	4.75
592-27-8	2-Methylheptane	4.75
592-41-6	1-Hexene	3.5
592-76-7	1-Heptene	4.08
593-60-2	Vinyl bromide	4.45
60-29-7	Diethyl ether	3.08
611-14-3	2-Ethyltoluene (o-Ethyltoluene)	5
620-14-4	3-Ethyltoluene (m-Ethyltoluene)	5
622-96-8	4-Ethyltoluene (p-Ethyltoluene)	5
624-64-6	trans-2-Butene	2.33
625-27-4	2-Methyl-2-pentene	3.5
627-20-3	cis-2-Pentene	2.91
64-17-5	Ethanol (Ethyl alcohol)	1.92
646-04-8	trans-2-Pentene	2.91
66-25-1	Hexanal	4.17
67-56-1	Methanol (Methyl alcohol)	1.32
67-63-0	2-Propanol (Isopropyl Alcohol)	2.5
67-64-1	Acetone (2-Propanone)	2.42
67-66-3	Chloroform	4.96
691-37-2	4-Methyl-1-pentene	3.5
691-38-3	cis/trans-4-Methyl-2-pentene	3.5
693-89-0	1-Methylcyclopentene	3.41
71-23-8	1-Propanol	2.5
71-36-3	1-Butanol (n-Butyl Alcohol)	3.08
71-43-2	Benzene	3.25
71-55-6	1,1,1-Trichloroethane (Methyl Chloroform)	5.55
74-83-9	Bromomethane (Methyl Bromide)	3.95
74-84-0	Ethane	1.25
74-85-1	Ethylene	1.16
74-86-2	Acetylene	1.08

CAS #	Name	ppbv to $\mu\text{g}/\text{m}^3$
74-87-3	Freon 40 Chloromethane (Methyl Chloride)	2.1
74-97-5	Bromochloromethane	5.38
74-98-6	Propane	1.83
75-00-3	Chloroethane (Ethyl Chloride) Freon 160	2.68
75-01-4	Vinyl Chloride	2.6
75-05-8	Acetonitrile	1.71
75-07-0	Acetaldehyde	1.83
75-09-2	Methylene Chloride (Dichloromethane)	3.53
75-25-2	Bromoform	10.51
75-27-4	Bromodichloromethane	6.81
75-28-5	Isobutane	2.42
75-34-3	1,1-Dichloroethane (Ethylidene Dichloride)	4.12
75-35-4	1,1-Dichloroethene (Vinylidene Chloride)	4.03
75-43-4	Freon 21 (Dichlorofluoromethane)	4.28
75-45-6	Freon 22 (Chlorodifluoromethane)	3.6
75-69-4	Freon 11 (Trichlorofluoromethane)	5.71
75-71-8	Freon 12 (Dichlorodifluoromethane)	5.03
75-83-2	2,2-Dimethylbutane (Neohexane)	3.58
760-21-4	2-Ethyl-1-butene	3.5
76-13-1	Freon 113 (1,1,2-Trichloro-1,2,2-trifluoroethane)	7.79
76-14-2	Freon 114 (1,2-Dichlorotetrafluoroethane)	7.1
763-29-1	2-Methyl-1-pentene	3.5
7642-04-8	cis-2-Octene	4.66
7642-09-3	cis-3-Hexene	3.5
7642-10-6	cis-3-Heptene	4.08
7688-21-3	cis-2-Hexene	3.5
78-78-4	2-Methylbutane (Isopentane)	3
78-79-5	Isoprene	2.83
78-87-5	1,2-Dichloropropane (Propylene Dichloride)	4.7
78-93-3	2-Butanone (Methyl Ethyl Ketone)	3
79-00-5	1,1,2-Trichloroethane	5.55
79-01-6	Trichloroethene (Trichloroethylene)	5.46
79-29-8	2,3-Dimethylbutane	3.58
79-34-5	1,1,2,2-Tetrachloroethane	6.41
80-56-8	alpha-Pinene	5.66
811-97-2	Halocarbon 134A	4.24
821-95-4	1-Undecene	6.41
872-05-9	1-Decene	5.83
87-68-3	Hexachlorobutadiene	10.84
91-20-3	Naphthalene	5.33
922-62-3	cis-3-Methyl-2-pentene	3.5
95-13-6	Indene	4.83
95-47-6	o-Xylene	4.42
95-49-8	2-Chlorotoluene (measured as 2- and 3-Chlorotoluene)	5.26

CAS #	Name	ppbv to $\mu\text{g}/\text{m}^3$
95-50-1	1,2-Dichlorobenzene	6.11
95-63-6	1,2,4-Trimethylbenzene	5
96-14-0	3-Methylpentane	3.58
96-37-7	Methylcyclopentane	3.5
98-06-6	tert-Butylbenzene	5.58
98-82-8	Isopropylbenzene (Cumene)	5
99-87-6	4-Isopropyltoluene (p-Cymene)	5.58

Estimate of Particulate Emissions from On-Road Vehicles in the Los Alamos Area

Section 6.1 of this paper contains a statement that the “particulate matter from commuter traffic in the Los Alamos area is in the range of approximately 21 tons each year.” The determination of that number is provided here.

Appendix A of an EPA emissions trends report for 1999 [EPA2001] provides a useful ratio. That EPA report states that 49,989,000 tons of on-road vehicle carbon monoxide (CO) were emitted nationwide in 1999. It also gives a PM_{10} value of 295,000 tons for those vehicles. Their ratio is almost 170 (169.45).

In an unpublished report, McBee [McBee2001] estimated that Los Alamos commuter traffic emitted about 4033 tons of CO each year. That estimate is reasonable. Using 2000 census data [Census2000], the ratio of the Los Alamos County population (18,343) to the US population (281,421,906) is 0.000065. Assuming Los Alamos vehicle ownership and emissions are similar *per capita* to the nation, $49,989,000 \times 0.000065 = 3249$ tons of CO. Plus, a significant number of commuters travel in from Santa Fe and almost none commute out. Thus, 4033 tons of CO is not unrealistic.

Thus, we have $4033/170 = 23.72$ tons as one estimate for Los Alamos vehicle particles. If we work from the nationwide PM_{10} value and the Los Alamos fractional population, we have $295,000 \times 0.000065 = 19.2$ tons. The average of the two numbers is 21.5 tons.

Therefore, we estimate that “particulate matter from commuter traffic in the Los Alamos area is in the range of approximately 21 tons each year.”

Estimate of Particulate Emissions from Fireplaces in the Los Alamos Area

Section 6.1 of this paper contains a statement that “Residential fireplaces in the area also contribute substantially to airborne particles, in the rough range of 29 tons/yr.” The determination of that number is provided here.

The 2000 Census [Census2000] states that Los Alamos County had 7937 housing units in 2000. The nation had 115,904,641 housing units. Thus, Los Alamos County has 0.0068% of the housing units in the country. If we assume that the number of fireplaces per housing unit is the same in Los Alamos as it is nationwide and that their use in Los Alamos is similar to nationwide use, then 0.0068% of the nationwide fireplace particulate emissions should be a good rough

estimate of the fireplace emissions in Los Alamos. The EPA trends report [EPA2001] states that the nationwide fireplace PM_{10} emissions in 1999 were 431,000 tons.

Thus, we have $431,000 \times 0.000068 = 29.3$ tons and estimate that “residential fireplaces in the area also contribute substantially to airborne particles, in the rough range of 29 tons/yr.”

Estimate of VOC Emissions from On-Road Vehicles in the Los Alamos Area

Section 6.3 of this paper contains a statement that “... the annual VOC emissions from commuter traffic in Los Alamos are roughly 400 tons per year...” The determination of that number is provided here.

As stated above in the particulate emission estimate for vehicles, the McBee study [Mcbee2001] estimated that non-Laboratory commuter traffic contributes about 4033 tons of CO to the Los Alamos County air each year.

Using the EPA study [EPA2001], the 1999 nationwide CO and VOC on-road vehicle emissions were 49,989,000 and 5,297,000, respectively. Their ratio is 9.44. Thus, we have $4033/9.44 = 427$ tons as one estimate for Los Alamos vehicle VOCs. If we work from the nationwide VOC value and the Los Alamos fractional population, we have $5,297,000 \times 0.000065 = 344$ tons. The average of the two numbers is almost 385.6 tons.

Therefore, we estimate that “the annual VOC emissions from commuter traffic in Los Alamos are roughly 400 tons per year.”

Estimate of VOC Emissions from Fireplaces in the Los Alamos Area

Section 6.3 of this paper contains a statement that “Emissions of VOCs from fireplaces in Los Alamos County are approximately 41 tons per year.” The determination of that number is provided here.

Using the fractional housing units (0.0068%) determined above and, assuming that the number of fireplaces per housing unit is the same in Los Alamos as it is nationwide and that their use in Los Alamos is similar to nationwide use, then 0.0068% of the nationwide fireplace VOC emissions should be a good rough estimate of the fireplace emissions in Los Alamos. The EPA trends report [EPA2001] states that the nationwide fireplace VOC emissions in 1999 were 608,000 tons.

Thus, we have $608,000 \times 0.000068 = 41.3$ tons and estimate that “emissions of VOCs from fireplaces in Los Alamos County are approximately 41 tons per year.”

References

[EPA2001] Environmental Protection Agency, “EPA National Air Quality and Emissions Trends Report, 1999,” EPA 454/R-01-004, www.epa.gov/oar/aqtrnd99/ (March 2001).

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[Census2000] United States Census Bureau (Department of Commerce), “United States Census 2000” [Online], www.census.gov/main/www/cen2000.html.

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