FINAL REPORT

The Feasibility of Performing a Chemical Dose Reconstruction Study at the INEEL

Centers for Disease Control and Prevention
Department of Health and Human Services

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Authors
Patricia D. McGavran, Ph.D., Environmental Risk Assessment, Inc., Boise, Idaho
Marilyn J. Case, Eagle Rock Scientific, Idaho Falls, Idaho

Principal Investigator
John E Till, Ph.D., *Radiological Assessments Corporation*

EXECUTIVE SUMMARY

This report summarizes the results of a study conducted to determine the feasibility of estimating exposures to the public from toxic chemicals released in the past from the Idaho National Engineering and Environmental Laboratory (INEEL). The analysis was based on documentation that was available related to the historical use and release of chemicals at the Site. Documents relevant to historical chemical dose reconstruction were identified, located, photocopied, and reviewed, and relevant information was entered into a database. Former and current Site personnel were interviewed about the use and release of chemicals. Information from these interviews was also entered into a database. Criteria were developed to determine which chemicals were most important considering their toxicity and potential to have been released. We conducted a screening analysis for approximately 108 chemicals. Ultimately, we selected 13 chemicals that possessed the potential to have exposed members of the public. These chemicals were further evaluated for their toxicity and potential to have exposed the public in the past.

In assessing the feasibility of performing a chemical dose reconstruction study at the INEEL, we attempted to answer two questions for each chemical under consideration.

(1) *Could* a dose reconstruction be conducted for this chemical? Was there enough information available to estimate the releases, characterize environmental degradation, determine fate and transport, and calculate an exposure concentration with reasonable uncertainty?

(2) If it was feasible to reconstruct releases of the chemical, *should* a dose reconstruction be performed? Does the preliminary information collected suggest that the amounts released could have been transported to locations where the public could have been exposed so that reconstructing the release and estimating the chemical's health risk to the public would be justified?

It was clear that there does not seem to be enough information available to reconstruct releases for hydrazine, hydroxylamine sulfate, beryllium and lead; however, based on the information that was available, it did not appear that large amounts of these chemicals were released to the air. The release of asbestos, cadmium, chromium, mercury, nitrogen dioxide, nickel, sulfur dioxide, sulfur acid, and 1,1,1-trichloroethane were also evaluated using available source term data, effluent and environmental monitoring data, and calculations of predicted concentrations at U.S. Highway 20/26 and the Site boundary. Based on these analyses, none of the chemicals appear to have been released in quantities sufficient to justify they be included in a dose reconstruction. Screening calculations and documentation suggest that it is unlikely that the air concentrations of these pollutants would have been high enough at the Site boundary or at U.S. Highway 20/26 to have caused health effects.

There was little information available to evaluate mercury releases from the Aircraft Nuclear Propulsion (ANP) Program. Interviews with retired workers suggested that a large amount of mercury was used for shielding but mercury was not routinely released into the environment. One spill, discovered in 1986 and cleaned up in 1995, was described. Potential for releases from buried mercury waste was also investigated.

Theoretical maximum cadmium and chromium concentrations in air from suspension of all of the cadmium potentially in the ICPP percolation ponds and chromium in TRA pond sediments were calculated using EPA-approved suspension rate constants. Predicted air concentrations were less than health risk-based screening concentrations used by the EPA. Chromium released to the air from cooling tower operations also appears to have been insufficient to cause concentrations above levels of concern.

Very little documentation on beryllium use and release at the INEEL has been found. Most of the information on beryllium use and potential release was obtained from interviews. Worker interviews suggest that beryllium may have been machined or hand filed in as many as six locations onsite. No records of environmental releases, or ambient air monitoring associated with any machine shops were found. Soil monitoring has not detected beryllium that may have been deposited as a result of releases from engine tests or a machine shop. Although a shop that machined and finished beryllium tools or parts may be of interest for historical worker health and safety, there does not appear to be any information about releases on which to base source term estimates. We have found no evidence to suggest beryllium was machined in quantities to justify including an assessment of beryllium releases or risk of cancer or chronic beryllium disease from inhalation for people offsite or at locations accessible to the public onsite.

ACKNOWLEDGMENTS

The authors wish to thank Kathleen R. Meyer and Paul G. Voillequé for their technical review, the INEEL Health Effects Subcommittee members and Centers for Disease Control and Prevention staff who reviewed and commented on this work as it progressed, and Sally J. Francis for her editorial support.

Note: At the request of the INEEL Health Effects Subcommittee, statements referenced to personal communications are designated as such in the text of the report. For example, the citation (Abbott 1997) was changed to (Personal Communication with Abbott 1997) and is referenced:

Abbott. M. 1997. Advisory Scientist. Lockheed Martin Idaho Technologies Company. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation* Regarding modeling of the atmospheric dispersion of pond sediments. INEEL Task Order Database MC Number 70710.

CONTENTS

EXECUTIVE SUMMARY iii

ACKNOWLEDGMENTS v

ACRONYMS xi

UNIT CONVERSION xii

INTRODUCTION 1

- History of the Dose Reconstruction 1
- Study Objectives 1
  - Document Database 2
  - The INEEL Health Effects Subcommittee 3

FACILITIES OF MOST INTEREST FOR CHEMICAL RELEASES 5

- Argonne National Laboratory-West 5
- Naval Reactors Facility 7
- Waste Areas 7
- Idaho Chemical Processing Plant 8
- Test Area North 9
- Other Areas of Concerns 9

CRITERIA FOR SELECTING CHEMICALS OF CONCERN 11

- Stage One 11
- Stage Two 13

LIST OF CHEMICALS OF POTENTIAL CONCERN FOR THE INEEL 15

EVALUATION OF RELEVANT EXPOSURE PATHWAYS 21

- Pathways of Exposure to Consider 21

SELECTION OF CHEMICALS OF CONCERN 23

- Information Used to Calculate the Ratios 23
  - Toxicity Information 23
  - Inventory Information 23
- Screening Ratios 28
- Conclusions and Recommendations for the Selection 30

SOURCES OF INFORMATION....31

INEEL Annual Environmental Reports....31
Technical Reports....34
Interviews....34
  Phase I Interview Notes....34
  Other Interviews....38
Logbooks, Ledgers, And Databases....38
INEL Nonradiological Waste Management Information System....39
RCRA and CERCLA Documents....41
Safety Analysis Reports....42
Planning Documents....43
INEL Historical Dose Evaluation....43
ICPP Reports....43
  ICPP Monthly and Weekly Progress Reports....43
  Campaign Reports and Shift Operator Logs....45
  ICPP Annual Technical Reports....45
  ICPP Effluent and Environmental Monitoring Reports....45
Air Emission Inventories....48
Operating Permit....51

PATHWAYS OF EXPOSURE CONSIDERED....53

Wildgame Pathways....53
Air Pathway....53
  Evaporation from Waste Areas....54
  Suspension of Soils and Sediments....54

INFORMATION AVAILABLE TO CALCULATE RELEASE, TRANSPORT, AND DOSES FOR THE CHEMICALS OF CONCERN....59

Asbestos....59
Beryllium....59
Cadmium....64
Chromium....66
  Chromium at TRA....67
  Chromium at ANL-W....69
  Chromium at NRF....68
  Chromium in Waterfowl....68
Hydrazine....69
Lead....70
Mercury....71
  Mercury at the ICPP....71
  Mercury Used for the ANP Program....73
  Mercury at CFA....75
Nickel....75
Nitrogen Oxides....75

        - Emissions Estimates 76
        - Standards 77
        - Ambient Air Monitoring 80
    - Sulfuric Acid 81
    - Sulfur Dioxides 81
    - 1,1,1-Trichloroethane 83
    - Other Chemicals 84
        - Hydroxylamine Sulfate 84
        - Slimicides 84
        - Asbestos and PCBs 86
    - Additional Chemicals 86
        - Explosive Residues 86
        - Hexone 87
        - Cyclohexamine 87
        - Gasoline and Diesel Fuels 88
- CONCLUSIONS 89

- REFERENCES 91

ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
ANL-W	Argonne National Laboratory-West
ANP	Aircraft Nuclear Propulsion (Program)
ARA	Auxiliary Reactor Area
ATSDR	Agency for Toxic Substances and Disease Registry
BTU	British Thermal Unit
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFA	Central Facilities Area
CFSGF	Coal-Fired Steam Generating Facility (at the ICPP)
CY	calendar year
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy Idaho Operations Office
EBR	Experimental Breeder Reactor
EG&G	EG&G Idaho, Inc.
ENICO	Exxon Nuclear Idaho Company, Inc.
EPA	U.S. Environmental Protection Agency
FAST	Fluorinel Dissolution Process and Fuel Storage (Facility)
FPR	Fuel Processing Restoration (Plant)
FY	fiscal year
GWSCREEN	Groundwater Screen (a model for assessing the risk for the groundwater pathway)
HEPA	high-efficiency particulate air (filter)
HTRE	Heat Transfer Reactor Experiment
IARC	International Agency for Research on Cancer
ICPP	Idaho Chemical Processing Plant
IDEQ	Idaho Division of Environmental Quality
IET	Initial Engine Test
INEL	Idaho National Engineering Laboratory
INEEL	Idaho National Engineering and Environmental Laboratory
INEELHES	Idaho National Engineering and Environmental Laboratory Health Effects Subcommittee
INWMIS	INEL Nonradiological Waste Management Information System
IRIS	Integrated Risk and Information Systems (database)
LMITCO	Lockeed Martin Idaho Technologies Company
LOFT	Loss-of-Fluid Test (Facility)
MCL	Maximum Contaminant Level
MSDS	material safety data sheet
NAAQS	National Ambient Air Quality Standards
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NIOSH	National Institute of Occupational Safety and Health
NO_x	nitrogen oxides
NO_2	nitrogen dioxide

N_2O	nitrous oxide
NRF	Naval Reactors Facility
NWCF	New Waste Calcining Facility
OMRE	Organic-Moderated Reactor Experiment
OU	Operable Unit
PBF	Power Burst Facility
PCB	polychlorinated biphenyl (arochlor)
ppm	parts per million
OSHA	Occupational Safety and Health Administration
RAC	Radiological Assessments Corporation
RCRA	Resource Conservation and Recovery Act
RESL	Radiological and Environmental Sciences Laboratory
RfD	Reference Dose for Ingestion
RfC	Reference Concentration for Inhalation
RWMC	Radioactive Waste Management Complex
RWMIS	Radioactive Waste Management Information System
SARA	Superfund Amendments and Reauthorization Act
SC&A	Sanford Cohen and Associates
SO_2	sulfur dioxide
TAER	Toxic Air Emissions Report
TAN	Test Area North
TLV	Threshold Limit Value (for Occupational Exposure)
TRA	Test Reactor Area
TREAT	Transient Reactor Test Facility
USGS	U.S. Geological Survey
VOC	volatile organic compound
WCF	Waste Calcining Facility
WINCO	Westinghouse Idaho Nuclear Company, Inc.
WRRTF	Water Reactor Research Test Facility
ZPPR	Zero Power Physics Reactor

UNIT CONVERSION

one million = 1,000,000 = 10^6
one thousand = 1,000 = 10^3
one hundred = 100 = 10^2
ten = 10 = 10^1
one =1
one tenth = 0.1 = 10^{-1}
one hundredth = 0.01 = 10^{-2}
one thousandth = 0.001 = 10^{-3}
one ten thousandth = 0.0001 = 10^{-4}
one millionth = 0.000001 = 10^{-6}
1 ppb = μg/kg in soil and μg/L in water
1 ppm = mg/kg in soil and mg/L in water
1 kg = 1000 g
1 mg = 0.001 g

1 gal = 3.785 L
1 lb = 0.453 kg, 1 kg = 2.205 lb
1 ton = 907.2 kg

INTRODUCTION

This report summarizes the results of a study conducted to determine the feasibility of estimating exposures to the public from toxic chemicals released in the past from the Idaho National Engineering and Environmental Laboratory (INEEL). The study was intended to provide the basis for recommending whether it is feasible to reconstruct chemical releases for the INEEL given the documentation available.

The study involved developing chemical selection criteria, screening chemicals of potential concern for offsite releases or releases that could have affected the public (as opposed to Site workers) using the criteria, evaluating the selected chemicals, and making recommendations about the feasibility of determining release estimates and exposure concentrations for these chemicals. At the same time, a database for keeping track of relevant documents and interviews was developed. Documents relevant to historical chemical dose reconstruction were identified, located, photocopied, reviewed, and entered into the database. We evaluated whether the quality of the documents and the information in them is adequate for dose reconstruction. In addition, former and current Site personnel were interviewed about the use and release of chemicals.

History of the Dose Reconstruction

In August 1991, the U.S. Department of Energy (DOE) published the *Idaho National Engineering Laboratory Historical Dose Evaluation* (DOE 1991a). The DOE put together an independent technical review committee called the Peer Review Panel and the State of Idaho selected a technical and stakeholder review committee called the Dose Evaluation Review & Assessment Advisory Panel. Both committees noted a lack of public, Native American, and other stakeholder involvement in the dose evaluation. The Governor of Idaho asked the Centers for Disease Control and Prevention (CDC) to perform a more detailed study with public involvement. The CDC completed Phase I of the study, creating a database of all documents at the INEEL relevant to an environmental dose reconstruction, in the fall of 1994. To more fully understand the impact of historic releases of chemicals and radioactive materials from the INEEL offsite, CDC and the INEEL Health Effects Subcommittee (INEELHES) advising CDC, requested that focused feasibility studies be undertaken to identify the need for future dose reconstruction work at the INEEL.

Study Objectives

The objective of this task order was to determine the feasibility of estimating exposures to the offsite public from toxic chemicals released from the INEEL. The study pertains to *historical* doses to the offsite public from *past* chemicals released from the INEEL. This project also involved developing a set of risk-based criteria for determining which chemicals are the most important to study and considering toxicity, quantities potentially released, completeness of exposure pathways, environmental fate and transport, and other relevant factors. The criteria that were developed and agreed to by the INEELHES are described in the section “Criteria for Selecting Chemicals of Concern.” We developed a list of chemicals to be screened using these criteria and selected chemicals for the screening based on their potential to have been released to the air. The results of the screening can be found in the section about titled, “Conclusions and

Recommendations for the Selection". We developed a database to compile and organize information about record relevant to the use and release of the chemicals of concern. We identified documents from the Phase I database, the recommendations of Site personnel, bibliographies, and other listings and obtained the documents from document repositories or individuals onsite. The documents of potential use were photocopied, reviewed, evaluated for usefulness, and briefly abstracted for the database.

Document Database

Marilyn Langan, a consultant to Radiological Assessments Corporation (*RAC*), developed a database for the study called the INELCHEM database. The database used Visual FoxPro , a commercially available Microsoft software product that is relatively easy to use. FoxPro creates database tables with the .dbf extension, which can also be read by other kinds of database programs, such as dBase, Clipper, and Access. The data in the tables can be saved in a number of different formats (such as delimited ASCII) or a format that can be imported into spreadsheets (such as Lotus or Excel) or word processing software (such as Word). The FoxPro tables are portable to either Macintosh or personal computers. Users would not need to purchase the software to browse the contents of the FoxPro tables we have developed.

The INELCHEM database had two entry forms: one for documents and one for interviews. Interview notes from Phase I were treated as documents and entered into the INEL Chemical Database. Interviews completed by *RAC* during this project were entered into the Interview Database.

Phase I interview notes and documents were identified as potentially useful by searching for keywords. The titles of all documents with the keywords 'chemical' in the keyword2.dbf table were reviewed. The Phase I database comment fields, ANALYSIS and ABSTRACT, were large memo fields where text was entered, such as abstracts of documents or interview notes. We searched these memo fields for the word chemical and for 21 potential chemicals of concern. A total of 1835 document titles and abstracts resulted. Many of these obviously pertained to radionuclide releases, but they had Idaho "Chemical" Processing Plant, "radiochemical" or "chemical separations" in the title or abstract.

Phase I database interviews that were tagged during the chemical keyword and individual chemical word searches were reviewed for usefulness and potentially useful documents were entered into the database. All interview notes regarding chemicals in the ANALYSIS memo field of the Phase I database were entered into the comment field of the INELCHEM database. The ANALYSIS memo field entries from the Phase I database appear to have been collected on a form, resulting in a columnar, list format that lacked punctuation. When this was cut and pasted into another FoxPro field, it appeared in paragraph form with the listings and spaces lost. To provide a readable file, the memo field contents were copied into a Microsoft Word file then reformatted. Punctuation (commas, semicolons, and colons behind listed items) was added, misspellings were corrected, and the information was then pasted into the COMMENTS fields of the INELCHEM Database. Each document entered into the database was identified by the reviewer's initials, date, and unique identification number.

In 1998 and 1999, C.M. Wood, with the Centers for Disease Control and Prevention (CDC) transformed the FoxPro Database into an Access Database. Access is a Microsoft product. The information in the INELCHEM Database, also called the Task Order 1 Database, is being combined with the document database being created for Task Orders 5 and 6. Task Order 5 is a feasibility study for conducting a dose reconstruction study for radionuclides released from the INEEL and Task Order 6 involves reviewing documents at the INEEL and the Seattle Records Center that were not adequately reviewed in Phase I. The database will be delivered to CDC when Task Orders 5 and 6 are completed. The MC Numbers associated with the reports referenced in this report (see references) correspond to the numbering system in the new Access Database that combines the documents used for Task Orders 1, 5 and 6.

The INEEL Health Effects Subcommittee

The CDC established the INEELHES, a federal advisory committee, whose members advise the CDC on community, Native American Tribal, and labor concerns about CDC activities. The subcommittee members provide advice and recommendations to the CDC, National Institute of Occupational Safety and Health (NIOSH), and Agency for Toxic Substances and Disease Registry (ATSDR). Progress of this work and methods to be considered have been presented to the INEELHES at each of their meetings using overhead slide presentations and technical memos.

The subcommittee reviewed and approved methods described in a technical memo titled *Criteria, Methods and Exposure Pathways Considered for Selection of Chemicals of Concern for Assessing the Feasibility of Performing a Chemical Dose Reconstruction Study at the INEEL* (McGavran and Till 1997a). The memo included risk-based criteria for determining which chemicals should be included in the feasibility study, a list of chemicals of potential concern to be screened, and a discussion of proposed exposure pathways to be considered.

A draft technical memo titled *Selection of Chemicals of Concern for Assessing the Feasibility of Performing a Chemical Dose Reconstruction Study at the INEEL* (McGavran and Till 1997b) was given to the subcommittee in December 1997, and it was discussed at their December meeting. The memo described the results of the screening and recommended that records containing information on 10 chemicals be reviewed and entered into the database. INEELHES members were asked to comment on the memo. Most of the comments received were oral comments on the record at the INEELHES meeting. Members asked that a simple summary table be added and that some of the descriptions of the chemicals be expanded. Written comments were received from several panel members and the CDC. Rather than finalize and distribute another version of the memo, in the interests of time and efficiency, the revised memo was incorporated into this report.

FACILITIES OF MOST INTEREST FOR CHEMICAL RELEASES

The INEEL, now under the supervision of the DOE, was established in 1949 by the Atomic Energy Commission to conduct research and develop nuclear reactors and related equipment. Over the years, 52 reactors were built at the Site. Many experimental programs, reactor tests and small-scale operations were conducted over the years. The INEEL Site covers an area of 900 square miles and has major facilities located at distant locations throughout the Site. Some of the major programs at the INEEL include the Chemical Processing Program at the Idaho Chemical Processing Plant (ICPP) (formerly called the Chemical Processing Plant), the Liquid Metal Fast Breeder Reactor Program at Argonne National Laboratory-West (ANL-W), the Naval Propulsion Reactors Program at the Naval Reactors Facility (NRF), the Reactor Materials Testing Program at the Test Reactor Area (TRA), and the Aircraft Nuclear Propulsion (ANP) Program at Test Area North (TAN). Various power production and waste management facilities of interest to this study are located throughout the Site.

During the course of this project, the name of the Idaho National Engineering Laboratory (INEL) was changed to the INEEL, with the word Environmental added to the name. Throughout this report, the acronyms INEL and INEEL refer to the same Site.

A description of the facilities in each area of the INEL that operated in the past was provided in the Phase I report (SC&A 1993). One of Sanford Cohen and Associates' (SC&A's) objectives in Phase I was to describe each facility, its operation, and the potential for releases of radioactive and chemical pollutants. The history and status of various facilities over time can also be found in the Site annual environmental reports and monthly progress reports. The following section includes a very brief description of the facilities at which the chemicals of concern were used and released. In the course of this work, we visited the ICPP, Central Facilities Area (CFA), NRF, TAN, TRA, ANL-W, and several facilities located in Idaho Falls, Idaho. We interviewed personnel and photocopied relevant documents stored at each of the facilities. Documents were identified from the Phase I database, references in key reports, and from interviews with personnel at each facility. The personnel were asked if they could recall or knew about any records pertaining to the use and release of chemicals. We appreciate the efforts of our primary contacts, especially Eddie Chew, DOE; Susan Mousseau, ANL-W; Andrew Richardson, NRF; and Doug Wenzel and Dan Staiger at the ICPP and Michael Abbott. They, in turn, introduced us to process engineers, industrial hygienists, record keepers, and others who were very helpful.

Argonne National Laboratory-West

ANL-W is a testing center that conducts advanced reactor systems research. Facilities have included the Integral Fast Reactor Program; the Experimental Breeder Reactor No. 2. (EBR-II), which has been operating since 1964; the Fuel Cycle Facility; the Fuel Manufacturing Facility, which manufacturers or fabricates the uranium-zirconium alloy fuel for EBR-II; the Transient Reactor Test Facility (TREAT), and the Zero Power Physics Reactor (ZPPR).

The EBR-II Cooling tower has been a source of liquid effluent. The makeup water was chemically treated with chromium and other chemicals. Liquid waste was generated in the cooling water discharged by air compressors, air cooling equipment, reactor auxiliary cooling system, primary pump, auxiliary boiler blowdown, demineralizer systems, steam traps, and other equipment. The cooling tower blowdown effluent flowed to a sulfur dioxide treatment tank for reduction of hexavalent chromium (a corrosion inhibitor) to less toxic trivalent chromium. The effluent discharged from the tank was combined with other liquid waste and flowed to a lift station where it was pumped to the interceptor canal, which drained into the Industrial Waste Pond. Liquid waste from the fuel assembly and storage building also flowed to the lift station.

One of the few sources of information for chemical use and discharge at ANL-W before the late 1980s was a draft document written in 1973, describing practices in 1972. In 1972, 19 kg of sodium sulfate and 33 kg of sodium phosphates were released to the Industrial Waste Pond in 9650 gal of blowdown (ANL-W 1973). The waste also contained trivalent chromium, zinc and sulfate ions and sodium salts from chemical treatment of the cooling water. Other industrial effluent contaminants were not measured. In 1972, an estimated 47 kg of zinc, 167 kg of trivalent chromium, 61,545 kg of calcium sulfate (resulting from calcium in well water reacting with sulfuric acid added to the water to maintain pH and to regenerate resin), and 5500 kg of NaOH (used to regenerate resin) were discharged in about 18 million gallons of blowdown water (ANL-W 1973).

The ANL-W Industrial Waste Pond is a 3-acre evaporation pond that received industrial waste effluent. The industrial waste that flowed into the waste pond contained boiler and cooling tower water, treatment chemicals and chemicals used in photographic processes. During 1972, nearly 43 million gal of water were discharged to the pond containing salts, boric acid, and relatively small amounts of solvents. None of the contaminants were chemicals of concern for the dose reconstruction (ANL-W 1973). The recently completed Superfund Remedial Investigation and Feasibility Study for ANL-W contains useful characterizations of waste sites, especially the blowdown ditch, ditch B and the industrial waste pond (Lee et al. 1997). The risk assessment was done for a future residential land use. The chemicals of concern [arsenic, hexavalent chromium, fluoride, polychlorinated biphenyls (PCBs), and organics] were evaluated for pathways of exposure (such as ingestion of soil and homegrown produce and groundwater pathways [Lee et al. 1997]), future potential exposures that are not relevant for historical dose reconstruction. For example, PCBs were a chemical of concern for ingestion of soil in the EBR-II transformer yard. The assessment for most of the waste areas was done for the groundwater and soil ingestion pathways. The air pathway was minor and no contaminants with risks greater than 1×10^{-6} onsite involved the air pathway. Offsite exposure concentrations and risks would be expected to be much lower than onsite concentrations and risks; therefore, finding no contaminants that present a risk onsite for conservative future scenarios suggests that offsite contamination from past releases would have been negligible.

An estimated 11 kg of zinc and 37 kg of chromium were lost to the atmosphere by being windblown (drift) from the cooling tower in 1972. Worst-case calculations were performed out of concern for worker safety and health and hexavalent chromium concentrations in air due to releases from the cooling towers were estimated to be less than occupational limits (ANL-W 1973). Site documents reported no chemical effluent discharges from the large, 200-ft high stack, which received high-efficiency particulate air (HEPA)-filtered effluent from EBR-II (ANL-W 1973).

The TREAT facility had a steam boiler that used oil and discharged effluent to the furnace stacks. The sulfur dioxide content of the flue gas was said to have been monitored periodically to determine compliance with air quality standards (ANL-W 1973). No calculations or monitoring data for the boiler were found in the search of the Phase I database. Other facilities at ANL-W, like ZPPR, and HFEF produced radioactive effluents. Other industrial waste discharges were small volumes from photography labs and building service facilities. The ZPPR-3 air exhaust system used a Chemical Warfare Service filter, presumably to help control radioactive emissions. No chemical constituents for the industrial waste from EBR-I, Boiling Water Reactor Experiment or ZPR-III were recorded in the 1973 ANL-W waste characterization report (ANL-W 1973).

Naval Reactors Facility

The NRF was established in the early 1950s to support the development of Naval nuclear propulsion. The primary facilities were the Expended Core Facility and three prototype nuclear propulsion plants, which were used for training Navy students. The Expended Core Facility was built in 1957 and has been expanded over the years. It examined spent nuclear fuel from the Navy, expended core components and material test specimens. The NRF Industrial Waste Ditch is a 3.2-mile long channel that received nonradioactive wastewater. The channel has been modified and dredged periodically over time. Dredged sediments were placed on the ditch banks. Metal constituents of dredge pile soils exceed background levels. NRF personnel reported that no hazardous compounds have been discharged since 1980. The ditch is now used for wastewater, acids, bases, water, runoff, and ion exchange regeneration solution discharges (DOE 1994a). Before 1980, wastes included photography and laboratory wastes and cooling system water from the prototypes and other equipment. Estimates of the waste concentration and total mass disposed of are given in the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) work plan for the facility (DOE 1992). Of interest are cooling system operations discharges of potassium chromate at 2000 ppm, 220 kg total, and sodium chromate at 500 ppm, 9500 kg total. Waste solvents were listed as trace amounts. Laboratory operations included mercuric nitrate at 10 ppm or <1 kg total and trace amounts of hydrazine and hydroxylamine sulfate (DOE 1992).

Until 1979, NRF liquid wastes were discharged to leaching beds. The Superfund investigation was done primarily for radionuclides, but it mentioned that oil was discharged to the leaching bed. Chromium was used for corrosion resistance in some of the shield tanks and was probably also discharged to the leaching bed. Chemicals were also discharged from the radiochemistry and training laboratory. An evaluation of the maximum amount of laboratory waste that could have been discharged to the leaching bed from the chemistry laboratory at A1W was made in 1969 and 1979 as a part of a proposed upgrade for processing equipment. Using the estimates of maximum laboratory discharge rates from 1970, they assumed 60% went to A1W. A conservative assumption that discharges continued until 1972 was made although the first S1W leaching bed was built in 1960. Combined discharge estimates for both leaching beds were small; 73 gal of carbon tetrachloride, 6 lb of mercuric nitrate, 9 lb of mercuric iodide, and 9 gal of hydrazine, in laboratory wastes (DOE 1995).

Waste Areas

Landfills and waste disposal pits in many of the areas onsite were used to dispose of waste oil, solvents, and metals, including chromium and mercury compounds. Most of the materials were buried in barrels or other containers and evaporation was a minuscule concern compared to infiltration of leaking containers to groundwater. Much of the waste was construction debris. Records of the waste received and disposed of were not kept during the early years (Phase I

Interview with Palmer MC 503; DOE 1995). Estimates of waste buried in the pits and landfills have been or are being made for CERCLA characterization studies, but estimating the amounts that may have evaporated would be difficult.

Idaho Chemical Processing Plant

The ICPP has received, stored, and processed spent fuel, calcined liquid high-level waste, and developed technology for chemical processing programs. The major mission of the plant, until 1992, was to process spent fuel to recover enriched uranium for reuse. Some of the facilities at the ICPP include the Fluorinel Dissolution Process and Fuel Storage Facility, where radioactive spent fuel is stored underwater and where fuel was dissolved and reprocessed; the Waste Calcining Facility (WCF), which converted high level liquid waste into granular solid which is stored in stainless steel encased concrete bins; the ICPP processing corridors, built in the 1950s for fuel reprocessing; and the High Level Waste Tank Farm, with 11 underground liquid storage tanks. Descriptions of the ICPP off-gas systems, evaporator, solvent extraction process and ion exchange system can be found in safety analysis and other technical reports (Dickey et al. 1972). The ICPP released nitrogen oxides, sulfur dioxide, mercury, and other metals in to air. Toxic metals, such as mercury and cadmium in liquid effluents, were discharged to the disposal well until 1985 when the use of the disposal well was reserved for emergencies and effluents were discharged to the percolation pond. The disposal well was sealed in 1989.

The ICPP Atmospheric Protection was installed in 1972. The design criteria for the system discussed the need for the filters, fans, and other equipment to be stainless steel and acid resistant because of the large amount of nitrogen dioxide in the off-gas, but the off-gas was not characterized. There were four main process off-gas systems: (1) vessel off-gas, (2) zirconium dissolver off-gas, (3) aluminum dissolver off-gas, and (4) WCF process off-gas. The vessel off-gas system vented all tanks and vessels except for the dissolvers. The zirconium dissolver off-gas has a caustic scrubber to remove hydrofluoric acid mist. The aluminum dissolver off-gas consists of other exhaust including the condensor-demister system. This system collects off-gas from the continuous dissolvers for aluminum fuels (of interest to us because of the mercury released), the evaporator, and the electrolytic dissolver. The condensor-demister system exhausts the off-gas from two batch dissolvers for aluminum fuels and can be routed to the offgas system or the Rare Gas Plant. The modifications in 1972 and addition of the Atmospheric Protection System were focused on filtering radioactive materials. A Preliminary Safety Analysis Report for the Atmospheric Protection System recommended that several nonradioactive pollutants be monitored, including sulfur dioxide, oxides of nitrogen, mercury, and trace metals (Nelson 1971). The influence of condensers and demisters on the nonradioactive pollutants was not addressed.

The high level wastes tanks at the ICPP are vented to the ICPP stack. The vent system in the cooled tanks includes a reflux condenser. The solid waste storage tanks are also vented to the stack. The filtering of radionuclides in any gas that might be evolved from the tanks is discussed in the Safety Analysis (Nelson 1971), but there is no mention of mercury or volatile solvents being vented from the tanks. Nitrogen oxides (NO_x) have also been released from the denitration facility in the basement of the CPP-602 building, which converts uranyl nitrate to uranyl trioxide. The off-gas from the denitrator enters the vessel off-gas system. The NO_x Reduction Pilot Plant is in the low bay area. It was used in the late 1980s to treat a simulated off-gas stream from the New Waste Calcining Facility (NWCF) for removal of NO_x using a catalytic reduction process and ammonia injected into the exhaust stream. The treated simulated off-gas was then vented directly to the main stack.

L.P. "Pete" Mickelsen, Plant Shift Manager at the ICPP, provided an interesting oral history of ICPP operations and processes in Phase I. Mr. Mickelsen had worked at the ICPP since 1952 and was familiar with every process. He said that very large quantities of nitric acid were used (400 L/hr) to precipitate barium nitrate in the RaLa process. He said no chemical explosions occurred at the ICPP, but there were criticality accidents (Phase I Interview with Mickelsen MC 525).

Test Area North

TAN includes the Initial Engine Test (IET) facilities that were used for the Aircraft Nuclear Propulsion (ANP) Program, which was ended in 1961, and then for the Space Nuclear Auxiliary Power Transient Program. The ANP Program attempted to build an airplane powered by nuclear energy. The ANP Program used mercury as shielding material. Another important program at TAN was the Loss-of-Fluid Test (LOFT) Facility, which operated from 1965 to 1975. This was a small-scale model of a commercial pressurized water reactor used to test accident conditions. The Three-Mile Island-2 Unit Core Offsite Examination Program at TAN examined Three-Mile Island core samples from 1985 to 1990.

Other Areas of Concerns

Percolation and evaporation ponds at CFA and TRA are also of interest for this study.

Chemical releases were not considered in the INEL Historical Dose Evaluation (DOE 1991a). The Environmental Survey's Preliminary Report from 1988, authored by DOE's Office of Environmental Audit, lists many "problem area's defined as existed or suspected environmental problems." However, most of these are of concern because of potential groundwater contamination. Of interest to the survey were

- Significant petroleum spills. Numerous petroleum product spills have occurred at the INEL from line and tank failures and transfer accidents. Four significant spills were used for the survey: one at the ICPP involving kerosene, one at TAN/LOFT involving diesel fuel, and two at CFA involving diesel fuel. These spills were not thought to have affected the public because access to the sites was controlled or the releases were underground leaks. Resuspension was considered insignificant because of the rapid seepage of liquid in the porous soil.
- Significant spills involving metals. Numerous releases have occurred through tank failures, cooling tower blowdown, and solvent disposal. Four significant spills involving metal contamination occurred at the ICPP and one at TRA. Hexavalent chromium release to groundwater was the main concern. Resuspension was thought to be minor and flow to surface water did not occur.
- Air impacts from ICPP stacks. The main and Fluorinel Dissolution Process and Fuel Storage (FAST) Facility stacks at the ICPP were the two main point sources of air contaminants and oxides of nitrogen drove the ranking. Four other elements listed as being evaluated were cadmium, mercury, fluoride, and boron.

CRITERIA FOR SELECTING CHEMICALS OF CONCERN

To make better use of limited resources, chemicals of potential concern for dose reconstruction were selected using risk-based criteria. We determined which chemicals were the most important to evaluate in two stages. The first stage was a conservative comparison of a release estimate to a toxic concentration. An upper-bound potential release quantity was derived using inventory or use amounts and predicted dispersion. A concentration that might be toxic was determined from published values described below. The second stage involved a more detailed analysis of environmental fate and transport parameters, degradation, exposure pathways, knowledge of processes for which the chemical was used, and other relevant contaminant-specific characteristics. The second stage evaluation was intended to provide a more realistic comparison of potential concentrations in the environment and toxic concentrations.

Stage One

The inventory amount was determined from historical documents; inventories, such as the Superfund Amendments and Reauthorization Act (SARA) Title III reports submitted by the Site to the Environmental Protection Agency (EPA); and other available records (DOE 1997a). We recognized that inventory records were likely to be incomplete and inventory amounts for earlier years of operation might not be available. The largest inventory amount reported for any one year was used.

Toxicity values were obtained or derived from the US Environmental Protection Agency's (EPA's) 1995 Health Effects Summary Tables; 1995 National Ambient Air Quality Standards (NAAQS) in the Code of Federal Regulations, Part 50; the 1996 Integrated Risk and Information System database; the most recent ATSDR's Toxicity Profiles; and workplace standards published by the American Conference of Governmental Industrial Hygienists (ACGIH) and by the Occupational Safety and Health Administration or NIOSH. Hazard identification information was obtained from the Reprotext database and ATSDR Toxicity Profiles. We used information on developmental and reproductive hazards in the workplace reported by ACGIH, NIOSH (1995), and Sax (1993). A carcinogenicity designation was given for all of the chemicals that might be carcinogenic. Published EPA designations (A, B1, B2, C, D, and E) were used, if available, followed by the International Agency for Research on Cancer designations, ACGIH categories, then information from the National Toxicology Program.

The following toxicity values were used depending on which values had been determined and published:

- Concentrations calculated from unit risk levels for a 1 in 10,000 (10^{-4}), 1 in 100,000 (10^{-5}) and 1 in 1 million (10^{-6}) increased cancer risk
- NAAQS
- Maximum Contaminant Levels (MCLs), (Federal Drinking Water Standards)
- Concentrations calculated from reference dose or reference concentration
- Workplace standards, threshold limit values. or permissible exposure levels, which have been divided by 10 to adjust for protection of healthy workers versus more sensitive individuals in the general population.

The lowest, most stringent value was used for the health effect of concern, which is the effect that occurs at the lowest exposure (most often chronic, developmental, or reproductive effects or cancer). The toxicity values listed above were developed by different agencies and groups for different purposes. In general, using values developed to protect the public from environmental contaminants was preferable to standards developed to protect workers from occupational hazards.

If no toxicity values were published, we examined Material Safety Data Sheets for animal toxicity data. The lethal dose for 50% of test organisms was divided by 100,000 as a conservative approximation of the threshold toxicity value (Layton et al. 1987).

The screening ratio for chemicals released into the air was the ratio of the estimated concentration to the concentration believed to be toxic. Mathematically,

$$\text{Ratio} = \frac{Q_a\ (\text{kg/s}) \times \chi/Q\ (\text{s/m}^3) \times 10^9\ (\mu\text{g/kg})}{\text{Tox}_a(\mu\text{g/m}^3)} \qquad (1)$$

where
Q_a = potential upperbound release rate of the chemical to the air
Tox_a = air concentration that corresponds to a level of concern (using the lowest published concentration – most stringent value)
χ/Q = atmospheric dispersion factor.

We used a reasonably conservative annual average χ/Q of 5.67×10^{-8} s/m^3 for the INEEL boundary, based on National Emission Standards for Hazardous Air Pollutants (NESHAPs). The standards require that compliance be demonstrated using models and procedures determined to be suitable by the EPA. This value is from NESHAPs calculations for releases from the ICPP, which involve a hypothetical scenario of an individual residing continuously at a point of maximum air concentration at the INEEL Site boundary. This is a conservative (or cautious) assumption that would lead to an overestimate of risk because no one resides at this location.

At the request of the INEELHES, other dispersion values were examined. Values were selected from χ/Qs published in Sagendorf (1996), for several locations where members of the public may have spent time. Scenarios examined included a bicyclist on U.S. Highway 20/26, which goes through the INEEL south of the ICPP; the cabin at Frenchman’s Creek, which is used for part of the year; a telephone repairman who might repair phone lines along roads onsite; and someone using onsite livestock grazing areas. The 1996 dispersion values for these locations were actually less conservative than the NESHAPs value. The consensus of the INEELHES was that the more conservative NESHAPs value was the most appropriate value to use for screening.

Most chemical discharges to the air were not measured, therefore we used the equation below to calculate the release rate to the atmosphere (Q_a)

$$Q_a\ (\text{kg/s}) = \frac{I\ (\text{kg}) \times Rf_a}{3.16 \times 10^7\ \text{sec/yr}} \qquad (2)$$

where
I = maximum annual inventory or usage amount (in kg)
Rf_a = release fraction.

The estimate of release rate assumed that 100% of the inventory was used each year. For volatile chemicals, the release fraction $RF_a = 1.0$, which is all of the chemicals assumed to have evaporated into the air. A release fraction of 0.005 was used for nonvolatile liquids and solids. Chemicals with a screening ratio greater than, equal to, or approaching 1 were to be subjected to further evaluation.

We knew that inventory information was not available for some chemicals. Using Equation (2), we calculated the material inventory necessary to produce a screening ratio approaching 1, and we tried to assess whether this amount could have been present onsite.

Obviously, inventory amounts were not useful for determining potential releases of compounds formed during processes, such as oxides of nitrogen formed from nitric acid in dissolvers or sulfur dioxide formed from combustion processes. We used monitoring information or knowledge of throughput for these processes to estimate releases and determine whether each pollutant should be further evaluated.

Stage Two

The second stage of evaluation involved gathering information about the use and disposal of the chemical, environmental fate, transport, degradation, transformation, and other characteristics of the chemical. This information allowed us to better determine the potential exposure and assess the need to evaluate the chemical in a dose reconstruction.

LIST OF CHEMICALS OF POTENTIAL CONCERN FOR THE INEEL

We developed the list of chemicals to be screened using the sources listed below:

- C.M. Wood's list of 973 C*hemicals and Radioactive Materials at the INEL*, compiled from the Phase I Document Database and Report (SC&A 1994)
- Phase I Report, prepared for CDC by Sanford Cohen and Associates (SC&A 1994)
- Interviews with retired and current INEEL personnel
- *Preliminary Draft Report of the Cohort Mortality Study at the INEL* (NIOSH 1993)
- *1989 Toxic Air Emissions Report* (TAER) (Ecology and Environment 1994).
- *List of Hazardous Substances in the Soil, Sediment and Groundwater at the INEEL* (ATSDR 1995).
-

In addition, we attempted to locate Fire Department inventory records for the INEEL. Several workers and retired individuals suggested we look for records the Fire Department may have kept on chemical hazards. The fire protection engineers for each area recorded the location of hazardous or reactive chemicals that would be of concern during a fire for most of the buildings onsite. These records were called hazard inventories or prefire plans. In most cases, only materials considered immediately dangerous to life or health were listed. In some cases, the amounts stored may have been recorded. There was also a CARDEX system, later called RunCards, which are now computerized, that could be examined by the firefighters as they responded to a fire alarm. The cards contained information about each building and the hazardous materials stored there. We talked with both retired and current personnel from the Fire Department, Fire Marshall's Office, area fire protection engineers, Landlords/Building Services; no one has been able to locate any of these records from the earlier years. It appears that as the information was updated, earlier versions were discarded. Retirees mentioned that the initial cataloging of materials was very time consuming and required Fire Department personnel to inspect each building, note the location and types of materials, and record the information. They believe that the older records should have been archived, but they could not suggest a probable storage location.

Jim Brown, a fire engineer at the INEEL, looked through the Fire Department historical records in storage. He found some incident response records and alarm test data but none of old CARDEX or inventory records. He did locate a prefire plan for the ICPP for 1982, which was photocopied and entered into the database. This listed amounts of chemicals stored in various rooms and seemed comprehensive. However, the amounts were all less than the SARA Title III amounts reported for the ICPP for 1989, so we used the SARA Title III amounts. Current prefire plans would be expected to contain similar, perhaps less specific information than the SARA inventories. We asked the following personnel about inventory records: George Rigby, deputy chief, Fire Department; Spense Settles, fire marshal; Mark Johnson, Fire Department; Gary Braun, Building Services; Jim Brown, fire engineer; Dick Beers (R.J. Beers), retired, (the first fire protection engineer at the Site); John Horan, retired head of the Industrial Hygiene Group, current INEELHES panel member; Todd Lewis, industrial hygienist to Fire Department; Ron Savage, retired, Springfield, Idaho; Ken Dierden, retired, Salmon, Idaho; Bill Harrie, retired industrial hygienist, Idaho Falls; Chris Bloxham, currently in charge of prefire plans; and Mark Hunter, retired fire engineer, Idaho Falls.

Some DOE sites are required to have a spill prevention control and countermeasures plan, which can be useful because these plans often contain descriptions of chemical and waste storage tanks; tank contents; tank capacities; and in-place containment measures, such as berms or dikes. Because of the lack of surface water at the INEEL, it does not have such a plan. However, the Site does have a *Site-Wide Contaminant Source Inventory*, which is an appendix to the *INEL Groundwater Monitoring Plan* (DOE 1993b). The Contaminant Source Inventory lists facilities and sites that have an impact on groundwater quality. Table A-1 in the document shows the type of facility in each area. A total of 998 facilities are tallied. The tank capacities were not totaled, but 89 aboveground tanks and 246 underground tanks were tallied. Another part of the effort, currently underway, is the *LMITCO Tank Inventory* (Personal Communication with Depperschmidt and Bennett 1997). This inventory lists the area, tank number, tank description, tank contents, operational status, removal date, CERCLA number, manager, contact, and capacity and also contains yes/no fields for mixed waste, new, regulated, empty/not empty information (Personal Communication with Depperschmidt and Bennett 1997).

From all of the sources described above, a draft list of potential chemicals of concern at the INEEL was prepared and reviewed by the INELHES and interested Site personnel. Various reviewers added 9 chemicals and the resulting list of 108 chemicals is shown in Table 1. The reference and location acronyms are defined in the table footnote.

Table 1. Chemicals of Potential Concern

Chemical	Reference and location[a]
Acetone	SC&A: ICPP, TRA, ANL-W; NIOSH; ATSDR
Acetonitrile	SC&A: ICPP
Aluminum	SC&A: ICPP, TAN, CFA, ANL-W; ATSDR
Ammonia	TAER: ICPP
Ammonium hydroxide	SC&A: ICPP, ANL-W
Ammonium nitrate	TRA
Aniline	SC&A: ICPP, ANL-W
Arsenic	SC&A: ICPP, TAN, NRF, ANL-W; NIOSH; ATSDR
Asbestos	SC&A: ICPP, TRA, TAN, NRF, ANL-W; NIOSH
Barium	SC&A: ICPP, TRA
Benzene	SC&A: ICPP, TRA, TAN, NRF, ANL-W; NIOSH; ATSDR
Beryllium	TRA; NIOSH
BETZ compounds	SC&A: PBF-302 Injection Well TRA
Biphenyl	OMRE
N-Butyl Alcohol, butanol	NIOSH; SC&A: ICPP
Cadmium	SC&A: ICPP, NRF; ATSDR
Carbon disulfide	SC&A: ICPP, NRF, ANL-W; NIOSH
Carbon monoxide	SC&A: TRA
Carbon tetrachloride	SC&A: ICPP, NRF, CFA, ANL-W; NIOSH; ATSDR
Chlorine	NIOSH
Chloroform	NIOSH; ATSDR
Chromium	SC&A: ICPP, TRA, TAN, NRF, ANL-W; NIOSH; ATSDR
Cobalt	ATSDR
Copper	NIOSH; ATSDR
Cyanide	TAN, NRF
Dichloroethane	ATSDR
Diesel fuels	SARA 312 Report
Diethanolamine	SC&A: TAN
Diethylhexylphthalate	ATSDR; TRA
Diethylphthalate	ATSDR
Dionodic	PBF-302 Injection Well and PBF Evaporation Pond
Dodecane	SC&A: ICPP TRA
Endrin	SC&A
Ethanol	TAER; NIOSH
Ethylbenzene	ATSDR
Ethylene glycol	TAN
Fluoride	SC&A: NRF
Fly ash	NIOSH
Freons	NIOSH; ICPP

Table 1. Chemicals of Potential Concern

Chemical	Reference and location[a]
Gasoline	SC&A: CFA
Gallium oxide	SC&A
HEDP, Hexaethyldiphosphate	
Hydroxy diphosphoethane	SC&A: PBF Evaporation Pond
Hexachlorobutyldiene	ATSDR
Hexane	NIOSH; ICPP
Hexone (methyl isobutyl ketone) (MIBK)	SC&A: ICPP TRA; TAER
Hydrazine	SC&A: PBF-302 Injection Well TAN
Hydroborofluoric acid	SC&A: ICPP
Hydrocarbon diluents, paraffins	SC&A: ICPP
Hydrochloric acid	SC&A: ICPP; NIOSH
Hydrofluoric acid	SC&A: ICPP, TAN, CFA, ANL-W
Hydrogen fluoride	NIOSH
Hydroxylamine sulfate	SC&A: TAN
Kerosene (AMSCO)	SC&A: ICPP, TRA
Lead	SC&A: ICPP, TRA, TAN, NRF, ANL-W; NIOSH; ATSDR
Lindane	SC&A: ICPP, NRF, TAN
Lithium	SC&A: TAN
Magnesium	NIOSH; ATSDR; ICPP
Manganese	ATSDR; ICPP
Mercury	SC&A: ICPP, TRA, TAN, CFA, ANL-W; NIOSH; ATSDR
Mercuric nitrate	SC&A: ICPP, TRA, TAN, CFA, ANL-W
Methanol	TAER; ICPP, TAN
Methoxychlor	SC&A: NRF
MethoxyDDT	SC&A: ICPP, NRF, TRA
Methylene B15	SC&A: TRA
Methylene chloride	NIOSH; ATSDR
Methyl ethyl ketone	NIOSH
Methylisobutyl ketone	ATSDR; ICPP
Monoethanolamine	TAN
Napthalenes	TAN
Nickel	TAER; ICPP
Nitrates	SC&A: ICPP; ATSDR
Nitric acid	SC&A: ICPP, NRF, ARL-W
Nitrous oxides	SC&A: ICPP; NIOSH
Oxalic acid	SC&A: ICPP, TAN
Perchloric acid	SC&A: ICPP
Phosphoric acid	SC&A: ICPP, TRA, NRF; NIOSH
PCBs	ATSDR; TRA, TAN
Potassium hydroxide	SC&A: TRA
Potassium Permanganate	

Table 1. Chemicals of Potential Concern

Chemical	Reference and location[a]
Propanol	TAER; SC&A: ICPP, TAN
Propylene glycol	SC&A: TAN
Selenium	SC&A: ICPP, NRF; ATSDR
Silver	SC&A: ICPP
Slimicide	SC&A: PBF–302 Injection Well
Sodium	SC&A: ICPP
Sodium hydroxide	SC&A: ICPP, TRA, TAN, NRF, ANL-W; NIOSH
Sodium nitrate	SC&A: CFA
Sodium tulytriazule	SC&A: TRA, TAN
Stoddard solvent	SC&A: 500 gallons CFA, TAN; TAER
Styrene	NIOSH
Sulfuric acid	SC&A: ICPP, TRA, NRF, ANL-W
Sulfur dioxide	SC&A: ICPP, TAN, ANL-W
Terphenyls	MORE
Tetrachloroethylene	TAER
Toluene	SC&A: ICPP NRF ANL-W; NIOSH; ATSDR
Toluene di isocyanate (TDI	NIOSH
Toxaphene	NRF
Tributyl phosphate	SC&A: ICPP, TRA; ATSDR
Trichloroethane (TCA, Trichlor)	SC&A: ICPP, NRF; ATSDR
Trichloroethylene (TCE)	SC&A: ICPP, CFA, NRF, CFA, ANL-W; ATSDR
Uranium	SC&A: TAN
Vanadium	SC&A: ICPP, TAN, NRF, ANL-W; ATSDR
Xylenes	NIOSH; ATSDR; TAN
Zinc	NIOSH; ATSDR; TAN
Zirconium	SC&A: ICPP, TAN, NRF, ANL-W

[a] ANL-W = Argonne National Laboratory-West; CFA = Central Facilities Area; ICPP = Idaho Chemical Processing Plant; NRF = Naval Reactors Facility; TAN = Test Area North; TRA = Test Reactor Area.

EVALUATION OF RELEVANT EXPOSURE PATHWAYS

Pathways of Exposure to Consider

Assessing the feasibility of conducting a chemical dose reconstruction for the INEEL involves determining which chemicals may have been released and if chemicals were transported in sufficient quantities to be of concern for human exposure. Although many chemicals have been used, stored, and buried at the INEEL, many have not been released to the environment or have not been transported offsite. Typically, dose reconstruction is most concerned with

- Materials that are released to the air and can be inhaled or ingested once deposited from the air onto vegetation, surface water, and soil and accumulated in livestock, game, and fish
- Materials that are released to surface waters that travel to offsite drinking water sources or accumulate in fish
- Materials that are released to soil and can become suspended into the air by wind erosion or be leached into groundwater and may move offsite
- Releases of materials to groundwater that can move offsite, which expose people who drink well water and use groundwater for other domestic purposes

Other exposure pathways, such as exposure to irrigation water, rainwater cisterns, or waterfowl, may also be of interest. Chemicals released to the air may be assessed for risk from inhalation or they might be deposited onto food and bioaccumulate up the food chain. Because the entire inventory is assumed to be available for release, hypothetical releases of materials spilled onto the soil and later resuspended would be accounted for in this initial assessment.

The INEEL does not discharge effluent to surface water that flows offsite; therefore, surface water is not considered a complete exposure pathway for dose reconstruction. Occasional flooding of the Big Lost River and retention ponds may result in transport of contaminants, but these surface waters do not represent pathways of exposure for people offsite. Flow in the Big Lost River infiltrates to the Snake River Plain Aquifer. Other surface water drainages that provide recharge to the aquifer at the INEEL include Birch Creek, Little Lost River, and Camas Creek (Bartholomay et al. 1995a). There are no liquid discharges to these streams from INEEL operations (DOE 1991a).

The Snake River Plain Aquifer is a primary supply of drinking water for most of southern Idaho. Disposal wells were used to inject wastewater into the Snake River Plain Aquifer from 1953 to 1984 at the ICPP, from 1964 to 1982 at TRA, and from 1953 to 1972 at TAN (Bartholomay et al. 1995a; Orr and Cecil 1991; Pittman et al. 1988.) Waste buried at the Radioactive Waste Management Complex (RWMC) includes organic compounds that have migrated via diffusion and floodwaters from waste disposal sites into the soil and into the underlying groundwater. Recent Resource Conservation and Recovery Act (RCRA) and CERCLA (Superfund) reports document this type of contamination.

The U.S. Geological Survey (USGS) maintains a monitoring network at the INEEL to determine the movement of wastes in the aquifer. Chemical and radioactive wastes have migrated from less than 1 to about 9 miles southwest of disposal areas at the INEEL. Tritium was detected in water from wells along the southern boundary of the INEEL between 1983 and 1985 (Bartholomay et al. 1995b). Sodium, chloride, nitrate, sulfate, chromium, lead, mercury, and organic compounds (like 1,1,1 trichloroethane and carbon tetrachloride) have been detected in groundwater beneath the Site (Bartholomay et al. 1995a). Chlorine-36, a sensitive tracer that can be detected at very low concentrations and is used to study groundwater movement at the INEEL, has been detected in offsite wells (DOE 1991b).

Groundwater moves from the northeast to the southwest under the INEEL, and it is eventually discharged to springs along the Snake River about 100 miles southwest of the INEEL. The USGS and Idaho Department of Water Resources also monitor the aquifer from the southern boundary of the INEEL to the Hagerman, Idaho area. To date, all contaminants measured were at concentrations less than drinking water standards (Bartholomay et al. 1995a).

Contaminant transport calculations in groundwater were also performed by *RAC* using the GWSCREEN groundwater model (Rood 1994; Rood et al. 1989). Calculations were done for a nondecaying, nonsorbing tracer, and they provided a conservative estimate of dilution at the nearest INEEL boundary location downgradient from the ICPP. Based on these calculations and the USGS and Idaho Department of Water Resources data, the INEELHES agreed that for past releases the groundwater pathway –(transport of contaminants in groundwater to offsite wells) does not appear to have been a complete pathway for people using groundwater offsite. Therefore, chemicals in groundwater are not evaluated as a part of this study. This does not imply that groundwater contamination may not have been important for workers exposed to onsite groundwater or that it will not be important for future exposures offsite. Groundwater contamination is of great interest to people in southeastern Idaho.

The INEELHES suggested that ingestion of wildgame that lived or migrated from onsite areas might be important for some people. Of particular interest were ducks, geese, rattlesnakes, jackrabbits, antelope, deer, and elk. The subcommittee thought that scenarios of subsistence hunting and poaching might have been realistic during the 1950s. Wildgame animals were also an important part of the diet of Native Americans.

Chemicals, most notably chromium, mercury, and organic compounds, that may have accumulated in wildgame and chemicals in retention ponds and areas to which waterfowl and other wildlife may have had access were evaluated further.

SELECTION OF CHEMICALS OF CONCERN

This selection of chemicals of concern was conducted according to the methods described in a technical memo submitted by Radiological Assessments Corporation (*RAC*) in July 1997, called *Criteria, Methods, and Exposure Pathways Considered for Selection of Chemicals of Concern for Assessing the Feasibility of Performing a Chemical Dose Reconstruction at the INEEL* (McGavran and Till 1997a). The criteria and methods and the exposure pathways are described in previous sections of this report.

The screening ratio was defined to be the estimated potential air concentration (derived from inventory records and predicted dispersion) to a toxic air concentration (health-based regulatory standard or threshold level) was calculated for chemicals of potential concern using Equations (1) and (2). The screening ratios and the values used to calculate them are shown in the table in Appendix A.

For some of the chemicals, information from which to estimate an inventory amount could not be found. A hypothetical inventory amount that would have had to have been used to obtain a screening ratio of 1 was calculated and is shown in the last column of Table 1 in Appendix A.

Information Used to Calculate the Ratios

Toxicity Information

The sources of the toxicity data used to calculate the screening ratios were described in detail in McGavran and Till (1997a). The inhalation pathway is of greatest interest for the selecting chemicals of concern because surface water and groundwater, historically, do not represent a complete exposure pathway for people offsite. Nevertheless, many of the compounds listed are of most health concern when ingested in drinking water or food. The EPA has derived oral slope factors or reference doses for many of these compounds that can be used for risk assessments evaluating groundwater, surface water, or drinking water pathways. However, no inhalation slope factors or reference concentrations for air have been determined for some of these chemicals. Some of these common water contaminants are also chemicals used in the workplace with occupational standards that can be used for the screening. Others, such as various nitrates and propylene glycol, are not atmospheric contaminants, even in the workplace, and no permissible exposure level for air has been determined for them.

No toxicity information, including any on current Material Safety Data Sheets (MSDSs), could be found for gallium oxide, Dionodic, or sodium tulytriazule. Sodium tulytriazule was reported to have been used at TAN and TRA (SC&A 1994). Eddie Chew found mention of sodium tolytriazole in INEL Nonradiological Waste Management Information System (INWMIS) records (Personal Communication with Chew 1997). It is likely that the compound was misspelled in the Phase I listing. Documents provided by ANL-W after we selected the chemicals of concern explained the use of tolytriazole (ANL-W 1987).

Inventory Information

Inventory amounts were derived from many sources. Key sources included

- SARA 312 reports for the INEEL, submitted to the EPA since 1989. These reports provide the maximum and average amounts of chemicals present during the year at various Site locations. In many cases, the maximum and average amounts reported were the same. We used the highest average amount found for any year.

- A memorandum written by L. C. Witbeck in 1990 to Argonne personnel listing an inventory for ANL-W in 1989, which was to be updated for the 1990 SARA report (Witbeck 1990).
- A memorandum from J. J. Volpe, Westinghouse Idaho Nuclear Company, Inc. (WINCO) written in 1987 which listed WINCO's contribution to the Emergency Response Notification sections of the SARA Title III regulations (Volpe 1987). This memo lists inventory amounts for chemicals that WINCO believed to be extremely hazardous substances.
- A solvent disposal study reported by J. C. Commander (Commander 1971a).

NIOSH researchers, reviewing historical documents at the INEEL for information relevant to worker exposures, were informed that we were trying to locate and photocopy any records about inventory or chemical use. NIOSH researchers were asked to look for any documentation about chemicals, including the amounts received, inventoried, used or stored, and to forward photocopies of relevant information to the CDC or to *RAC*.

In some cases, information was available on the release or discharge of materials rather than their use or storage. The INWMIS or CERCLA documents (described further on pages 39–42, such as the work plan for the NRF Industrial Waste Ditch (DOE 1992), estimated the amounts of materials discharged. Many of the documents report estimates of the volume used, purchased, stored or discharged. For most liquids, it was assumed that 1 gal equaled 8.345 lb or 3.79 kg.

All compounds containing the element or chemical of concern were included in the inventory. For example, the category beryllium includes beryllium oxide and beryllium sulfate; manganese includes all manganese compounds and permanganates; and chromium includes chromates, dichromates, and chromic acids. Volpe (1987) lists an inventory of 13,470 lb of cadmium nitrate and 12,400 lb of cadmium sulfate in 1987 at the ICPP, probably used for the FAST program. Because these compounds have toxicity characteristics similar to cadmium salts and cadmium metal, they were combined under cadmium. Some compounds were evaluated separately. An inventory amount up to 1 million lb of zinc bromide was given in the 1990 and 1992 SARA reports (DOE 1991b, 1993), for TRA, ANL-W, NRF, and TAN in 1992 and at TAN in 1990. Because of the large amount and differences in toxicity, this compound was listed separately from the zinc compounds. For similar reasons, mercuric nitrate, ammonium salts, and sodium salts are listed separately from mercury, ammonia, and sodium.

Diethylphthlate, ethylbenzene, and hexachlorobutadiene were identified in ATSDR (1995) as chemicals in the soil, sediment, or groundwater at the INEEL. We have not found inventory information or any documentation about the use of these chemicals. It is unlikely that they would have been released to the air in sufficient quantities to be of concern offsite. Fly ash, hexane, methyl ethyl ketone, and toluene diisocyanate were identified in NIOSH (1993) as having a potential for exposing workers at the INEEL. Although these chemicals may have presented an occupational hazard, we did not find inventory or release information for them, and it is unlikely they were used in ways or in quantities that would have presented a health hazard offsite. Rather than exclude them from the screening, a hypothetical amount that would have had to have been released in order for a concentration at the toxic threshold concentration to occur at the Site boundary was calculated for these chemicals and is shown in Table 1 in Appendix A. An inventory amount of more than 200,000 kg of hexachlorobutadiene, a relatively potent carcinogen, would be needed to result in a ratio (of a hypothetical air concentration to a threshold toxicity value) of 1. More than 10 million kg of diethylphthlate or ethylbenzene would be required to obtain a ratio of 1. It is not likely that amounts as large as these would have been used or released.

The inventory amounts for hydrocarbon diluents, paraffin, and kerosene were often combined and reported as a single value. The inventory amounts reported here for each hydrocarbon are probably overestimated because they include more than the one compound.

SC&A listed the compound hydroborofluoric acid as a chemical used at the ICPP. The 1990 SARA report states that fluoboric acid was stored at the ICPP and ANL-W with a maximum amount of 100,000 lb, and Volpe (1987) reported that 18,455 lb of fluoboric acid were on hand at the ICPP.

Other than amounts consistent with use as an analytical standard, no inventory information has been found for several of the pesticides that were probably used onsite in the past, such as endrin, lindane, methoxychlor, and DDT. None of the people interviewed remembered large amounts of these compounds being used or can suggest where records of insecticide, herbicide, or rodenticide use might have been retained. During a Phase I Interview, T Suniga, Facilities & Maintenance, CFA (Phase I Interview with Suniga MC 1143) provided information on the Logbook of Herbicide (Roundup) use from 6/12/85 to the present, which included the hours spent spraying, other chemicals used, area sprayed, and the responsible person spraying. Maintenance Work Order Forms for the application of chemicals, and MSDSs were also kept in her files. Records for spraying before 1985 were not available.

The climate of the INEEL makes extensive use of chemicals to control fire ants and mosquitoes unlikely, but pest control was practiced to some extent. Because of the lack of information about pesticides, these materials cannot be evaluated further.

PCBs were considered in the screening, resulting in a ratio of 1.2×10^{-6}. We used inventory amounts for PCBs from 1989 because they were thought to be more accurate as well as larger than earlier values. We used a group of large transformers located near a series of drainage ditches at ANL-W as the worst-case scenario for the DOE’s environmental survey assessment of the potential for release of PCBs from transformers (DOE 1988). No offsite hazard from PCBs was predicted. Transformers that may have contained PCBs were also stored in a 65 by 140-foot fenced yard adjacent to CFA-667, called the transformer yard. Soil sample analyses found levels of PCBs in the yard to be less than 2 mg/kg, well below levels that would require inclusion in Superfund assessments (DOE 1999).

Weekly and monthly reports for the Chemical Processing Plant from 1953 through 1957 were reviewed for any information that might help estimate an inventory amount during that time. The contents of the reports vary, but the 1953 and 1957 reports contained the quantities of nitric acid, mercuric nitrate, ammonium hydroxide, aluminum nitrate, and occasionally hexone or tributyl phosphate charged to the dissolver for each kilogram of uranium dissolved. In most cases, the total amount of uranium charged to the dissolver for the month was not given. For those months when it was reported, the total amount of chemicals used can be determined. The processing rate each month and the chemical composition of the dissolving solution varied considerably from month to month. For the purposes of screening, we averaged values from several months each year to estimate an annual usage amount. The resulting estimate was certainly an overestimate because no processing was done during some months (for example

March, April, and June of 1954). Except for nitric acid, which was assumed to be used as a 60% solution unless otherwise indicated, solutions were assumed to be concentrated.

The fuel processing rates were often given in the monthly reports, for example 1.5 kg/day in November 1953. These rates were for the days processing took place, and it was not appropriate to average the rates over a year.

The amount of uranium processed for each campaigned was compiled in Staiger (1997), but it was difficult to convert these values to annual production. For future work to determine the use and release of chemicals from the ICPP more detailed estimates of the amount of uranium processed could be obtained from Safeguards and Security Unit of the Materials Control and Accountability Department of Lockheed Martin Idaho Technologies Company (LMITCO). For the purposes of this analysis, we used estimates of the amount of uranium processed in 1957.

The first extraction process used at the ICPP used hexone (methyl isobutyl ketone) as the solvent. In 1955, tributyl phosphate replaced hexone as the first cycle solvent. An ICPP monthly progress report estimated that 29.9 lb (13.5 kg) of hexone was used for each kilogram of uranium dissolved in January 1957. The same amount was reported for February 1957. The total amount of uranium dissolved was not given, but Staiger (1997) estimates that 700 kg of uranium was dissolved in 1957. From this, we can estimate that 9508 kg of hexone might have been used that year. Depending on the fuel being dissolved, 1.5 to 8 lb of mercury was used per 1 kg of uranium processed. We used reported values to derive and average monthly consumption of nitric acid, mercuric nitrate, ammonium hydroxide, aluminum nitrate and tributyl phosphate (see Table 2).

Table 2. Estimate of the Amount in Kilograms, of Chemicals Used in the ICPP Dissolver for the Month or an Average Month from That Year[a]

Month and year	Nitric acid (kg)	Mercuric nitrate (kg)	Ammonium hydroxide (kg)	Aluminum nitrate (kg)	Tri butyl phosphate (TBP) (kg)
October 1953	14,604	30	1,240	6,722	
September 1955	63,201	23	20	20,605	678
December 1955	120,328	196	581	27,954	246
January 1957	34,376	95	33,143	13,416	
Average ± Standard Deviation	58,127 ± 46,018	86 ± 80	8,746 ± 16,272	17,174 ± 9,153	462 ± 305

[a] Derived from information in the ICPP monthly progress reports (Phillips Petroleum Company 1953–1957).

Production summaries were also provided in five annual technical reports for the ICPP from 1971 through 1974 (Buckam et al. 1972; Allied Chemical Corporation 1973a, 1976; Buckam and Bower 1974, 1975). Amounts of chemicals reported to have been used in these four reports were totaled for each year, converted from gallons and pounds to kilograms and summarized in Table 3. It appears that more aluminum nitrate and nitric acid were used in the early 1950s than in the 1970s at the Chemical Processing Plant. Consumption values for mercuric nitrate and ammonium hydroxide were not reported in the monthly reports for the Chemical Process Plant in the 1950s. Values from recent SARA reports, which are larger than the monthly values reported in the early 1970s, were used for these chemicals.

Table 3. Chemical Usage Amounts, in kilograms, from 1971 to 1974[a]

Year	Nitric acid (kg)	Kerosene (kg)	Calcium nitrate (kg)	Aluminum nitrate (kg)
1971	81,174	303,454	200,000	
1972	68,277		330,000	78,898
1973	125,365			
1974	166,730	609,753	365,455	237,273
Average	110,386 ± 44,816	456,603 ± 216586	298.485 ± 87,113	158,085 ± 111,988

[a] Derived from ICPP annual technical reports (Buckam et al. 1972; Allied Chemical Corporation 1973a, 1976; Buckam and Bower 1974, 1975).

The most processing was probably conducted in the mid-1980s (Liable 1997). According to the DOE report Linking Legacies, which shows a graph of fuel reprocessing at the ICPP the greatest total kg of uranium recovered was in 1958, followed by 1974 and 1983 (DOE 1997c).

There are many power producing generators, emergency power generators, and several power plants onsite used to generate electricity and steam, including one coal-fired power plant at the ICPP. The rest of the power plants burn fuel oil and the generators burn diesel fuel. Although coal piles may be a source of metals and sulfuric acid contamination to surface water and groundwater, these pathways are not complete for the INEEL and coal stores were probably not large enough to create a fugitive dust problem offsite. Of more concern are the nitrogen dioxide, sulfur dioxide, and particulates released into the air from the stacks of the power plants. Releases of these pollutants were evaluated in this feasibility study.

Fuel oil consumption by the steam generation plant was reported for some months, and is summarized in Table 4.

Table 4. Fuel Oil Consumption Reported for the ICPP[a]

Month year	Fuel oil consumption (kg)
October 1953	241,556
January 1956	101,818
December 1956	105,454
January 1957	66,909
Monthly Average	128,934 ± 77,065

[a] From ICPP monthly progress reports (Phillips Petroleum Company 1953–1957).

The ICPP annual technical reports estimated fuel oil consumption to have been 116,000 gal in 1972 (Allied Chemical Corp. 1973b). The SARA report for 1990 showed an average inventory amount ranging up to 10 million lb (DOE 1991b). The SARA report for 1992 reported fuel oil stores ranging up to 50 million lb (23 million kg) (DOE1993). It appears that amounts of fuel oil reported in stores in the 1950s may have been smaller than in later years. The inventory amounts in the SARA reports were the largest values reported.

An inventory amount for uranium was difficult to derive from the records reviewed. Uranium inventories were reported for accountability purposes, by campaign, for the uranium processed and produced. It is difficult to derive annual or monthly average amounts from these data because the processing rate was inconsistent. Several isotopes of uranium exist in several chemical and physical forms, such as oxides, nitrates, in fuel elements, slugs, liquid waste in tanks, and granular waste in silos. An estimate for the largest total inventory that may have existed at any time is not available. To obtain a ratio of 1, an inventory of 5.82×10^8 kg is required. It is not likely that this amount of uranium would have been kept on hand. The amount of uranium recovered in 1958, the year of greatest recovery was about 2800 kg (DOE 1997c). Recent inventories are on the order of hundreds of kilograms at most (Personal Communication with Liable 1997).

Several chemicals might have been released to the air and might be important to consider as inhalation hazards, but they would not be expected to be held in inventory. Rather than being used and discharged from the processes, these chemicals were produced and released. The best examples of these are oxides of nitrogen and sulfur dioxide.

Screening Ratios

The calculated screening ratio, a ratio of the potential amount released to a toxic amount was an attempt to answer the question, “If all of the volatile compounds or a fraction of the nonvolatile compounds onsite during the year of the greatest reported inventory was released into the air, could toxic concentrations have been reached at the location of a potential receptor at U.S. Highway 20/26 or near the Site boundary?” Using the assumptions described in McGavran and Till (1997a), a ratio greater than 1 was estimated for chromium; a ratio between 0.1 and 1 was calculated for asbestos, beryllium, mercury, and trichloroethane; and a ratio greater than 0.01 was estimated for cadmium, hydrazine, lead, nickel, and sulfuric acid.

In Table 1 of Appendix A, a toxic air concentration corresponding to the 10^{-5} increased lifetime cancer risk level was used for the cancer causing chemicals. Table 5 shows the ratios that would have been calculated if risk levels of 10^{-4} and 10^{-6}, rather than 10^{-5} had been used.

Table 5. Screening Ratios Calculated for Carcinogens Using Different Lifetime Cancer Risk Levels

Chemical	Ratio using 10^{-4}	Ratio using 10^{-5}	Ratio using 10^{-6}
Asbestos	0.06	0.6	6.0
Arsenic	4.5×10^{-7}	4.5×10^{-6}	4.5×10^{-5}
Benzene	2.1×10^{-5}	2.1×10^{-4}	2.1×10^{-3}
Beryllium	0.097	0.97	9.7
Cadmium	0.0068	0.068	0.68
Carbon tetrachloride	1.6×10^{-7}	1.6×10^{-6}	1.6×10^{-5}
Chloroform	3.4×10^{-5}	3.4×10^{-4}	3.4×10^{-3}
Hydrazine	0.002	0.02	0.2
Nickel	0.002	0.02	0.2

None of the screening ratios estimated for the carcinogens using the 10^{-5} risk level were greater than 1; however, the ratio for beryllium was very close to 1. If a 10-fold lower value for the carcinogenic air concentration is used, corresponding to a cancer risk level of 10^{-6}, then the screening ratios for asbestos and beryllium exceed 1.

Inventories were not available for 19 of the chemicals listed in Table 1 in Appendix A. The amount of terphenyl and biphenyl that would have been used for the cooling the Organic-Moderated Reactor Experiment (ORME) reactor was probably much less than the 10 billion kilograms required to obtain a screening ratio of 1. Based on the processes and bulk chemical use reported in monthly and weekly progress reports, the amounts required for aniline, barium, diethylphthlate, endrin, ethylbenzene, fly ash, hexane, hexchlorobutadiene, lindane, magnesium compounds, DDT, methoxychlor, methyl ethyl ketone, perchloric acid, propanol, propylene glycol, styrene, tetrachloroethylene, toxaphene, toluene diisocyante, and xylenes seem to be much larger than what would have been used or stored. As previously discussed, most of these chemicals were added to the list to be evaluated based on their inclusion in ATSDR's list of chemicals in groundwater or other media or NIOSH's list of chemicals of potential occupational concern for their studies on workers.

About 6×10^5 kg of hydroxylamine sulfate would have been required to obtain a screening ratio of 1. This chemical may have been used in chemical processing in years for which we do not have inventory information. An inventory for slimicides of 8×10^7 kg would be needed to calculate a screening ratio of 1. Water treatment chemicals might have been tracked by purchase orders, but their use is not detailed in technical reports. Mention of hydroxylamine sulfate or slimicides in reports being reviewed was noted and we had hoped to determine an inventory amount for these, if possible.

Table 6 summarizes the screening ratios.

Table 6. Ten Chemicals with the Highest Screening Ratios

Chemical	Ratio greater than 1	Ratio between 0.1 and 1.0	Ratios between 0.01 and 0.1
Chromium	12.3[a]		
Beryllium	9.71[a]		
Asbestos	6.05[a]		
Cadmium		0.68[a]	
Mercury		0.27	
Hydrazine		0.20[a]	
Nickel		0.19[a]	
Trichloroethane		0.13	
Lead			0.03
Sulfuric Acid			0.02

[a] These chemicals cause cancer. Their ratios were determined using concentrations that EPA calculated to correspond to an increased lifetime cancer risk of 1 in 1 million.

Conclusions and Recommendations for the Selection

The results of the selection suggested that records, reports, and documents containing information about asbestos, beryllium, cadmium, chromium, hydrazine, lead, mercury, nickel, oxides of nitrogen, sulfur dioxide and 1,1,1-trichloroethane should be photocopied, reviewed, and entered into the database. We also resolved to note any reference to amounts of hydroxylamine sulfate, corrosion inhibitors or slimicides used or released. The feasibility of conducting a chemical dose reconstruction on all of these materials was evaluated.

Selecting chemicals for further evaluation in the feasibility study was an ongoing process throughout the study. As documents were reviewed, information regarding the amounts of chemicals used and released was noted and we continually assessed whether evidence warrants adding chemicals to those that should be included in a dose reconstruction.

SOURCES OF INFORMATION

Information on chemical use, storage, release, recycling, transport, and disposal was derived from Site-generated reports; internal memos and letters; documents in the literature; documents produced by other government agencies; and interviews with former and current Site personnel, the State of Idaho DEQ and Idaho Department of Health and Welfare officials, INEELHES members, and others with knowledge or interest in the study. A description of plant document tracking systems, record keeping systems, and major document repositories can be found in the Phase I report (SC&A 1994). This section contains a brief summary of the various types of reports generated by the Site and the information the reports contain.

INEEL Annual Environmental Reports

Annual environmental reports were prepared each year after 1978 by the Radiological and Environmental Sciences Laboratory (RESL), which in 1993 was renamed the Environmental Science and Research Foundation. These reports present the results of various environmental monitoring programs.

The format changed over the years and the reports were expanded to include more photos, graphics, and nonradiological data. The reports included a tabulation of the facilities that were operating, operable, in standby status, not in use, and under construction; major programs under development at the Site; and the operating contractor during that year. After 1987, the annual reports also list environmental permits in effect each year. The operating status of the major facilities could be derived from the annual reports and could be supplemented with more detail provided from the quarterly and monthly reports for facilities of particular interest.

The air monitoring and later the nonradiological monitoring sections of the annual environmental reports contained a description of the measurement of airborne particles. Since the *1978 Environmental Monitoring Program Report for Idaho National Engineering Laboratory Site* (RESL 1979), nonradioactive particles in air were routinely monitored using the same filters used to monitor radioactive particles. The net weights of particles collected on quarterly composites of weekly filters was determined for each station. The approximate detection limit in 1978 was 35 $\mu g/m^3$. The average concentrations were given for boundary locations and distant towns. The concentrations near the Site were not different from those distant, and most of the airborne particles were said to “probably (be) windblown dust from the desert floor.” The content of this section on particulate monitoring changed little over the years. In May of 1992, a sampler was established at CFA and another at the Craters of the Moon National Monument, as part of the National Park Service Interagency Monitoring of Protected Visual Environments (IMPROVE) network. Very similar descriptions and results were given through the years.

Since the 1978 annual report, the maximum sulfur dioxide and nitrogen dioxide concentrations at the Site boundary have been calculated using the MESODIF air dispersion model and estimates for total discharges reported for each year. The total sulfur dioxide discharges were calculated from the sulfur content of the heating oil, coal, or other fuel and the amount of fuel burned as reported in the INWMIS report. NO_x emissions from fuel were calculated using EPA emissions factors and the amount and type of fuel reported in INWMIS. The calculated maximum concentrations were below EPA’s ambient air quality standards.

Table 7 summarizes the calculated release of sulfur dioxide and nitrogen dioxide (reported in INWMIS and in the annual environmental reports) and the maximum concentrations calculated for the southern Site boundary (reported in the annual environmental reports).

Table 7. Calculated Release and Maximum Concentrations of Sulfur Dioxide and Nitrogen Dioxide at the Southern Site Boundary

Calendar year of annual report	Total SO_2 calculated to have been released (kg)	Maximum concentration calculated for the Site boundary ($\mu g/m^3$)	Total NO_2 calculated to have been released (kg)	Maximum concentration calculated at the Site boundary ($\mu g/m^3$)
1978	Not given	0.3	Not given	0.5
1979	Not given	0.2	Not given	0.3
1980	Not given	0.4	Not given	0.4
1982	3.3×10^5	0.3	2.7×10^5	0.25
1985	3.3×10^5	0.7	1.8×10^5	0.4
1988	2.0×10^5	0.5	8.3×10^5	2.0
1991	1.3×10^5	0.2	5.7×10^5	0.8
1993	1.4×10^5 [a]	0.4	6.0×10^5 [b]	1.8

[a] Converted from the reported value of 139 Megagrams (metric tons).

[b] Converted from the reported value of 600 Megagrams (metric tons).

The annual reports compared these estimates to air quality standards. The ambient air quality standard for sulfur dioxide is 80 $\mu g/m^3$. The predicted concentrations of 0.2 to 0.7 $\mu g/m^3$ were about 0.25 to 0.9 % of the standard. The standard for oxides of nitrogen is 100 $\mu g/m^3$. The highest predicted concentration of 2.0 $\mu g/m^3$ was 2% of the standard.

The 1982 Environmental Monitoring Program report notes that the ICPP received a variance from the State of Idaho for visible air emissions due to nitrogen oxides in the plume from the main stack (RESL 1983). The report stated that emissions did not constitute any health problem for workers or residents. The atmospheric transport modeling predicted concentrations at the Site boundary that were 1% of the ambient air quality standard. The report stated “short term ambient measurements on the INEL Site during 1982 confirm low nitrogen dioxide concentrations from all sources.”

The 1983 Environmental Monitoring Program report also announced the establishment of a monitoring station for sulfur dioxide and nitrogen oxides (Hoff et al. 1994). The 1983 report said that the NWCF at the ICPP was operating under a variance for visible emissions due to NO_2. Visual determination of opacity was routinely made twice a week. All of the observations for 1983 were below the 60% opacity specified in the variance.

In the 1984 Environmental Monitoring Program report five primary sources of nonradioactive airborne effluents were given: (1) the ICPP calciner, (2) the coal fired steam plant, (3) fuel oil used for heating, (4) motor vehicle exhausts, and (5) fugitive dusts from waste burial and construction activities. This report also listed inorganic compounds measured in liquid effluent. The 1984 report said, “Other waste effluents are calculated from the amounts of chemicals used for water treatment, for corrosion control, for demineralization, as cleaners, as algaecides, and occasionally from waste acids.” (Hoff et al. 1985).

Monitoring of sulfur dioxide, nitrogen oxides and carbon oxides at the Coal-Fired Steam Generating Facility (CFSGF) was noted, although the sulfur dioxide emissions were calculated from the sulfur content and amount of fuel burned rather than measured.

The *1985 Environmental Monitoring Program Report for the Idaho National Engineering Laboratory Site* also characterizes liquid waste effluents (Hoff et al. 1996). Nonradioactive liquid wastes were disposed of primarily to a waste ditch at NRF; seepage ponds at LOFT, TAN, TRA, Water Reactor Research Test Facility (WRRTF) and ICPP; a lined evaporation pond at the Power Burst Facility (PBF); an Industrial Waste Pond at ANL-W; and to sewage treatment plants in other locations.

The *1987 Environmental Monitoring Program Report for the Idaho National Engineering Laboratory Site* (Chew and Mitchell 1988) described two small nitric acid spills and contained the first mention of chlorinated solvents in groundwater under the Site. Identification of the source and efforts to remediate groundwater were discussed. The ICPP nitrate plumes in groundwater and other nitrate plumes were also described. The NO_x and SO_x ambient monitors did not operate in 1987.

The *INEL Site Environmental Report for Calendar Year 1988* reported that the ICPP CFSGF was shutdown because a continuous NO_x monitor was out-of-calibration. The monitor was calibrated and the facility was restarted. Concentrations of NO_x before and after the calibration were thought to have been within permit limits. Leaks of hydrofluoric acid leak to the ICPP waste system and nitric acid release to a waste pond were reported (Hoff et al. 1989).

The Yellowstone fire smoke was detected by the particle monitors in 1988. Two nitrogen oxide monitors were activated to fulfill the permit to construct the Fuel Processing Restoration (FPR) Plant, and the monitor used previously at Van Buren was repaired and restarted. Ambient SO_2 was not monitored in 1988 (Hoff et al. 1989).

The *INEL Site Environmental Report for Calendar Year 1989* describes testing of the vapor extraction unit for carbon tetrachloride under the RWMC, remediation of trichloroethylene in groundwater at TAN, and other CERCLA and RCRA activities (Hoff et al. 1990). An underground leak of about 1000 gal of gasoline from a station at CFA was reported. A lead inventory and use reduction program was initiated. Sulfur dioxide monitoring resumed and was reported for the fourth quarter 1989.

The *INEL Site Environmental Report for Calendar Year 1990* contains a compliance information summary that explained current regulations to which the Site had to comply. The Site was listed on the EPA’s National Priorities List of Superfund Sites in 1989. A chronology of air permits in effect and consent orders and environmental impact statements submitted were given in the annual reports after 1990.

The *INEL Site Environmental Report for Calendar Year 1991* reported a 200-gal sulfuric acid spill at TRA, small diesel fuel spills, and a 300-gal sulfuric acid spill. The Toxic Release Inventory reported thresholds were exceeded for trichloroethane, nitric acid, sulfuric acid, and ethylene glycol.

The INEL Site Environmental Report for Calendar Year 1992 mentioned many small spills and releases, such as 2 qt of ethylene glycol and 300 gal of sulfuric acid to the leach pond at TRA. The release of a corrosion inhibitor used to treat steam condensate, which contained cyclohexylamine, was reported and this compound was replaced with a new corrosion inhibitor.

The Toxic Release Inventory report to the EPA included trichloroethane, nitric acid and methyl isobutyl ketone. New monitors for particulate material in air were placed at CFA and Craters of the Moon. The portable stack emission monitor used at ANL-W was also described. The effluent monitoring results are reported in a similar format as previous years but the report noted new and expanded programs for sampling liquid effluent.

The *INEL Site Environmental Report for Calendar Year 1993* reported on environmental monitoring programs and cleanup activities (Mitchell 1994). The report says that nitrogen oxide emissions were routinely monitored by WINCO at the NWCF and sulfur dioxide, nitrogen oxides, and carbon oxides were monitored at the CFSGF. The monitoring data were published in the INWMIS quarterly reports. The Idaho State University monitoring program was summarized, and RESL and Idaho State University results compared in the “Quality Assurance” section. The annual reports for 1993, 1994, and 1995 (Mitchell 1994; Mitchell et al. 1995; Mitchell et al. 1996) were reviewed and information about nonradiological monitoring was summarized and entered in the INELCHEM database.

Technical Reports

We reviewed many technical reports on special studies, experiments, processing problems or solutions, new technology, process improvements, research and development, waste reduction, and other projects. We asked Susan Mousseau at ANL-W to try to locate any records kept at the facility pertaining to the historical use or release of chemicals. She found several relevant documents not located in Phase I. Perhaps the most useful was a D*raft Facility Waste Description* report for ANL-W from 1973 (ANL-W 1973). A final version of this report was not located. The report includes useful descriptions of process waste generation and disposal. Boiler operations, discharges to the Industrial Waste Ditch, and chromium released to the air from cooling tower drift were discussed. The release of chromium to liquid effluents was also estimated. A table in the report contains a summary of nonradioactive gases released from ANL-W. The table provides estimates of the amount of sulfur (measured in pounds per year) discharged from 1963 to 1972 and the gallons of cooling tower drift and amount of chromium discharged in the cooling tower drift. The amount of chromate in liquid discharges from ANL-W was also estimated in pounds per year from 1962 through 1972. The report notes that in 1964 and 1965, hexavalent chromium was not reduced to trivalent prior to discharge (ANL-W 1973).

Interestingly, Lee C. Witbeck, then retired, was interviewed in Phase I and referred to a Radioactive Facility Waste description he had written called “the yellow book,” which was ANL-W’s contribution to ERDA-1536 (Phase I Interview with Witbeck MC 1733). The waste description and the “yellow book” may be the same or very similar documents.

Interviews

Phase I Interview Notes

Former and current Site employees interviewed during Phase I offered opinions on the chemicals of concern for historical dose reconstruction. This information, found in the interview notes from Phase I, is summarized in Table 8. Many of the chemicals listed were obviously of concern for worker exposure or waste disposal rather than because of the potential for significant releases to the environment.

Table 8. Chemical of Potential Concern Identified By Former and Current Site Employees

Interview with	INELCHEM Database MC number	Chemicals of potential concern	Of concern for	Area or facility
J. Downes	387	cadmium hydrofluoric acid nitric acid oxides of nitrogen asbestos	Industrial Hygiene, waste handling	ICPP
Terry Chesnover	501	lime sodium sulfite polyphosphate	Used at CFSGF	CFSGF, ICPP
Tom Byrnes	504	hydrogen fluoride HBF4 nitric acid aluminum nitrate cadmium sulfate cadmium nitrate	Used for the fluorinel dissolution process	The FAST Facility, ICPP
L.P. "Pete" Mickelsen	525	barium nitrate fuming nitric acid sulfuric acid red chromic acid sodium hydroxide ammonium hydroxide boric acid carbon tetrachloride aluminum nitrate mercuric nitrate hexone TBP	Used at the ICPP	ICPP
L.R. (Russ) Stuart	527	hexone TBP nitric acid NaK solvents	Worker, used at the ICPP	ICPP
Doug R. Wenzel	528	dodecane hexone TBP nitric acid hydrofluoric acid	Used in the ICPP processes	ICPP
Anonymous	530	hexone TBP hydrocarbon diluents n-dodecane aluminum nitrate- NaK hydrofluoric acid sulfuric acid	Used, released or spilled at the ICPP	ICPP
Christy Frazee	532	metal oxides mercury kerosene	Calciner operations	ICPP calciner
Walt Mickelson	533	NaK ammonium nitrate nitric acid potassium permanganate phosphoric acid mercury	analytical lab, fuel separations, old WCF, solvent burner, rare gas plant, , NWCF and fluorinel dissolution process /FPR Plant	ICPP
Dee J. Williamson	531	PCBs mercury	Site remediation, waste areas	Operable Unit (OU) 1, OU 3, OU 4, OU 8,

Table 8. Chemical of Potential Concern Identified By Former and Current Site Employees

Interview with	INELCHEM Database MC number	Chemicals of potential concern	Of concern for	Area or facility
		asbestos kerosene chemical hydrogen fluoride		OU 11 and OU 13, respectively
Roy P. Grant	1734	metals ethanol sodium carbonate chromium-cooling tower silver-photolab	Use and disposal	ANL-W
Rich L. Batten	1763	dimethylamine hydrazine sulfuric acid slimicides solvents sodium hydroxide chlorine chromium	Use and disposal	ANL-W, EBR-II
Richard E. "Dick" Kaiser	14332	lithium hydride magnesium perchlorate methylethyl ketone toluene methylisobutyl ketone battery acid	Use in processes	ANL-W, TREAT, ZPPR
Carl W. Borror,	26,568	sulfuric acid chlorine biocides chromates	Use in the processes	NRF
Rick L. Pepiot	26,569	sulfuric acid	Use	NRF
Kenneth A. Schreck	26,570	sulfuric acid	Use	NRF
S Havlovick and R Rubick	26,953	asbestos beryllium oxide- ZPPR cadmium dioctyl phthalate ethanol ethylene glycol freon lead lithium hydride mercury- 600 lb per cask; methylene chloride pesticides sodium sodium hydroxide sulfuric acid	Industrial hygiene	ANL-W
Jerry Zimmerle	26,982	mercury trichloroethylene tetrachloroethylene dichloroethylene	Waste Area Groups, groundwater contamination	TAN, Waste Area Group 1
Lavar O. Zohner	26,984	hydrofluoric acid hexone	Use, potential release	ICPP

The chemicals mentioned in the interviews were part of the feasibility study's initial list of chemicals of potential concern. Concerns about worker safety and handling of sodium and sodium potassium metal was raised by several of the workers interviewed in Phase I. NaK is a highly reactive liquid metal. It would not be expected to persist in the environment. It is clearly more of a worker safety hazard than an offsite exposure concern. The EBR-II reactor at ANL-W is submerged in a large container filled with molten sodium. The primary sodium is cooled through a heat exchanger that has a second sodium loop. The sodium is contained and is not open to the environment (ANL-W 1973).

Other Interviews

Approximately 40 retired and current INEEL workers were interviewed as a part of the feasibility study. These individuals were asked for more specific information on the use and release of the chemicals of concern. These interviews were entered into the INELCHEM database. Information used in this report that was obtained from interviews is referenced as a personal communication with *RAC* researchers.

Logbooks, Ledgers, And Databases

People responsible for databases, logbooks, and reports kept or compiled by the INEEL were included in the Phase I database. Many of the personnel responsible for these sources of information when the Phase I interviews were done have since changed positions. Some of the contacts were no longer listed in the INEEL directory.

Haz-Trac is a database containing chemical lists, locations, point(s) of contact, and quantities of bulk and package chemicals at the ICPP. Haz-Trac lists the chemical coordinators throughout the ICPP who order and inventory chemicals. Since 1989, the Haz-Trac database has been used primarily as a vehicle for SARA (311 and 312) inventory reports. Haz-Trac evolved from another program called "Chemlec," which was used to track the chemical requirements and purchasing for the Operations Group at the ICPP during 1983–1984 (Phase I Interview with J. Downes MC 387). In addition, a MIP database, which contained inventory records from the ICPP warehouse, was described. The MIP database listed chemicals that were ordered, received, and issued. Carol Jones, interviewed at the ICPP in Phase I, thought that the MIP may provide one of the best available sources for the historical use of chemicals at the ICPP.

Phase I interviewers also noted that EG&G Idaho, Inc. (EG&G) may have "microfilm records procured by EG&G of chemical purchase orders going back at least 10 years" (Phase I Interview with Jones MC 387). However, Brian Morshita, said to be the keeper of the EG&G microfiche, is no longer in the INEL directory and LMITCO personnel in purchasing were not aware of microfiched records of this kind and did not know where they would be found. Photocopies of records were not obtained in Phase I and in 1997, and many of the records referenced in Phase I were not found or did not go back in time far enough to be useful. Except for NRF, which has retained receiving records since startup, the chemical purchasing and receipt records generally go back no further than 1990 or 1991. The NRF's traveling requisition cards are stored in the NRF traffic offices in Building 24.

Although they emphasize radiological concerns in the earlier years, occurrence reports, operating event reports, unusual occurrence reports, spill logs, and other accident reporting systems are also available and might be used to compiled information on chemical spills and accidental releases. Some of these reports were entered into the Phase I database. The chemicals of concern that were spilled or associated with an accident should have been found in the search of the database abstracts. All of the items identified from the search were obtained, reviewed, and incorporated into this report.

INEL Nonradiological Waste Management Information System

The INEEL Industrial Waste Management Information System (IWMIS) is a computerized system for reporting nonradiological waste information. The IWMIS has been used at the INEEL since 1971 and has served as the official record for all types of industrial waste that has been stored or disposed at the INEEL. In addition to the INWMIS database, annual reports of the INWMIS data have been published since 1979.

According to interviews done by SC&A in Phase I, the INWMIS reports date back to 1978 and were more complete after 1980. INWMIS data was collected from 1971 to date The Radioactive Waste Management Information System (RWMIS) was retrofitted from data as far back as 1963. There was an attempt to retrofit all the solid waste data back to the 1950s but in 1971 the Site decided to consider records generated prior to 1963 non-usable. Consequently, the RWMIS database doe not contain the pre-1963 data (Phase I Interviews with D. Litteer, MC 14585 and R. Grant, MC 1734). Information on the RWMIS and INWMIS database and reports can be obtained from Debbie Litteer, who has maintained the data for many years.

The first in the series of annual reports which contain data from the INWMIS is the Industrial Waste Management Information System for 1979 and Year-to-Date Report [IDO-10057(79)]. In this first report, data were summarized for each INEL facility for the periods 1971-1976, 1977, and 1978. The summaries included the quantities of liquid industrial waste and the volumes of solid waste disposed, fuel oil and water consumed, and the quantities of SO_2 and particulates released. Data were presented as computer printouts from the IWMIS database.

The following individual record-to-date summaries were included in this document:

- Report 1 – INEL Monthly Water Usage Summary. This report summarized the quantity of water pumped at each facility and the quantity of water disposed to the atmosphere, ground surfaces, and subsurfaces. The percent accountability was also shown.
- Report 2 – INEL Year-to-Date Water Usage Summary. This report provided the quantity of water pumped and disposed and the percent accountability at each facility for the year-to-date.
- Report 3 – INEL Industrial Waste Summary. This report summarized the quantity and type of industrial waste for each area at the INEL. The waste was shown by Types 1 through 9, which correspond generally with the standard classifications for sanitary wastes. The waste types were trash, cafeteria garbage, wood and scrap lumber, masonry and concrete, scrap metal, oil, solvents, chemicals, and others. The report included data for the year-to-date (1978) and record-to-date (1971-1976, 1977, and 1978).
- Report 4 – INEL Airborne & Liquid Disposed Substances summary. This report provided the monthly total weight of all reported substances disposed to the environment during 1978. It also provided the total amount of waste disposed of in 1978.

- Report 5 – INEL Monthly Fuel Oil Summary. This report summarized information on the types and quantities of fuel oil used during the month for each facility at the INEL. It also provided estimates of the quantities of SO_2, NO_x, and particulates released to the atmosphere.
- Report 6 – INEL Year-to-Date Fuel Oil Summary. This report provided similar information to Report 5 for the year-to-date.
- Industrial Waste Management Information for each facility by year, starting in 1978. This was data from the INWMIS database. Each facility was designated by a two-digit number (XX). Numbers for some of the facilities in the 1978 report were:

Number	Facility or Area
11	ANP
12	ARA
13	CFA
14	ICPP
18	NRF
22	TAN
23	TRA

The data is reported by category with the facility number and the category number. Categories were:

- Report Series XX4 – Airborne Disposed Substances Summary
- Report Series XX5 – Liquid Disposed Substances Summary
- Report Series XX6 – Industrial Waste Summary
  A description for each type of industrial waste handled at the INEL follows:

Waste type	Description
1	Trash
2	Cafeteria Garbage
3	Wood and Scrap Lumber
4	Masonry and Concrete
5	Scrap metal
6	Oil
7	Solvents
8	Chemicals
9	Other (specified by facility)

- Report Series XX7 – Water Usage and Disposal Summary.
- Report Series XX8 – Fuel Oil Usage and Stack Effluents Summary (DOE-ID 1979).

- The INWMIS reports after 1979 were similar. The industrial waste data associated with activities at the INEL for 1985 years previous (record-to-date) were summarized in the INWMIS for 1985 and Record-to-Date [DOE/ID-10057(85)]. Summaries of the quantities of liquid industrial waste, the volumes of solid waste, the fuel oil and water used, and the quantities of SO_2 and particulates released were included. The waste data were from the INEL Industrial Waste Management Information System (IWMIS). The reports included Record-to-Date Summaries – Summaries of sanitary waste (cubic meters), oil solvents (liters), liquid waste (kilograms), airborne waste (kilograms), fuel oil (liters), fuel oil SO_2 (kilograms), fuel oil particulates (kilograms), and water used (liters) during the periods 1971-1982, 1983, 1984, and 1985 for the entire INEL and specific facilities.
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The 1991 annual Report, INWMIS 1991 and Record to Date [DOE/ID-10057(91)], included the same data reported in a slightly different format. The report included:

- Record to Date Summaries – Summaries of sanitary waste (cubic meters), oil solvents (liters), liquid waste (kilograms), airborne waste (kilograms), fuel oil (liters), fuel oil SO_2 (kilograms), fuel oil particulates (kilograms), and water used (liters) during the periods 1971-1988, 1989, 1990, and 1991 for the entire INEL and specific facilities. This also included specific substances released during these periods.
- INEL Record to Date Detail Summaries – These reports and graphs detailed the record to date quantity and type of industrial waste for each INEL facility. This section also included a record to date report of all airborne and liquid industrial waste substances for the period 1989 to 1991 and a cumulative total for 1971 to 1988.
- INEL 1991 Year-to-Date Summaries – These reports summarized the year-to-date quantity of water pumped from the aquifer and discharged and the percent of waste accounted for at each facility; the quantity and type of industrial waste for each INEL facility; the types and quantities of fuel oil used at each INEL facility; and the gross volumes and the weights of hazardous waste generated by facilities associated with the INEL.
- Area 1991 Detail Data – These reports summarized data on both airborne and liquid disposed substances, industrial waste, water usage, and disposal, fuel oil and diesel usage, coal usage, and mixed waste and hazardous waste generated at each facility.

Subsequent reports were similar. Another report generated on waste disposal was the *Aqueous Radioactive- and Industrial-Waste Disposal at the Idaho National Engineering Laboratory through 1982* (DOE/ID-22069, USGS-85-0636). This report listed in tabular form, the annual radioactive- and chemical-aqueous-waste disposal data for wells and ponds at the INEEL. Data included amounts discharged to ICPP disposal well since 1961. The radionuclides included in the listing were H-3, Co-60, Sr-90, I-129, and Cs-137 and the chemicals listed included sodium, sulfate, phosphate, and chloride ions.

RCRA and CERCLA Documents

These documents are associated with legislative requirements for cleanup of hazardous waste sites. The INEEL was added to the EPA's National Priorities List of Superfund Sites on

November 21, 1989. A Federal Facility Agreement and Consent Order for the INEL was signed by the DOE Idaho Operations Office (DOE-ID) and the State of Idaho in December 1991. The goal of the agreement was to ensure that potential or actual releases of hazardous substances to the environment from the INEEL are thoroughly investigated in accordance with National Pollution Contingency Plans and that appropriate response actions are taken as necessary to protect human health and the environment. Of use to us, is the fact that investigations, work plans, and site characterization done as a part of the CERCLA or RCRA cleanup activities can provide information on chemical contamination of soil, air, and water and the history of that contamination. Superfund documents are publicly accessible and copies of most of these are kept in the Public Reading Room in Idaho Falls.

The CERCLA remedial investigation and feasibility studies, site characterizations, risk assessments, and associated work plans and reports may contain useful facility disposal histories, descriptions of the nature and extent of contamination, remedial objectives, and maps. The human health risk assessments are most often done for contaminants in groundwater and soil that could affect the health of people living on the land in the future. The assessments consider a hypothetical maximum exposure scenario involving ingestion of groundwater, garden vegetables, and other pathways that are not relevant to dose reconstruction. Similarly, any ecological risk assessments also apply to onsite scenarios. However, the monitoring data associated with Superfund activities may be useful, especially any estimates of air concentrations, soil concentrations, and background levels. Recent chemical monitoring data may be the only monitoring data available for some of the chemicals. The RCRA Part B Permits were also reviewed and contained little information of interest for historical releases.

Numerous storage tanks for diesel fuel, gasoline, fuel oil, and solvents are described in the CERCLA site characterizations. Generally, the goal of the studies on fuel tanks involved characterization and remediation of soil and groundwater. Atmospheric releases of these materials or their volatile components was not a concern.

Safety Analysis Reports

Safety analysis reports have been required by DOE for each facility, defined as activities or operations that involve radioactive or fissionable materials in such a form or quantity that a nuclear hazard potentially exists to employees or the general public (DOE 1997a). Historically, these reports, especially those from the earlier years, did not address chemical hazards. The safety analysis reports generally had useful process descriptions, an inventory of hazardous materials, and an evaluation of potential releases that might be the consequences of accidents. The safety analysis reports for the ICPP noted the production of nitrogen dioxides and mercury.

In addition, Health Services Laboratory Reports from about 1967 to 1978 and Operational Safety Reports dating back to the 1950s were also available. John Horan, a member of the INEELHES and former Director of Health and Safety Division of the Atomic Energy Commission at the INEEL, was familiar with these reports. He also described and discussed with the INEELHES, safety interviews the Atomic Energy Commission conducted in the 1950s and 1960s.

Planning Documents

Recently written emergency plans and RCRA contingency plans describe actions that the facility will take to minimize hazards to human health and the environment from fires, explosions, and other unplanned releases. Spill avoidance and response plans, emergency preparedness plans are often associated with the plans (DOE 1997a).

INEL Historical Dose Evaluation

The *Idaho National Engineering Laboratory Historical Dose Evaluation*, published in 1991 by DOE, was intended to evaluate potential radiation doses from 1952 to 1989 to a hypothetical individual who lived at an offsite location with the highest concentration of radionuclides in air (DOE 1991a). Doses from chemical contaminants were not addressed. However, this document has been very useful because it provides concise, well-summarized historical information on facilities and operations at the Site and a chronology of operations.

ICPP Reports

ICPP Monthly and Weekly Progress Reports

An almost complete set of ICPP monthly and weekly progress reports was obtained from Dan Staiger's office at the Willow Creek Building in Idaho Falls. Some of the ICPP monthly and weekly progress reports provided information regarding the use and release of process chemicals. The information important for chemical use and release estimates was not classified and sanitized versions of the reports were photocopied and reviewed. From September 1954 through November 1956, the ICPP monthly progress reports contain utility use and production information including total steam; process steam; fuel oil; salt; and treated, raw, and potable water. Beginning with the January 1955 report, information regarding chemical use was provided. Amounts of nitric acid, catalyst mercuric nitrate [$Hg(NO_3)$], ammonia, and aluminum nitrate were given as pounds per kilogram of uranium charged to the dissolvers. Beginning with the January 1956 report, additional chemical use information was reported, including amounts of Amsco, TBP, and Hexone consumed. A December 15, 1955, report section entitled "Composition of Off-Gas from Batch Uranium and Aluminum Dissolution" reported information regarding the off-gas concentrations of nitrous oxide, nitric acid, nitrogen dioxide, and hydrogen. Weekly ICPP production reports from January 27–February 2 and through October 27–November 2, 1957, reported the same utility production and consumption data. Chemical use amounts were not provided, but information regarding uranium storage inventory, feed preparation, extraction, inventory process holdup, losses, process equipment waste, and the amount of waste sent to storage was given.

The monthly reports from 1953 and 1957 contained the pounds of nitric acid, mercuric nitrate, ammonium hydroxide, aluminum nitrate and occasionally hexone or tributyl phosphate charged to the dissolver for each kilogram of uranium dissolved. In most cases, the total amount of uranium charged to the dissolver for the month was not given, but for the months that it was, the total amount of chemicals used can be determined. The processing rate each month and the chemical composition of the dissolving solution varied considerably from month to month. This information was used as inventory input for screening and selecting chemicals of concern. Values from several months each year were averaged to estimate an annual use amount. In most cases, amounts from inventories taken after 1989 were larger than the inventories derived from the ICPP monthly reports published in the 1950s. However, the amounts of mercuric nitrate and ammonium hydroxide reported in the monthly reports were larger and were used for the screening calculations.

A series of ICPP weekly production reports from November 1– 7 through November 22–28, 1959, gave the same utility information previously described. Also provided was service information, which includes disbursements and quantities received or made of liquid and gaseous nitrogen, nitric acid, and aluminum nitrate. Monthly ICPP production reports from 1963 through 1979 reported similar utility information, but service information was only noted through 1967. Beginning with the January 27–February 26, 1969, report, the utilities production data were expanded to include sulfuric acid, phosphorous, sulfite, and caustic. Chemical use of gaseous oxygen, calcium nitrate, kerosene, and nitric acid was given in the January 27–February 26, 1971, report. Beginning with the January 27–February 26, 1974, report, the utilities production data were again expanded to include sodium hydroxide, sodium sulfite, trisodium phosphate, and sulfuric acid in addition to the utility information previously described. In 1980, the reports begin to contain less information, only mentioning limited utilities production data in the text. This continued through 1984. In the January 1985 report, three figures provided information regarding percent SO_2 removal, pounds NO_x released per British Thermal Unit (mmBTU), and percent opacity for the CFSGF. Reporting of this information continued through 1988, and in 1989, similar figures provided information regarding pounds SO_2 per million BTU and pounds of NO_x emitted per million BTU. This format continued through 1992. From 1988 through 1992, stack NO_x emissions from the ICPP Main Stack in tons were also provided.

As an example, the ICPP Monthly Report for March 1973 contained sections on fuel handling and storage, fuel storage facilities, fuel reprocessing (which contained the amount and type of fuel dissolved), solvent extraction, waste calcining and treatment, the utilities powerhouse (which often contained the amount of fuel burned) and maintenance activities (Allied Chemical Corporation 1973b).

Dan Staiger, who graciously let us intrude in his office for several days and photocopy all of the monthly and weekly progress reports he had collected, is currently working to characterize the calcined waste. He has reconstructed, to the extent possible, the campaigns that were run and analytical results available on waste going into the calciner, and he has tried to quantify the constituents of the waste. He has good knowledge of the types of fuels processed at various times and the wastes produced. We obtained copies of three excel spreadsheets that he has compiled. The first spreadsheet contains a list of all reports generated from the ICPP (over 2100 entries) with titles, authors, and dates from 1953 to present. The file also lists Site document numbers for the ICPP production monthly reports series with dates and name changes; it includes the IDO-, PTR-, AY-, AMB-, FMC-, SGS-. WLR-, MAIR-, WCM- LFE-. SMH- series of reports from October 1953 to September 1994. The second spreadsheet contains processing information, campaign data, and shipments at the ICPP since the 1950s. The third spreadsheet contains time trends of the volume of waste sent to various waste tanks for all years of operations. Dan Staiger has also reviewed daily production reports since 1988. He has compiled these in a WordPerfect file and they are also available on microfilm. We asked Dan Stiager about correlating production campaigns and rates of dissolution and calcining to chemical releases because stack releases of chemicals were not measured. He thinks this would be difficult because transfer systems may have been tight when the plant was running at a significant capacity, and leaks may have been greater when the processes were not running or more personnel were not present to detect and stop releases.

Campaign Reports and Shift Operator Logs

In addition to the monthly progress reports, another set of ICPP reports called campaign reports were produced. Dan Staiger has also collected these. Daily production reports from 1988 and later are available in an electronic format. These were filled out by the production shift manager. Another record for the ICPP, the shift operator logs, are available on microfiche, probably through the 1970s.

Several people interviewed recognized that portions of the campaign summary reports (primarily the process data/flow sheets) could be used to determine estimates of the quantities of chemicals involved during the processing campaigns as well as potential releases to the environment and waste streams (Phase I Interview with Kimball MC 499; Personal Communication with Wenzel 1997; Personal Communication with Staiger 1997).

ICPP Annual Technical Reports

The Phase I database had one entry for an *Idaho Chemical Programs Annual Technical Report*. This was located and the Technical Library holdings were searched for others. We found five of these reports published by Allied Chemical for 1971, 1972, 1973, 1974, and 1975 (Buckam et al. 1972; Allied Chemical Corporation 1973a, 1976; Buckam and Bower 1974, 1975). The reports varied slightly in format. They all summarized the WCF operations and gave the number of campaigns conducted over what time period, the downtime, the gallons of waste processed, and the volume of solids produced per campaign for each time period. Modifications to process equipment and pollution control equipment were described. Special studies were summarized, for example, testing of NO_x abatement (reduction) methods in 1972, testing decontamination solution formulations for effectiveness in 1974, and characterizing particle size distributions in off-gas in 1975. Three of the reports had a table (Tables V, XIII, and XVII) that listed five or six chemicals used by the WCF. For 1971, kerosene (80,000 gal or 0.36 gal/gal of waste) and nitric acid (21,400 gal or 0.095 gal/gal of waste) were listed (Buckham et al. 1972). For 1972, fuel oil (116,000 gal) and nitric acid (18,000 gal) were listed. For 1974, kerosene (366,800 gal) and nitric acid (366,800 lb) were listed. (Buckham and Bower 1975). It is unfortunate annual reports of this kind were not published for more years. Similar information, including the volume of fuel burned and modifications to process equipment was available in some of the monthly reports.

ICPP Effluent and Environmental Monitoring Reports

The ICPP published quarterly and annual effluent monitoring reports. Reports for 1983 through 1985 were quarterly. From 1986 to 1992 and beyond, the reports were annual and measurements were reported for the calendar year, or for December to December. After the third Quarter of 1985, the reports were called environmental monitoring reports; however, with the exception of a few ambient air quantity monitoring measurements in 1985, effluent monitoring data were still reported. Effluent concentrations before 1983 were reported in letter reports or monthly reports.

The 1983 quarterly reports reported NO_x emissions, which were continuously monitored. The NO_x concentrations were below the ambient air quality standards, but visible emissions exceeded the State of Idaho opacity standards of 20%. The State granted the DOE a variance from the standard for the time period of January 1983 through December 31, 1984. The variance limited the opacity to a maximum of 60%. The opacity exceeded this limit once in January and was close to the limit about six times during the year. The reports included a plot of the visual observations of opacity with 95% confidence limits. Calculated and visually observed opacities correlated well. The daily ppm NO_x recorded by the monitor was shown for the days when the NWCF was operational and the monitor was working. The NO_x levels measured ranged from 110 ppm to 575 ppm and averaged about 370 ppm (WINCO 1984; EINCO 1984).

In all of the reports from late 1983 to 1995, concentrations of arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, chloride, fluoride, nitrate, sodium, sulfate, endrin, lindane, toxaphene, 2,4-D, and methoxychlor, and total dissolved solids, pH, and conductivity measurements in milligrams per liter were reported for the service waste. This was liquid effluent that was sent to the injection well and later to the percolation pond. The monthly average concentrations of the contaminants detected were graphed. Generally, barium, cadmium, chromium, lead, and mercury were detectable in the service waste but the organic contaminants were below the detection limits. A new standard operating procedure for the sampling and analysis of pesticides was implemented in 1984, and after 1984 sampling was done less frequently. After 1986, sampling appears to have been done annually for the pesticides that were less than the detection limits for all years (WINCO 1983; EINCO 1993). During the fourth quarter of 1985, the new ICPP percolation pond was put into use and flows to the injection well were officially terminated (WINCO 1986). The ICPP injection well was used in subsequent years in emergencies (WINCO 1986; Krivanek 1988a, 1988b, 1989). The injection well was sealed in December 1989 (WINCO 1991). Volatilization of compounds discharged to the ponds was not addressed in any of the effluent monitoring reports.

The 1984 quarterly reports were similar to the 1983 reports. Levels of NO_x measured ranged from 130 to 460 ppm. The opacity readings taken for the second quarter of 1984 ranged from 33 to 49% with a mean of 42% for 16 readings. Opacity was calculated from the NO_x measurements, and the difference between visual and calculated opacity was determined for each run. The mean of the differences was 2.4% with the visual reading being about 2.4% higher (WINCO 1984). The DuPont monitor was replaced with a new Beckman NO_x monitor, which was used after April 18. The NWCF was shutdown June 17, 1984, for the rest of the year. No NO_x emissions and no visual opacity or calculations were reported for this time period. The monitor continued to operate and readings were said to have been negligible (WINCO 1985a).

Beginning in the fourth quarter of 1984, the reports included a section on monitoring of the CFSGF stack for sulfur dioxide and nitrogen oxides. During the last quarter of 1984, monitoring was done during two approximately 3-week time periods (6 weeks total) in October, November, and December. The average emission rate for NO_x was 0.45 lb/mmBTU in October and 0.39 lb/mmBTU in December, both under the 0.5 lb/mmBTU EPA emission limit. The minimal removal efficiency for sulfur dioxide was supposed to be 70% but was monitored to be 67.7% in October and 84.5% in December (WINCO 1985a).

There were no NO_x emissions during the first and fourth quarters of 1985 because the NWCF was not operating. The reports for the second and third quarter were not in the ICPP-Library at the time the other reports were photocopied. Because of extensive equipment failures, the ambient air monitoring program was not operating the first quarter of 1985. All four high volume samplers were inoperative in December. Parts to repair the monitors were ordered and a new preventive maintenance schedule and a more extensive spare parts inventory was planned.

The CFSGF stack was monitored for sulfur dioxide and nitrogen oxides and emissions were within limits and similar to 1994 with NO_x emissions of 0.31, 0.20, and 0.35 lb/mmBTU in January, February, and March and 0.32, 0.40, and 0.32 lb/mmBTU for October, November, December 1985, respectively. The roof of the vehicle monitoring facility was the only site used for ambient air monitoring. The total suspended particulate concentrations measured were less than the primary and secondary standards of 260 and 150 $\mu g/m^3$ for 24 hrs (WINCO 1986). In reports after 1985, ambient air monitoring was not mentioned; however, it was addressed in the Site annual reports.

During 1986, the NWCF, and consequently the NO_x monitor, did not operate (Krivanek 1988a). The NWCF did not operate for the first 9 months of 1987, and NO_x was not monitored. Reporting of NO_x releases from the stack was converted from concentrations to tons per month and tons per year in 1987. In 1987, 52 tons were released in September, 111 tons in October, 72 tons in November, and 101 tons in December (Krivanek 1988b).

From 1986 to 1992, the CFSGF was monitored for sulfur dioxide and nitrogen oxides and opacity and emissions were within limits. Monthly average values were given in lb/mmBTU (British Thernal Unit) and were compared to the limit of 0.5 lb/mmBTU.

The amount of coal burned, the average sulfur content, and the average BTU per pound of coal were reported in 1987 and later reports. Table 9 provides the average sulfur content reported each year.

Table 9. Average Sulfur Content of the Coal Burned at the CFSGF (1987–1992)[a]

Year	Average sulfur content
1987	0.66
1988	0.66
1989	0.60
1990	0.56
1991	0.62
1992	0.50

[a] Krivanek (1988b).

Compared to other power plants, the CFSGF is a relatively small one; it burned a total of 12,692 tons of coal in 1986 and 12,464 tons of coal in 1992.

According to the 1988 report, another limit was being imposed on the NO_x emissions. The report indicated that although they did not violate any ambient air standards, NO_x emissions must not exceed limits imposed by the draft FPR Plant Safety Document– (a permit required by Idaho Division of Environmental Quality [IDEQ]). The limits set for the main stack were 388 lb/hr and 1700 ton/yr. The total NO_x released in 1988 was estimated to be 725 tons, well below the proposed annual limit. The hourly limit was not exceeded (Krivanek 1989). The new limit must have been implemented because NO_x emissions after 1988 were compared to the 1700 ton/yr limit. All of the NO_x emissions estimated and reported in the annual reports were below the 1700 ton/yr limit.

Air Emission Inventories

The air emissions inventory was initiated at the INEL in the fall of 1989 as a result of a Monitoring and Oversight Agreement between the State of Idaho and DOE-ID. The inventory documents sources and emissions of nonradioactive pollutants. Information from the air emissions inventory has been used to prepare the Title V Operating Permit for the INEL as required by the Clean Air Act. Both the air emissions inventory and the operating permit applications are of use in understanding recent emissions and may well apply to historical emissions, depending on how processes, off-gas handling, pollution control, and other factors have changed.

The air emissions inventory has been updated annually since 1989. The inventory for 1989, the first year for which a report was published, is called the *Toxic Air Pollutant Emission Inventory for Calendar Year 1989* (Ecology and Environment 1994). This first inventory was done from 1989 to 1991 and was published in 1994. Ecology and Environment (1994) is a two volume, several hundred-page document. Every vent was inventoried at that time buildings and potential sources were surveyed. Standardize forms were developed to collect the survey data. Detailed data were collected on vents that were potential sources. Vents that were not potential pollution sources were eliminated and recent reports only include sources for which there is an emission. These data were compiled on another set of inventory forms, called the Phase II forms, which were categorized into levels. Level 1 forms contain information on stacks and the source, and Level 2 forms contain information about chemical sources, fuel burning equipment, and chemical storage. Level 2 forms are used to gather source-specific information needed to make emissions estimates. Level 3 forms are used to compile information on the chemicals, fuels, or other materials used, and Level 4 forms record the pollution control equipment, monitoring equipment, and other design information applying to fume hoods, paint booths, and similar facilities. Examples of these forms were photocopied for this study. Copies of the completed forms are kept by the facility as documentation for the air emissions estimates.

The emissions inventory is kept on an ORACLE-based database system. INEEL contractors and their associated facilities provide information on sources and emissions to the inventory each year. The air emissions inventory uses the EPA's Compilation of Air Pollution Emission Factors (AP-42) to calculate emissions for most of the sources. Usually, two estimates were calculated, an 'actual' emission estimate and a 'maximum' emissions estimate. Actual emissions estimates are calculated using actual throughput data. Maximum estimates are calculated assuming maximum design capacity and a 24 hrs/day, 365 days/yr operating rate. In 1989, the inventory reported the following emission points: 50 for radionuclides, 14 process and manufacturing points for toxic chemicals, 206 for storage tanks, 36 for boilers, 7 for liquid or gas handling operations, 2 for degreasing and cleaning operations, 13 for solids handling and 10 for surface coating operations. Use and disposal information for many of the materials appears in a computer printout in an appendix to the 1989 report (Ecology and Environment 1994). Another appendix lists all of the storage tanks considered and the emission estimate for each tank. Working losses for tanks were also calculated. Information used for the calculations such as stack data, operating hours, pollution control equipment, and the efficiency is entered on the forms described above. Two hundred and seventy of these forms were printed out in an appendix of the report. In a series of separate appendices, similar data for fuel burning equipment, including boilers and small engines, were given on forms. The percent nitrogen, sulfur and ash of fuel, amount of fuel burned, and other supporting information for the emissions calculations is given. Pollution control equipment data for each piece of equipment entered is also printed in an appendix to the Air Emissions Inventory. The emission estimates for some of the toxic air pollutants were summarized by area. For example, Table 10 contains mercury emissions estimates by area reported in the 1989 inventory.

Table 10. Annual Mercury Air Emission Estimates By Area for 1989

Area	Actual annual air emission estimate for mercury (in ton/y)
ANL-W	9.88×10^{-7}
B-08 (diesel generator)	2.18×10^{-8}
B-16 (furnace exhaust system)	5.36×10^{-8}
B-23 (diesel engine)	2.18×10^{-8}
B27 (diesel generator)	2.18×10^{-8}
CFA	1.05×10^{-5}
ICPP	6.00×10^{-3}
EBR-II	9.42×10^{-6}
INEL	1.85×10^{-4}
NRF	8.71×10^{-5}
PER	1.08×10^{-6}
TAN	4.99×10^{-5}
TRA	2.09×10^{-4}
TREA(T)	1.02×10^{-7}
WMF	1.87×10^{-7}
Total	6.55×10^{-3}

Emissions estimates taken from Table 3 in the Appendix to the Air Emissions Inventory for the total toxic air pollutant emissions for the Site were given for cadmium and mercury. The actual annual emission estimate in tons per year in 1989 for cadmium was 1.17×10^{-7} ton/yr and the estimate for mercury was 6.56×10^{-3} ton/yr, which agrees with the total we compiled from facility-specific estimates ((Ecology and Environment 1994).

Although radionuclide emissions were estimated for various percolation and evaporation ponds, chromium, lead, and other metals were not included in the air emissions for the ponds.

In 1995, the inventory listed 10,500 vents and approximately 650 of these were thought to be possible emission sources. The air contaminants reported in 1995 included nitrogen oxides, sulfur oxides, carbon monoxide, volatile organic compounds (VOCs), particulates, and hazardous air pollutants.

For NO_x in 1995, 16 sources were listed for ANL-W, including the boilers in the EBR-II power plant. Total NO_x emissions estimates were 7.3 ton/yr actual and 200 ton/yr maximum. CFA sources included the No. 2 fuel oil boilers and the craft shop. Total NO_x emission estimates calculated for CFA were 49 ton/yr actual and 95 ton/yr maximum. Total NO_x emissions estimates were 71 ton/yr actual and 620 ton/yr maximum for the ICPP in 1995. NRF had only one significant source of nonradiological pollutants the three boilers used for building heating. Total NO_x emissions estimates were 13 ton/yr actual and 150 ton/yr maximum for NRF in 1995. The PBF emissions included the Special Power Excursion Reactor Test III area, converted to the Waste Experimental Reduction Facility, which included a 4.8 million BTU/hr incinerator, a melting furnace, compactor, and area, where waste was cut up using plasma torches. PBF also reported emissions for two boilers used for heating in the winter. Total NO_x emissions estimates for the PBF were 0.5 ton/yr actual and 32 ton/yr maximum in 1995. TAN had seven boilers that provided steam for heating. Total NO_x emissions estimates were 11 ton/yr actual and 192 ton/yr maximum for TRA in 1995. TRA sources included diesel electric generators and the Advanced Test Reactor cooling tower. Total NO_x emissions estimates were 79 ton/yr actual and 560 ton/yr maximum for TRA in 1995. Stationary sources were grouped separately. Emission estimates were given for diesel engines, boilers, propane burning equipment, laboratory fume hoods, organic chemical storage tanks, paintings and welding operations, and inorganic chemical storage tanks (DOE–ID 1995b).

Table 11 summarizes the emission estimates for 1995 for the chemicals of concern for this study. Emissions estimates were not given for hydrazine or 1,1,1-trichloroethane.

Table 11. Emission Estimates for Chemicals of Concern for the Feasibility Study

. Pollutant	Actual 1989 annual emission estimate (ton/yr)	Maximum 1995 annual emission estimate (ton/yr)
Cadmium	1.1×10^{-8}	1.1×10^{-8}
Chromium	3.6×10^{-4}	4.3×10^{-3}
Lead	2.8×10^{-3}	5.4×10^{-1}
Mercury	1.1×10^{-4}	4.9×10^{-2}
Nitrogen oxides	230	1900
Sulfur oxides	120	1900

Most of the emissions come from fuel burning equipment, primarily boilers and diesel engines. The total nonmethane volatile organic chemical emissions were 11 ton/yr actual and 50 ton/yr maximum (DOE–ID 1995b). Compared to facilities that use large amounts of cleaning solvents, this emission is relatively low.

A Phase I interview with Mr. Ferrara described the Air Emissions Inventory that was being prepared in 1989. Mr. Ferrara worked for DOE-ID in 1989 on a program to inventory all operational facilities for criteria pollutant emissions (NO_X, SO_X, PM10, CO, ozone, and lead). The ultimate goal of this inventory was to identify INEEL operating facilities with criteria pollutant air emissions for the purposes of permitting. A database was developed and was turned over to EG&G in 1991. In 1992, Mr. Ferrara began working on an inventory for toxic chemical air emissions, toxic chemicals being defined by federal regulations, and the toxic chemical list proposed by the State of Idaho. The draft report was scheduled to be released in August 1993 and the final toxic air inventory was to be merged with the air emission inventory in 1993 (Phase I Interview with Ferrara MC 15257). It appears that the 1989 air emissions inventory included air toxics.

In summary, the air emissions inventory annual report gives emissions by area. It also lists information such as the changes, removal, or sources and changes in control equipment that occurred that year. The 1989 inventory has the most comprehensive listing of sources. Many of these did not meet IDEQ reporting requirements and were not considered emissions sources. The 1989 inventory has a good description of facilities in each area, which often includes schematics of the ventilation and exhaust systems, but almost all of the descriptions relate to emissions of radionuclides.

Operating Permit

The IDEQ grants permits for discharges of pollutants to the air in the State of Idaho. The Title V Operating Permit Application as well as Permits to Construct and supporting materials are kept by the IDEQ in Boise, Idaho. The application is a large, multi-volume document, organized by facility, submitted by LMITCO in 1995. The Permit Application was included in the INELCHEM database, but it was not copied for this initial feasibility study. The air permit should contain emissions estimates and supporting data, such as descriptions of exhaust systems, pollution control equipment, and calculations. Relevant parts of the application, specific for chemical and facility, could be photocopied, probably best done through a Public Information Request to Linda Smith, IDEQ, 1410 N Hilton St., Boise, Idaho 83706. Dan Salgato (208-373-0431) is the current contact for the IDEQ Permitting. The Operating Permit contact for the US DOE is Woody Russell, Environmental Engineer at the Idaho Operations Office in Idaho Falls.

PATHWAYS OF EXPOSURE CONSIDERED

In 1997, The INEELHES reviewed the issues associated with determining the pathways to be considered. After considerable discussion, and gathering additional information on groundwater transport, unusual pathways, wildlife and waterfowl, and potential locations of receptors, the subcommittee agreed that the air pathway was the pathway that should be considered for chemical exposures to the offsite public.

The pathways relevant for the chemicals selected were the same as those identified before the selection. Further analysis of the relevancy and completeness of the pathways was completed for the specific chemicals of concern. Inhalation was the pathway of concern for all of the chemicals, although we recognized that mercury in air may eventually present more of a hazard from deposition into aquatic systems and the methylation and subsequent bioaccumulation in fish that may be consumed by humans.

Wildgame Pathways

Addition information on bioaccumulation of mercury by game birds or waterfowl at the INEEL has not been found. A considerable amount of information has been gathered by the Environmental Research Foundation (Morris 1994). Foundation representatives gave a presentation to the INELHES in 1997 on the wildgame pathways. Data on the uptake of radionuclides by waterfowl on ponds and other wildlife has been gathered. The number of ducks in the relevant flyway, and the probability of a contaminated duck being harvested have been researched by Foundation scientists. The INEEL also has information on the ecology of antelope, rodents, rabbits, reptiles, and other animals that live on the Site. A summary of radionuclide analysis in road kill and big game harvested by hunters can be found in the INEL annual reports (Hoff et al. 1992).

The INEL Historical Dose Evaluation report (DOE 1991a) acknowledges that some biotic pathways do exist at the INEEL. The report refers to RESL publications by Markam and Randall (updated in Morris 1994). The evaluation says, “The most important biotic pathway is through game animals that can assimilate some radioactivity onsite then migrate offsite. However, the probability of a hunter shooting one of these animals shortly after the animal leaves the INEL is small. … Doses, although unlikely, might be as high as 10 mrem.” (DOE 1991a).

Chemicals, most notably chromium, mercury, and organic compounds, that may have accumulated in wildgame and chemicals in retention ponds and areas to which waterfowl and other wildlife may have had access were evaluated further.

Air Pathway

The air pathway includes releases from stacks, vents, building exhaust, engine exhaust, and open fires; evaporation of volatile materials from ponds, spills, tanks and processes; and particles released or produced from wind suspension. Although pollutants discharged from process stacks seemed to be of greater interest to the public, releases from the diesel engines of buses, generators, emergency generators, trucks, and pumps were not insignificant.

For the purposes of this study, we were interested in evaluating the potential for trichloroethane and mercury to have evaporated from ponds or spills and in assessing exposure to airborne dust containing contaminants, such as chromium, suspended from pond sediments or soil.

Evaporation from Waste Areas

The amount of material volatilized could be estimated from the volume discharged and the surface area of the pond if we were to make assumptions about the temperature, the quantity of material that was unbound and available for evaporation, and other factors. However, evidence of discharge of large amounts of trichloroethane or mercury to waste ponds has not been found. Trichloroethane was found in TRA pond sediments, and mercury was released (in amounts that required cleanup due to potential risks to workers doing remediation) to the CFA pond in simulated calcine.

Suspension of Soils and Sediments

Waste ponds or spills to soil that may have become dry and been subjected to dispersion by wind erosion were of interest. The historical dose evaluation report stated, “The resuspension of contaminated surface soil is not an important pathway for this analysis (DOE 1991a). Analysis of continuous air samples from the INEEL Site boundary have only rarely detected radionuclides that might have come from contaminated soils. Analysis of air samples from the RWMC, one of the INEEL facilities with the greatest potential for resuspension, indicate that doses at the INEL Site boundary would be less than the other doses evaluated in this report (Hoff et al. 1990)” (DOE 1991a).

Although radionuclide emissions were estimated in the 1995 air emission inventory for various percolation and evaporation ponds, chromium, lead, and other metals were not included in air emissions estimates for the ponds (DOE-ID 1995). The DOE Environmental Survey Team considered resuspension insignificant for many of the spills that occurred because of the rapid seepage of liquid in the porous soil (DOE 1988).

The Site has been involved in some NESHAPs diffuse source calculations for wastewater discharge and laundry discharge to the pond at CFA. The CFA laundry effluent contains metals, and the effluent was sampled monthly for metals in 1988 and 1989. Using the highest annual average concentration and conservative assumptions about the flow rate, a projected release after 20 years of inventory had accumulated was calculated. An upper-bound estimate of the maximum air concentration that a worker located 100 m from the pond and a member of the public on U.S. Highway 20/26, 2700 m south of CFA, might be exposed to was calculated to be less than the 10^{-6} increased risk level for carcinogens and less than EPA and State standards. Actual downwind concentrations were predicted to be much less (Abbott 1991a). Radiological impacts for the CFA evaporation pond being proposed in 1991 were also calculated (Abbott 1991b). Radiological doses from the pond at TRA, if the pond were allowed to completely evaporate, have also been calculated (Abbott 1991a).

Limits for liquid based on the potential for wind dispersion of dry sediments were formulated using air dispersion modeling. However, in general, researchers do not have the impression that high wind events suspending pond sediments has been a problem at the INEEL. This issue has been raised and examined, and the general consensus of researchers involved in the air dispersion modeling seems to be that the sediments are crusted, and if the ponds are not disturbed (excavated, bulldozed, or the crust broken by land moving equipment), the material is not subject to significant wind erosion (Personal Communication with Abbott 1997, Personal Communication with Ritter 1998). Studies of dry areas, the 'bathtub ring' or piles of dredged materials, have been conducted for the CERCLA characterizations and the contaminated material appears to have remained in the top layers of the soil.

ANL-W. The ANL-W industrial waste pond was an unlined evaporation pond built in 1959. The pond was 3 acres in area and about 4 m deep. It was fed by four industrial waste ditches. The pond overflowed to an area north of the pond. The edges of the pond were vegetated with cattails and 10–12 ducks and their ducklings were said to live on the pond. Most of the waste discharged to the pond in the 1980s came from the EBR-II cooling towers and blowdown (steam system pressure release valves). Liquid waste from other water coolant systems and storm and snowmelt runoff water accounted for much of the rest of the discharge. The main source for industrial waste contaminants were the chemicals used for water treatment and for regeneration of ion exchange resins. These included the slimicides, BETz C-30, Betz J-12; the biocide, chlorine; the corrosion inhibitors, Beta 2020-2040, Nalco 7270, and Nalco Elim-OX; and the ion exchange regeneration reagents, sulfuric acid and sodium hydroxide. The pond also received photographic processing waste, although the silver was removed in the 1980s before discharge. Unknown amounts of hydrazine and silver were discharged to the pond in the earlier years of operation.

The pond sediments were sampled in 1986 and chromium VI was not found in the sediments. Further sampling for other metals was conducted and experiments on sediment samples were conducted to answer questions about the chemical transformation of chromium in the pond sediments. The experiments suggested that the pond is a reducing environment and that chromium VI was reduced to chromium III within a few hours by filterable chemicals, microorganisms, or decaying organic matter. Analysis of silver, lead, cadmium, chromium and barium in the pond sediments showed that levels were low, generally less than 1% of the EPA limits for hazardous waste. The metals appear to be complexed in insoluable sulfide and other anion compounds. Well logs, original analytical sheets for the EP Tox analysis of pond sediments, borehole water analyses were attached to the report (Villarreal 1986).

TRA. The TRA chemical waste pond was designed to receive chemical wastes from the TRA demineralization plant. These waste were primarily wastewater from ion exchange column regeneration solutions and water softeners that were mostly sulfuric acid, sodium hydroxide, and sodium chloride. The TRA chemical waste pond was first used in 1962, and pesticides, biocides, solvents, and PCBs may have been discharged to the pond. Trichloroethane has been detected in sediment samples. Estimates of the amount of wastewater discharged was 79 million L in 1975 compared to 25 million L in 1983. A very limited number of sediment samples from 1983 found concentrations of mercury as high as 45 μg/kg. Chromium was not listed as a contaminant. In another sampling effort, concentrations ranged from 39 to 5345 μg/kg for 1,1,1-trichoroethylene, from 31 to 91 mg/kg for mercury, and from 7 to 100 mg/kg for lead (Burns et al. 1990).

The CERCLA remedial investigations for the TRA note that over the years liquid wastes were discharged to the sewage lagoons, retention basin, warm waste pond, chemical waste pond, cold waste pond, and the disposal well. Chromium in reactor cooling water and other wastewater was discharged to the warm waste pond. After November 1964, water containing chromate was discharged to the disposal well and in 1972 chromate was no longer used as a corrosion inhibitor in the reactor cooling water. After 1972, phosphate-based corrosion inhibitors were used. The cold waste pond received cooling water from blowdown during reactor operations (Martin-Lewis 1992). The TRA warm water waste pond sediments had an average chromium concentration of

4536 mg/kg in 1991. Concentrations of other metals were relatively low (Beller and Bessent 1991). The air pathway was not considered in the investigation because an air pathway from the contaminated perched water system was said not to exist (Martin-Lewis 1992).

An investigation of the TRA pond predicted that because hexavalent chromium is mobile and would be transported with the water percolating through the pond, the chromium left in the pond would be reduced, immobile trivalent chromium. Hull (1989) concluded that "almost all of the chromium discharged to the pond is still in the pond sediments" but the uncertainty was large. Based on monitoring data, 4820 to 19,600 kg of chromium was estimated to be in the sediments. Chromium concentrations in the deep perched water zone were greater than drinking water standards. As part of a discussion about the conceptual model for exposure, Hull (1989) acknowledges that another mechanism for contaminant migration could occur if the pond dries out. The water was said to provide a shield and without it employees and biota could receive a radiation dose and windblown sediments could also expose employees and biota. The "if, could" nature of these statements suggests that the pond, in 1989, had not been dry (Hull 1989).

Auxiliary Reactor Area. The Auxiliary Reactor Area (ARA) chemical evaporation pond was used to dispose of wastewater from the ARA-I facility. The pond has received waste from the materials testing laboratory since 1971 (Stanisich et al. 1992). A closure plan estimated that 20 L/yr of acids and 20 L/yr of nonchlorinated solvents had been discharged (Alexander and Saint-Louis 1988). By 1992, the pond was said to be approximately 875 m^2 in size. It no longer received wastewater and was dry most of the year. A sampling and analysis effort was conducted in 1990 to characterize the Site. Many metals, including beryllium, cadmium, chromium, lead, and mercury were found above background levels (Stanisich et al. 1992).

The ARA chemical evaporation pond is located about 14 km from the Site boundary and about 1.6 km from U.S. Highway 20. The potential for windborne migration of contaminants was addressed in Stanisich et al. (1992), which said, "the atmospheric transport potential may be mitigated because the contaminants were found in low quantities and were restricted to one or two discrete locations in the pond and because the contamination was found in areas with a comparatively large amount of vegetation, which would tend to minimize particulate transfer." They acknowledged that atmospheric transport to personnel working at the ARA-I facility doing maintenance or security work was possible. Transport via game animals was not considered a pathway because of the small size of the contaminated area. For the risk assessment, a site-specific upperbound airborne particulate concentration of 20 $\mu g/m^3$ was used to determine the exposure for workers at ARA-I. The contaminant concentration of the particulate in the air was assumed to be the same as the pond sediment concentration. The Hazard Quotient for the inhalation pathway was 0.006 for chromium III and 0.0009 for chromium VI, well below 1. The cancer risk for Chromium VI totaled 2×10^{-7} for the worker scenario. The future residential noncarcinogenic Hazard Quotients calculated for chromium were also less than 1 for all pathways (Stanisich et al. 1992). Recognizing that CERCLA baseline risk assessments are conducted using very conservative assumptions and for very different reasons, the risk assessment is useful because risks to hypothetical onsite workers and future residential users (including children) assumed to grow vegetables, ingest soil, and drink groundwater are less than risk levels of concern. The offsite exposure would be expected to be even lower.

CFA. The CFA-674 pond was investigated in the course of a Remedial Investigation and Feasibility Study prepared in 1996. It received waste from the chemical engineering laboratory, which operated from 1953 to 1965. Liquid waste discharged to the pond may have included kerosene, chromic acid and dichromate solutions, and trichloroethylene. Calcine (simulated) was disposed of in the pond and contributed metals to the pond. The pond was also used to dispose of construction rubble, including asbestos-based roofing material. Sampling was done in 1989, 1993, and 1994 and indicated that mercury exceeded the regulatory level for hazardous waste and other metals exceeded background concentrations. PCBs and asbestos were also found. A time-critical removal action was performed in 1994 to remove mercury contamination that was above the occupational risk levels allowed. Approximately 2345 m^3 of mercury-contaminated soil was removed from the ground; it included calcine, soil contaminated by calcine, and soil contaminated by liquid effluent discharges (McCormick et al. 1996).

PBF. As a part of a CERCLA investigation, chromium content of the PBF evaporation pond was sampled at 20 locations. The average concentration in sediments was 712 mg/kg. The average sediment depth was 13.2 cm. The total chromium content was estimated to be 232 kg. Records in the Lockheed Martin Idaho Technologies Company Administrative Record state that when the cleanup goal for cesium is attained, then the cleanup goal of 800 mg/kg for total chromium is sure also to be attained (EG&G 1990).

Disposal histories for these liquid effluent waste disposal areas are probably available after the mid-1980s and for ICPP and ANL-W for the 1970s. Based on similarities in the processes and production or operating procedures, available data might be used to derive disposal concentrations for earlier years. A history of when the ponds dried up and for how long would be needed to adequately characterize the potential for suspension of materials into the air. As far as we know, no such chronology has been compiled. It is unclear whether the operating history of ponds in the progress reports is adequate to estimate of the amount of wind erosion that may have occurred. In recent years, more fugitive dust emissions have been characterized and determination of releases from fugitive dust emissions is underway.

Historical radionuclide monitoring might be used to derive release estimates for nonradioactive contaminants that were not monitored. For example, if the amount of radioactive cesium discharged to a pond had been estimated, the air concentrations attributed to dust emissions had been measured, a relationship between the two could be established. This same relationship might be applied to chromium. If the amount discharged had been estimated or measured then the amount released to the air could be estimated based on the suspension of cesium. However, monitoring for radioactive emissions to air from the ponds does not appear to be available. Calculations of potential air concentrations have been done (Abbott 1991a and 199b).

Although it has not all been collected during the feasibility study, there is probably sufficient CERCLA monitoring data for the ponds to derive estimates of how much metal is in the sediments. For the CERCLA characterizations and risk assessments reviewed to date, the suspension of materials from the ponds was considered insignificant compared to the releases to groundwater. Several pertinent CERCLA documents are being prepared or are in draft form and have not yet been finalized and approved for release to the public. The source term for the suspension of contaminants in soils or sediments of evaporation ponds, settling basins, and waste ditches would be difficult to determine. We know that contaminated sediments were periodically dredged from the NRF ditch and some of the ponds dried up from time to time, but information on the disturbance of the dried sediments, high wind events, particles sizes, and other factors useful for determining potential releases does not appear to be readily available. As they are finalized and published, CERCLA characterizations of the ponds should be reviewed as a part of

Task Order 6 for additional information that would help us understand the potential for airborne dust exposure.

Given the lack of information, we decided to calculate air concentrations that might result if the entire inventory of metals in the ponds were to be suspended into the air. These calculations were done for chromium and cadmium and are described in the next section.

INFORMATION AVAILABLE TO CALCULATE RELEASE, TRANSPORT, AND DOSES FOR THE CHEMICALS OF CONCERN

For those chemicals that had ratios greater than or close to 1, more information on their use, storage, disposal, and release was reviewed to help determine whether they should be evaluated in a chemical dose reconstruction. The environmental fate and transport, the form of the chemical released, potential degradation, transformation, and other characteristics of the chemical were used to better determine the potential for exposure to offsite public at concentrations that may have presented a health risk.

This section summarizes the information found about each chemical of concern after the screening was complete and relevant documents were obtained and reviewed. It presents our understanding of the use and release of the chemical and our findings as they relate to determining if a dose reconstruction could be conducted and whether or not each chemical should be included in future dose reconstruction studies.

Asbestos

Asbestos is a known human carcinogen. It causes lung cancer and lung disease. Asbestos insulation was used extensively in the 1950s when many facilities at the INEEL were initially constructed. Asbestos materials may be found in roofing, pipe and vessel insulation, building insulation, gaskets, packing, siding, and other building materials. The materials have been removed when they deteriorated or as renovations, maintenance, and repairs were done. Worker protection necessitates that asbestos controls be in place during all removal operations. Asbestos has not been subject to storage in large amounts, leakage, spillage, or routine release to the environment. It is unreasonable to assume that much of the asbestos present could have been dispersed into the air because most of the asbestos onsite is in insulation and building materials. Asbestos should not be evaluated further because it is primarily found in building materials that are resistant to environmental transport unless seriously degrading or the building is demolished. If a building is imploded, exploded, or demolished all at once, asbestos would be released to the air and would be subject to deposition and resuspension with time unless precautions were taken to contain it. It is likely that most of the buildings with asbestos materials have been remediated or destroyed in the last decade when awareness of asbestos hazardous was high and precautions were taken to protect workers and limit dispersion of asbestos fibers.

Findings for asbestos: A reconstruction of asbestos releases should not be conducted because exposures to members of the public seem very unlikely.

Beryllium

Beryllium causes lung cancer in laboratory animals and can cause a serious lung disease in people sensitized to beryllium. Very little information on the use and release of beryllium was found in the documents reviewed. Beryllium metal and beryllium oxide materials were reported in the 1990 SARA inventory as ranging up to 45,455 kg.

According to worker interviews, beryllium was used as a reflector for neutrons in several reactors and was used for the ANP Program. Based on interviews, the Oil, Chemical and Atomic

International Union Center Report (1998) listed MTR, ETR, ATR, EBR-II, ZPPR, EBOR and the ANP reactors as those that may have used beryllium reflectors.

In a Phase I interview (Phase I Interview with Kaiser MC 14332) R.E. Kaiser, an engineer working with the TREAT facility at ANL-W and a reactor supervisor working with ZPPR since 1968, said that beryllium used at the ZPPR was received as bricks and no powders or machining was done at ANL-W. It is likely that almost all of the beryllium inventory at the INEEL was made up of solid bricks and reflector materials.

Beryllium Dust from Machining or Other Operations

Beryllium dust is a serious respiratory hazard because beryllium inhalation can cause cancer and fatal lung disease. No written documentation in site reports or memos indicating that beryllium was machined or otherwise processed so as to have caused beryllium dust releases was found. The Oil, Chemical and Atomic International Union Center interviews found that beryllium machining or hand filing was performed at TAN-607, ATR, ETR, MTR, WRRTF and TRA-653 and that beryllium blocks were cut with a chop saw for disposal in the TAN-607 machine shop (Oil, Chemical and Atomic International Union Center 1998). An interoffice memo described inclusion of requirements for the safe handling of beryllium in a manual to be used at the ATR. Whether or not beryllium was to be machined or handled in such a way to produce respirable dust is not clear from the memo (Coward 1972).

Although we reviewed no reports, memos or other documents suggesting that beryllium was machined at the INEEL, NIOSH interview notes suggest that special materials made of beryllium were made at the INEEL. NIOSH researchers interviewed workers who described a beryllium machine shop at TAN (Personal Communication with Utterback 1998).

In addition, Brian K. Morris, a member of the INEELHES representing the Oil, Chemical and Atomic Workers International Union Local in Idaho Falls, had heard that tools made of beryllium metal displayed at the Bradbury Museum setting in Los Almos, New Mexico were labeled as having been made at the INEL (Personal communication with Morris 1998). *RAC* researchers spoke with Gary Franklin, a educator with Bradbury Museum described an exhibit of four tools made of beryllium and copper with a sign, which says, “Tools Used in the Manhattan Project”. Although there are four tools on display, the museum has about 50 tools stored in its archives and recently sent several tools to a museum in Norway. The information available on these tools does not include the location of where they were made but three company names were listed as manufacturers for the tools: Sampson's Forge, AMPCO, and BerylCo. As far as we know, these manufacturers were not affiliated with any past INEEL contractors. *RAC* searched listings of industrial manufacturers and found that AMPCO Metal is located in Milwaukee, Wisconsin and has been in business since 1914. She found that BerylCo was a division of American Metal located in Pennsylvania. No Listings for Sampson’s was found.

In an e-mail to C.M. Wood, Dan Yurman, INEELHES member, said that “beryllium machine tooling took place at Test Area North according to Dennis Kaiser, a retired INEL manager. The parts were used at Rocky Flats”.

In a number of e-mails, Chuck Broscious, INEELHES member, voiced concerns about beryllium use at the INEEL. He brought up statements from a workers compensation case: Michael P. Cawley Claimant, vs. Idaho Nuclear Corp. Employer, and Insurance Company of North America, Defendants, heard by the Idaho Supreme Court, December 29, 1989, No. 17514.

Chuck Broscious said Michael Cawley "died from his exposures at the INEEL." Chuck described statements made in a deposition by medical doctors that "personally feel Mr. Cawley has significant interstitial lung disease, most likely resulting from his exposure back when he worked at the atomic energy site in the 1960's, due to significant exposures he had at that time to radiation and beryllium. It may very well be that the latter, i.e. beryllium, was his major problem." "The major issue at this time is to determine whether this disease is progressive, which berylliosis can be, and whether he should have any treatment." Chuck Broscious wrote that Mike Cawley worked at the Test Reactor Area Instrument shop for 18 years before changing jobs to the Bureau of Standards. Mr. Cawley described "lathe mills" and "machine shop tools". The quotes suggest that the Atomic Energy Site had a shop that worked with beryllium. It is not clear from this testimony that the lung disease was chronic beryllium disease (as opposed to many other types of interstitial fibrosis) or that a beryllium machine shop operated at the INEEL (although Chuck Broscious believes that this was the only Atomic Energy Commission site at which Mr. Cawley worked). These communications suggest that a machine shop at Test Area North (TAN) and/or TRA worked with beryllium.

Chuck Broscious also quoted Dick Rothermel as saying "Benefits of the Program to nuclear reactor technology were many… benefits include…development of beryllium fabrication techniques". Mr. Rothermel has retired from the INEEL and now lives in Missoula, Montana. He said that he did not mean to imply beryllium parts were fabricated at the INEEL. As far as he knew, all of the beryllium components used in the ANP Program were machined elsewhere, probably in Evandale, Ohio. He said they inserted the parts at the INEEL, but they were manufactured elsewhere.

No records of environmental releases, or ambient air monitoring associated with any machine shops were found.

Although a shop that machined and finished beryllium tools or parts may be of interest for historical worker health and safety, there does not appear to be any information about releases on which to base source term estimates nor evidence to suggest beryllium was machined in quantities to justify including an assessment of beryllium releases in a dose reconstruction for offsite releases.

Chronic Beryllium Disease Surveillance

Paul Creighton, Director of Occupational Health Group the INEEL thought that most of the beryllium used on site had been used as cladding or as a neutron absorber for a reactor or reactors at the Test Reactor Area (TRA). The beryllium materials used were not machined on site. As far as he knew, no employees have Chronic Beryllium Disease (CBD) or have reported beryllium exposure from the INEEL. He thought that the surveillance program may involve as many as 30 people who live in the Idaho Falls area but he believed that these people were exposed at the Rocky Flats Plant or at Oak Ridge, years ago (Personal Communication with Creighton 1999).

Duane Hilmas, Technical Director for the Oak Ridge Associated Universities Beryllium Surveillance Project said that people living in Idaho Falls were included in the project, which is a DOE complex-wide screening project to test people with a potential for developing CBD. (The Former Beryllium Worker Medical Surveillance Program, ORISE/CER, web site: www.orau.gov/ehsd/cer.htm). He said that people living in Idaho Falls were being tested every three years and are due for testing in 1999. Three years ago, most of the people tested in Idaho

Falls had been exposed to beryllium at other sites. He was not aware of any reports of a beryllium machine shop at the INEEL. He would not be surprised if beryllium components were machined in existing machine shops but has not heard reports from workers of a machine shop or other facility where people were exposed to beryllium.

Beryllium Used for the ANP Program

Beryllium reflectors were used for the aircraft engine reactors. The reflectors in the reactors and aircraft engines seem to have been contained but how these materials may have deteriorated and whether beryllium may have been released in the course of the aircraft engines tests was unclear. *RAC* sought to obtain more information on the aircraft engine components and their integrity during the tests from additional interviews.

Retired engineers (Dick Rothermel, Donald Suckling and Lewis Mason), told *RAC* individually over the telephone, what they knew about the integrity of the beryllium components during engine tests and offered their opinion of whether or not beryllium could have been discharged from the stack or otherwise released into the environment from the ANP Program tests. Don Suckling worked with the ANP program beginning in 1954. He thought that the beryllium machining was done at other sites, not at the INEEL. Beryllium metal and beryllium oxide were used as reflector materials (to reflect neutrons back into the reactor core so that a chain reaction occurred) but were not fabricated onsite. He felt that the beryllium used in the engine reactors would not have been ground up nor melted and released. Core meltdown occurred but the beryllium components were contained. Lewis Mason, an engineer for the ANP in the 1950s, said that beryllium would not have been released from the engine tests because the beryllium parts were separate from the coolant airstream. He said that the program handled a large amount of beryllium, but it was probably not machined onsite. He said that in handling beryllium components, they used standard operating procedures that involved protective clothing. Beryllium inserts were used in the engines but he does not recall these “being overtemperature”. He worked on the experiments and engine tests that would have most seriously damaged the reflector. These involved meltdown of the reactor core and the fuel but not the reflector.

RAC also talked with Jay Kunze’, who worked on the ANP Project and is now Dean of Engineering at Idaho State University in Pocatello. To the best of his knowledge, no beryllium was used in the core of any of the reactors tested. He said a large amount of beryllium was used by the program for the reflector that surrounded each reactor core. The reflector was at a much lower temperature and although the core was melted in at least one and maybe several tests, the reflector was not. The reflector and core were separate. He said that no beryllium should have gone up the stack. He added that the ANP workers were very careful with beryllium because they knew it was alleged to cause lung cancer and serious lung disease. He said, “we were aware of berylliosis and were scared of beryllium… we weren’t scared of radioactive materials but we were scared of beryllium”. He thought that a little bit of machining, manufacturing and alteration of parts may have been done at the INEEL but the beryllium used in the reflectors was fabricated offsite.

The individuals interviewed had all worked on the ANP project and seemed to have a good technical knowledge of the experiments that were done and how things were constructed. All three described the beryllium reflectors as being made of rods or curved plates that surrounded the core. The reflectors in the ANP reactor cores were made of hexagonal pieces of beryllium that were about 16 inches long. In later years the reflectors for the NASA Gas Core Reactor were made of curved slabs of beryllium about 6 inches thick and about 4 ft × 2 ft in dimensions. The slabs were put together in a circle to surround the reactor core, which was about 6 ft in diameter. The three individuals corroborated each other in stating that the beryllium was used as a reflector and that the core and beryllium reflector were separate. The core was melted on occasion but the beryllium was not. It was also separate from the coolant airstream and although core components may have gone up the stack, beryllium probably did not. They thought beryllium used in the reflectors was probably contained and saw no reason for the reflector to have been degraded or blown apart in any of the experiments.

Henry Peterson and Eddie Chew (1997), who both worked on the historical dose evaluation (DOE 1991a), recalled that beryllium oxide tubes were used in IET heater cores. Beryllium concentrations in air resulting from this use were thought to have been much lower than occupational standards and soil concentrations at TAN were not significantly different from levels due to background concentrations of beryllium in soil (Personal Communication with Chew 1997).

Although there seems to some confusion as to what constitutes a reactor ‘core’, as opposed to a ‘reflector’, it seems unlikely that beryllium was released from the IET tests in a form or quantity to have been an inhalation hazard.

Other Potential Beryllium Uses and Releases

Industrial Hygiene survey sheet data suggested that beryllium thermocouple fabrication work that may have involved welding, brazing and soldering, occurred at Central Facilities. The surveys were performed in 1989 but there is no indication of when the work occurred or for how long (Oil, Chemical and Atomic International Union Center 1998).

C.M. Wood, with CDC, found a letter from the Oak Ridge Associated Universities written in December 1988 about a former EG&G Idaho Medical director mentioning a beryllium shield that was blown up as part of an outdoor experiment in 1964 or 1965. C.M. Wood said that Eddie Chew was unable to relate this to any events researched for the Historical Dose Evaluation. Don Suckling, Lewis Mason and Jay Kunze were not aware of a ‘beryllium shield’ having been blown up in the 1960s. They commented that this did not make sense because beryllium is not a good material for shielding. They thought it was not related to the ANP program. Jay Kunze recalled several reactors that were blown up and wondered if this might not refer to the SNAP-10-A reactor that was tested in the 1960s or 1970s. It was one of the reactors designed for space and he recalled that it was blown up with explosives, perhaps near TAN. He was not sure if the reactor had a beryllium reflector. In an e-mail to Dr. Roy Ellsworth, Chair of the INEELHES, written on June 1, 1999, Chuck Broscious said that according to NIOSH protocol A-3, beryllium was used in the Space Nuclear Auxiliary Power Transient (SNAP) Program which tested beryllium reflected reactor performance at TAN’s IET site. If the exploded reactor had a beryllium reflector the beryllium may have been dispersed into the environment. However, we cannot reconstruct beryllium releases nor predict particle size or dispersion with the limited information available.

Waste beryllium in the ANP reflectors was buried at the RWMC subsurface disposal area (burial grounds). There is no indication that this beryllium has been dispersed in the air to present an inhalation hazard.

Effluent and Environmental Monitoring

As far as we know, no other monitoring data collected as a part of RCRA and CERCLA studies have identified beryllium in soil that may have been deposited as a result of releases from engine tests or a machine shop. Beryllium was found to be elevated above background levels in sediments of the ARA Chemical Waste Pond (Stanisich et al. 1992). The CERCLA risk assessment at the ARA chemical waste pond evaluated the increased cancer risk to remedial workers exposed to maximum concentrations of particulates from chromium in the pond sediment. They calculated a risk of 2×10^{-7}, less than risk levels of concern for the worker scenario. Chromium is a more potent carcinogen than beryllium and is found at much higher concentrations in the sediments than beryllium. The risk analysis suggests that airborne suspension of contaminated dusts from the pond would not have affected the public, especially for contaminants found at relatively low levels like beryllium.

Findings for beryllium: It would be very difficult to determine a reasonable source term estimate for beryllium metal and beryllium compounds cannot be done because of a lack of information. Although we have found no evidence that dust containing beryllium compounds or metal was dispersed into the air in amounts that may have affected the public, the use and release of beryllium is not well documented. Most of the beryllium in the inventory appears to have been used as solid materials for reflectors would not have been subject to dispersal into the air. Environmental monitoring has not indicated that a measurable amount of beryllium was released from facilities at the INEEL. The information collected to date suggests that beryllium was not released in sufficient amounts to have affected people off-site. C.M Wood, with the CDC, will be searching for additional information about beryllium machine shops and beryllium releases from the ANP Project or other programs, through the completion of Task Order 6.

Cadmium

Cadmium inhalation can cause lung cancer. The screening ratio calculated for cadmium was based on conservative inventory estimates that included many cadmium compounds in various forms, many of which may not be available for transport offsite or absorption into people. At the time of the selection, it was recommended that cadmium be evaluated further for the wildgame and the air pathways if cadmium was found to have been discharged in large amounts to ponds. Such ponds could have dried up, resulting in air suspension of sediments. Discharges to the ponds may have also contributed to cadmium concentrations in waterfowl.

The inventory estimate for the cadmium compounds stored at the ICPP included the kilograms of the cadmium nitrate and cadmium sulfate. Including the anion in the total amount overestimated the amount of cadmium. Cadmium nitrate and cadmium sulfate were used as a part of the fluorinel dissolution process in the FAST Facility ICPP-666 (Phase I Interviews with Byrnes MC 504 and Frazee MC 532). In a discussion about the ICPP percolation pond effluent measurements, the 1986 ICPP Environmental Monitoring report stated that cadmium concentrations were increased in the effluent because of work for the FAST Facility hot startup. Cadmium was used as a neutron poison for the fuel dissolution process at the FAST Facility, but an acceptable alternative was being sought (Krivanek 1988a). Cadmium continued to be used in the FAST Facility process for sometime and although elevated, concentrations did not exceed the MCL (drinking water standard) or the EPA Toxicity Limits (WINCO 1985a, 1985b).

Cadmium in airborne dust which may have been suspended from percolation pond sediments has not been addressed in any of the Site documents we reviewed. Orr and Cecil (1991) estimated that from 1961–1988 an average of 400 million gal/yr of effluent was discharged to the ICPP ponds and disposal well. Discharges to the well were estimated by “Pittman and others” to average about 363 million gal/yr (Orr and Cecil 1991), suggesting that discharges to the ponds were about 37 million gal/yr or 1.04×10^9 gal over the 28 yr time period. The annual environmental reports suggest that discharges to the ponds were increased in the late 1980s when the disposal well was no longer used for routine disposal. As much as 584 million gal of liquid effluent may have been discharged each year after 1989, compared to roughly 37 million gal/yr prior to 1989.

For the purposes of the screening calculations we assumed that 2.3×10^9 gal were discharged for the four years of 1989–1992. From 1953 to 1960, we assumed the same volume was released each year as that reported for 1961–1988, i.e. 37 million gal/yr for a total of 259 million gals for the seven year period. We assumed that a total of 3.6×10^9 gal or 1.36×10^{10} L were released to the ponds during the entire time period from 1953–1992. According to the Historical Dose Evaluation (DOE 1991a), the FAST Facility began operations in 1985. It seems likely that 1985 and 1986 were the peak years for cadmium discharges. We do not know how much cadmium was released in the effluent before or during the FAST Facility operations. ICPP effluent reports stated that concentrations of cadmium in effluent discharged to the ponds and well were less than the MCL of 0.005 mg/L (ENICO 1984; WINCO 1984, 1985a, 1985b). For screening purposes we assumed that the effluent concentration was at the MCL for the entire time period of operations. Using these very cautious assumptions, we estimated that less than 68 kg (1.36×10^{10} L $\times$ 0.005 mg/L = 6.8×10^7 mg) of cadmium could have been discharged to the ICPP ponds.

We performed screening calculations to determine if cadmium in pond sediments would present a significant risk to potential offsite receptors. Using the highest possible inventory in the pond (68 kg cadmium), a resuspension rate constant of 10^{-12} s^{-1}, and a conservative dispersion factor of 5.67×10^{-8} s/m^3 (the dispersion factor value agreed upon by the INEEL Health Effects Subcommittee), we estimated that the maximum air concentration at the nearest site boundary would be 3.8×10^{-15} g/m^3 or 3.8×10^{-9} $\mu g/m^3$. The resuspension rate constant has been estimated for the INEEL using EPA’s approach for rapid assessment of exposure to particulate emissions from surface contamination sites (EPA 1985). Application of this model with specified input parameters has been approved for used in CERCLA-related risk assessments by the EPA Region 15, DOE-ID, and the State of Idaho. The estimated resuspension rate constant of 10^{-12} s^{-1} is considered to be realistic for aged, undisturbed soils and was presented in the Track 1 and Track 2 guidance (DOE 1992b, DOE 1994c). Using an even more conservative approach, based on field studies in the Richland, Washington area by Sehmel (DOE 1980) and applying INEEL wind speed data, an average resuspension rate of 10^{-10} s^{-1} for particles up to about 10 μm in diameter has been calculated. This resuspension rate constant was used in earlier INEEL impact analyses for ponds (Abbott 1991a, 1991b, 1991c). Using this more conservative value, the more conservative estimated air concentration would be 3.8×10^{-7} $\mu g/m^3$. This is far below any health risk-based exposure limits or guidelines.

J. Downes, manager of industrial hygiene at the ICPP, said that analyses have shown approximately 1% cadmium in solid calcined wastes (Phase I Interview with Downes MC 387). Unlike mercury, cadmium is not particularly volatile and amounts released from the main ICPP stack from calcining and dissolution were not of concern for effluent or environmental monitoring. The Site-wide emissions estimate from the 1989 Air Emissions Inventory was very low, about 1.06×10^{-4} kg or 0.1 g (Ecology and Environment 1994).

Findings for cadmium: Cadmium was discharged to the ICPP disposal well and to the percolation pond. Releases of materials to the air from the pond have not been measured. Screening calculations predict that air concentrations from suspension of all of the cadmium in the pond would be well below concentrations of health concern. Because liquid effluent concentrations were less than the MCL and most of the cadmium seems to have been retained in the calcined product, cadmium dispersion and release into the air would not have been expected to affect the public. Therefore, cadmium should not be included in a dose reconstruction study.

Chromium

The screening ratio calculated for chromium was 12.3. The chromium inventory included many different chromium salts, chromium solutions, chromic acids, and chromium containing corrosion inhibitors and water treatment chemicals. All of the chromium was assumed to be in the more toxic hexavalent form.

Chromium was released in wastewater and cooling water to evaporation ponds, some of which might have dried up allowing the chromium in sediments to become suspended in the air. Chromium compounds were used as corrosion inhibitors for large volumes of cooling water used in many reactors and other equipment onsite over the years. Also, red chromic acid was said to have been used in zirconium fuel process (Phase I Interview with Mickelsen MC 525). Chromium was detectable in service waste discharges from the ICPP, but chromium releases from the stack did not appear to be a concern. Chromium was also emitted from various cutting, machining, and welding operations, but the amounts would not have been large enough to have affected the public.

Perhaps the chromium discharges of most interest for this study were the releases to evaporation, retention, filtration, and percolation ponds onsite. As explained previously, in the section on the pathways of exposure considered, information needed to determine emissions to the air from the suspension of chromium-contaminated sediments is not readily available. We had hoped that sufficient monitoring of radionuclides suspended from dry pond sediments would have been done to allow us to draw parallels useful for estimating chromium releases. But little information about pond sediment and dispersion was available.

Hexavalent chromium released to groundwater was of concern for many of the CERCLA characterizations but has been mentioned as a contaminant of particulates in very few. Hexavalent chromium is a demonstrated human carcinogen. It is important to note that chromium is reduced in surface waters containing organic matter to the less toxic and less carcinogenic trivalent form.

A more detailed discussion about pond sediments is summarized in the section on the pathways of exposure considered. Information in records on chromium discharged in cooling water for specific areas is summarized below.

Chromium at TRA

Hexavalent chromium was used as a corrosion inhibitor in TRA reactor cooling water loops from 1952 to 1972. From 1952–1964, an estimated 11,000 kg of chromium in wastewater was discharged to the unlined filtration pond at TRA. Chromium was discharged to the disposal well after November 1964. Approximately 14,000 kg was discharged to the well at TRA from 1965 to 1972 (Mann and Knobel 1988).

A report from 1970 suggests that about 20,000 lb/y of BETZ-194 or dianodic, containing chromium, was added to the cooling water for various TRA reactors. Cooling tower blowdown water was discharged to the TRA disposal well. The concentration of Cr+6 ions in the cooling tower blowdown stream was reported to be 4-5 ppm and dilution from other waste streams reduced the concentration to about 1 ppm going into the well (Nebeker and Lakey 1970). In 1972, polyphosphate replaced chromium as the corrosion inhibitor used for the cooling tower.

USGS studies have shown that chromium in groundwater onsite exceeds the drinking water standard. The highest concentrations seem to be in samples from a well about 500 ft south of the TRA. (Mann and Knobel 1988). Hexavalent chromium is reduced to trivalent chromium in sediments with organic matter. About 50 sediment samples from the TRA pond had total chromium at a level greater than background, but no samples showed hexavalent chromium above the detection limit (Hull 1989). Hexavalent chromium is mobile and would be transported with the water percolating through the pond. The chromium left in the pond would be reduced to less mobile trivalent chromium. Hull (1989) concluded that “almost all of the chromium discharged to the pond is still in the pond sediments” but the uncertainty was great. Based on monitoring data, the estimate of chromium remaining in sediments was 4820 to 19,600 kg. Chromium concentrations in the deep-perched zone were greater than drinking water standards.

Because chromium VI is mobile in water and is reduced to chromium III, little or no chromium VI has been left in the ponds or soils that might be subjected to wind dispersion. The CERCLA risk assessments use a conservative ratio of 86% chromium III to 14% chromium VI in sediments (Stanisich et al. 1992).

We performed screening calculations to determine if the chromium in TRA pond sediments could have presented a significant risk to members of the public. Using the highest possible inventory in the pond (19,600 kg chromium), a resuspension rate constant of 10^{-12} s^{-1}, and a conservative dispersion factor of 5.67×10^{-8} s/m^3, we estimate that the maximum air concentration at the nearest public exposure point would be 1.1×10^{-12} g/m^3 or 1.1×10^{-6} $\mu g/m^3$ Using an even more conservative resuspension rate constant of 10^{-10} s^{-1}, the air concentration would be 1.1×10^{-10} g/m^3, or 1.1×10^{-4} $\mu g/m^3$.

The highest concentrations calculated were just less than the most conservative risk-based screening levels used by the EPA for chromium compounds, 1.6×10^{-4} $\mu g/m^3$ (this assumes a 1:6 ratio of chromium VI:chromium III) (EPA 1996). It is important to note that the screening calculations were very conservative and were based on a high suspension constant, a maximum inventory amount and the assumption that all of the material in the pond would be suspended. A more realistic scenario would assume some small fraction of the metal was suspended, at a rate reasonable for the INEEL. It might also be more appropriate to compare the predicted concentration to a less conservative screening level for inhalation of chromium III compounds. The occupational exposure limit for chromium III compounds of 500 $\mu g/m^3$ (NIOSH 1995), is well above the predicted concentration.

From 1971 to 1983, an estimated 118 kg of chromium was discharged to the ICPP injection well and 36 kg in liquid waste at the PBF (Orr and Cecil 1991). Discharges were estimated using information in logbooks that recorded the concentration of chromium in cooling water and the amount of cooling water passed through the cooling systems. Unlike radionuclides, chromium concentrations in effluent or in the pond were not routinely monitored. Orr and Cecil (1991) stated that no chromium disposal was reported at the INEL from 1984 to 1988, presumably because many of the chromium-based water treatment chemicals had been replaced.

Chromium-based water treatment chemicals were used in relatively large quantities at ANL-W. The EBR-II cooling tower blowdown was discharged to the ditch then to a pond. A sulfur dioxide gas injection system was used as a chromium reduction system at ANL-W from approximately 1962 until late 1979. The chemistry of the pond kept the chromium in a reduced form. Cooling tower drift could be as high as 0.1% based on design information but a study done by or for M. Kim demonstrated that the drift was about 0.0001% (ANL-W 1973). Chemicals in the drift precipitate on the gravel around the towers (Phase I Interview with Batten MC 1763).

In 1972, an estimated 167 kg of trivalent chromium was discharged in 1.8×10^7 gal of EBR-II cooling tower blowdown water. An estimated 37 kg of chromium was lost to the atmosphere by being windblown (drift) from the cooling tower in 1972. Worst-case calculations were done out of concern for worker safety and health and hexavalent chromium concentrations in air were calculated to be less that occupational limits (ANL-W 1973).

Cooling tower drift from TRA facilities should also be considered. No assessment or calculations similar to those done for ANL-W for cooling tower drift have been reported for TRA, as far as we can determine. Heat from the ANL-W reactors was recovered for power generation. Discharges to the TRA towers would have been much larger than for the ANL-W towers and the chromium concentrations in the air and on the ground around the towers may have been higher than the concentrations calculated and measured at ANL-W. Although chromium in cooling tower drift might be an occupational safety issue for workers close in to the TRA towers, it is unlikely that the drift would have affected the public.

Chromium at NRF

K.A. Schreck, with the NRF, stated that all the prototype plants contain primary shields that use chromated water as part of the shielding material. There have been some small spills of chromated water at the S1W and A1W prototypes, but all the water was contained. Before reprocessing operations, a discharge pit at the south end of the S1W spray pond was used to collect discharges of primary coolant. The discharged coolant would then be sent to a leaching pond outside the main NRF perimeter fence (Phase I Interview with Schreck MC 26570). An inventory amount for the chromium in the leaching pond was not available in the documents we reviewed.

Chromium in Waterfowl

Little is known about the potential pathway for chromium exposure via ingestion of waterfowl that may have used ponds containing chromium in the water or sediments. Trivalent chromium has a low tendency to bioaccumulate. Trivalent chromium tends to form stable complexes with silt and clay particles or decaying plant material. Studies of the accumulation of chromium in sewage sludge and toxicological studies on chickens and black ducks, suggest that 10-100 ppm in the bird's diet caused no adverse health affects (Eisler 1986), but accumulation of chromium in the tissues of the birds was not mentioned in the publication (Eisler 1986). Chromium has been widely used as a corrosion inhibitor in cooling waters used in industry, especially the electric power industry, which has released high concentrations of chromates and Chromium (VI) salts to surface waters. Concentrations of bluegills and large mouth bass in lakes in Tennessee where large amounts of chromium has been discharged, were not different than fish in control locations (Eisler 1986), which suggests chromium does not accumulate in these fish.

Levels of chromium-51 have been measured in the plastic-lined TRA ponds and in a few ducks on the ponds. Bioconcentration factors have not been developed and the relationship between the concentration of chromium-51 and total chromium is unknown (Personal Communication with Warren 1997).

Findings for chromium: The potential for chromium to have been suspended from pond sediments was evaluated using risk assessment and site characterization information from CERCLA studies. Cooling tower drift was also evaluated. Maximum exposure concentrations and risk to workers done by the Site for people at U.S. Highway 20/26 or other areas of public access, calculated for both cooling tower drift at ANL-W and for suspended waste pond sediments at and TRA were less that the occupational limits or EPA screening levels for or future residential users onsite. Offsite exposure concentrations would be less than the onsite concentrations that were calculated using very conservative assumptions. To further characterize these releases would require a great deal more research and modeling, which may not be justified because screening calculations (done using a cautious estimate of the suspension rate, conservative estimates for pond inventories, and the assumption that all of the material in the pond was suspended) predicts that dispersion of pond sediments would not have resulted in air concentrations greater than concentrations of health concern. Calculations done using more realistic assumptions would result in concentrations well below regulatory screening levels. Considering these findings, we recommend that any future dose reconstruction not include chromium exposure via the air pathway.

Chromium does not appear to concentrate in fish, waterfowl or other game animals and it is unlikely that consumption of animals that frequented the disposal ponds would have significantly contributed to the public's chromium exposure. Further evaluation of this pathway is not recommended.

Hydrazine

At the 10^{-6} risk level, the ratio for hydrazine was 0.2. We thought it was worthwhile to find out more about how hydrazine was used in the process and the potential for its release. The toxicity of hydrazine was not well recognized until the 1970s. In the 1980s, it was found to cause cancer. Hydrazine is a reactive, flammable liquid used as an intermediate in the production of agricultural and industrial chemicals, a reactant, rocket fuel, and a reducing agent for nuclear fuel reprocessing. It has also been used as a medication for sickle cell disease and cancer.

Very little information was found on hydrazine use at the Site. Hydrazine was listed as a chemical used by the EBR-II chemistry laboratory and it was used as an oxygen scavenger, apparently in EBR-II boiler feedwater and/or cooling water from 1976 to 1986 (Phase I Interview with Batten MC 1763). Hydrazine used in these processes was probably released to the waste pond at ANL-W, but we did not have enough information to estimate the amount used and released.

At other DOE chemical extraction plants, hydrazine mononitrate was used in large amounts as reductant for chemical processing, but no evidence that this chemical was used in large amounts at the ICPP has been found.

Hydrazine has a relatively low vapor pressure and is soluble in water. Hydrazine released to air, water, or soil rapidly degrades by oxidation and biodegradation. Hydrazine in air is quickly destroyed by chemical reaction within minutes or hours, depending on the concentration of ozone and hydroxyl radicals in the air. Most hydrazine in air would be expected to have degraded within several hours of its release. Hydrazine released to water and soil can dissolve in water or sorb onto clay soils, but most of the hydrazine in water and soil would be expected to have been gone within a few weeks because of oxidation and biodegradation. Hydrazine does not tend to biomagnify up the food chain.

Findings for hydrazine: The information needed to estimate a source term for hydrazine is not available. The potential for hydrazine to be transported offsite in air or water would have been limited by its rapid degradation. Further research on the release of hydrazine seems unwarranted.

Lead

Lead is a developmental neurological toxin. A screening ratio of 0.0269 was calculated for lead and lead compounds. While the onsite inventory amount for lead was large, most was used in solid shielding materials, such as lead sheeting, lead pellets, and shot used for shielding and lead pipes. Although workers have reported that lead powder was used to repair shielding at the ETR (Oil, Chemical and Atomic International Union Center 1998), reports of large amounts of lead being melted or used as a powder or in oil have not been found. Several safety personnel and industrial hygiene reports described a lead poisoning incident involving none workers using lead burners in the confined space at the bottom of a concrete basin. As far as we can determine dispersion of lead was not an environmental concern, suggesting that lead compounds were not discharged in large amounts. Before 1984, approximately 145.5 kg of lead was released to the environment, primarily into the infiltration pond at the ICPP (Orr and Cecil 1991).

The lead shop and lead storage area at CFA-687 were used to store and recycle lead scrap until 1986. Records on the amount of lead stored were not kept. Soil sampling of the storage area indicated elevated lead levels, and approximately 153 m^3 of soil, asphalt, lead shot, and scrap was excavated. Lead must have continued to have been processed in the lead storage area CFA-43 because in 1988 a molten lead spill of about 4.5 kg was reported. The spill was allowed to harden and was taken up for recycling. Approximately 304 m^3 of soil was excavated from the storage area because of lead levels (McCormick et al. 1996). Data on the amount of lead recycled and processed through the shop, the air exhaust systems, and other information to consider in evaluating potential releases was not found in any of the records reviewed. The air emissions estimated or described in the operating permit application or the air emissions inventory for lead fumes and particles were for 1994, when the shop was not operating and emissions were low.

Findings for lead: Lead releases could be estimated but a large release of lead fumes and dust from Site operations would be required for the lead to have reached concentrations of concern offsite. There are very few records for the lead shop operations. Estimates of throughput and assumptions about processes would have to be derived from interviews with people who worked at the lead shop. Similar shops at other DOE facilities have been characterized and might be used to predict potential emissions from the INEEL shop depending on the similarities between them. Information might best be collected from people who have worked in the shop. Further investigation of lead releases from the CFA shop and storage area may not be warranted because of the inventory amounts reported and the resistance of solid lead materials to dispersion in air or absorption through inhalation. Therefore, lead should not be included in a dose reconstruction.

Mercury

Mercury released to the environment can be transformed into methylmercury and bioaccummulate up the food chain. Methylmercury adversely affects the nervous system, especially in children. Atmospheric mercury deposition into lakes and streams can result in mercury accumulation in fish. Mercury released to the air is generally of concern because of its impacts on aquatic systems, especially fish. Consumption of fish with high levels of mercury can cause neurological effects in people.

Mercury (mercuric nitrate) was used at the ICPP as a catalyst to dissolve aluminum fuels, and the waste (aluminum fuel raffinates) that was calcined contained mercury. Mercury was also used as shielding for the ANP Program engine, Heat Transfer Reactor Experiment-III (HTRE-III). An unknown amount of mercury was spilled onto the railroad tracks used for the ANP Program in the 1950s. The spill was discovered in 1986, and the mercury-contaminated soil was cleaned up in 1995. Retirees interviewed by the Oil, Chemical and Atomic International Union Center (1998) recalled frequent “small” spills of less than 1 gallon of mercury along the rail tracks and within TAN-607. Mercury was also discharged to an evaporation pond at CFA in calcine and liquid effluent. Small amounts of mercury in laboratory and other wastes were discharged to other waste disposal ponds and disposal wells at many other facilities.

Mercury at the ICPP

At the ICPP, mercury was released to the air from the dissolver, WCF and vessel-vent off-gas systems. Mercury in liquid wastes may have evaporated, been vented from tanks, and been released from evaporators.

The aluminum-clad fuel dissolvers that used mercury have operated since 1955. Dissolution was continuous with the catalyst added to the bottom of the dissolver and solution sent through solvent extraction overflowing from the top. Most of the mercury went through the first extraction column with fission products in the first cycle raffinate, which was set to the high level waste tanks (Herbst 1979). The high mercury content was of interest to researchers determining ways to process the high level waste.

Herbst (1979) is a master’s thesis on the mercury in liquid and gaseous effluents from the ICPP. He used a dichotomous sampler with fiberglass filter and silver zeolite to collect gaseous mercury and attempted to conduct a mass balance. At that time, the process off-gas exhausted to the ICPP stack included the dissolver off-gas, the WCF off-gas, and the vessel off-gas. All three exhausts were subject to pollution control equipment. The combined exhaust was also put through a filtering system installed in 1975, called the atmospheric protection system, which consisted of fiberglass prefilters and a bank of HEPA filters (Herbst 1979). Two dissolver off-gas systems were in operation. One combined the aluminum dissolver exhaust with the electrolytic dissolver off-gas (the electrolytic dissolver was used to dissolve stainless steel fuels). The other was from the zirconium dissolver, which evolved hydrogen that was exhausted to the stack after the HEPA filters. This exhaust was filtered separately from the nitrogen oxide rich off-gas from the WCF. The WCF vented process off-gas containing nitrogen dioxide and mercury. The exhaust was subjected to cyclones, scrubbers, adsorbers, and HEPA filters. The vessel off-gas system vented all of the other tanks and vessels in the extraction process. Herbst (1979) found that more mercury was exhausted from the atmospheric protection system than was entering in the WCF off-gas. Apparently, the dissolver was not operating during this period. The additional mercury was thought to be coming from the tank farm in the vessel off-gas (Herbst 1979).

Herbst (1979) also sampled the evaporator collection tanks, the WCF feed and scrub recycle solutions, the service wastewater, and drinking water. Future plans to sample the vapor above the tank for mercury were mentioned. The waste calnicer was calculated to receive about 2100 ±200 g/day of mercury in as much as 8000 L/day of high level waste. The scrub recycle mercury content was variable. Herbst (1979) estimated that 400 ±100 g/day of mercury went into the calcined waste, 1300 ±130 g/day remained in the nitric acid scrub recycle solution, 370 ±90 g/day were removed by the absorbers, and 25 ± 7 g/day were filtered by the HEPA filters. The estimate for gaseous mercury exhausting from the WCF was 5 ±1 g/day. Most of the mercury was retained in the scrub recycle solution. The concentration of mercury in the solution was variable. Mercury built up in the solutions with time and the solution was recycled into the process and recalcined. Also, periodically the absorbers were drained and flushed with nitric acid and water. The mercury in the wash solutions was sent to storage tanks. Samples of the vessel off-gas taken when the evaporator was shutdown indicated that the evaporator was not a significant source of mercury to the off-gas. Mercury in the evaporators boiling nitric acid would be expected to vaporize and condense in the overheads. The evaporator overheads were discharged to the service waste systems, which were discharged into an injection well during most of the time the facility operated. A mercury concentration of 3.5 ±0.4 mg/L was found in the condensate hold tanks. The service waste was said to contain 0.0015 ±0.0004 mg/L mercury. One sample contained 0.25 mg/L (Herbst 1979). The analysis seems to have been carefully done. Collection efficiency of the gaseous sampler was determined using ^{203}Hg to be about 96%. The abstract and conclusion do not mention that the aluminum fuel dissolver was not operating when samples were collected, but the section with details on the mercury sampling indicates this was the case. Using a stack dilution factor for the worst weather condition (class B, looping), a ground concentrations of 0.08 μg/m^3 was calculated. The EPA's ambient air standard was 1 μg/m^3. The author also noted that a proposed radioiodine cleanup system, involving silver zeolite, would also remove mercury (Herbst 1979). However, such a system seems never to have been used on the ICPP stack.

The total mercury released from the ICPP stack was estimated to be "up to 25g/day." Herbst (1979) concluded "the mercury in the gaseous effluent is below established environmental limits. However, the mercury in the liquid effluent… does at times exceed the drinking water standard."

A safety analysis from 1963 estimated that 20% of the mercury introduced into the WCF with the feed might be vaporized and released to the air in the off-gas. The emission rate was calculated to be about 97 g/h for 'commonly processed' waste, corresponding to a grade level concentration of 0.007 mg/m^3, based on a X/Q value of 2.5×10^{-4} sec/m^3. This concentration was less than the continuous exposure limit of 0.1 mg/m^3 reported for the time (Lakey and Bower 1963). For comparison, the occupational threshold limit value for mercury vapor is currently 0.05 mg/m^3 for skin exposure, and 10 mg/m^3 is considered immediately dangerous to life and health (NIOSH 1995).

Robert Schindler, a chemical engineer with the ICPP, estimates that 1–1.5% of the mercury in the NWCF feed went up the stack as the result of operations in 1997 (Schinder 1997, 1998a). He believed that most of the mercury charged to the aluminum dissolvers in years past was retained in the waste solution as mercuric nitrate. He also believed that most of the mercury evolved from the calciner is mercuric chloride, based on the large amounts of chloride in the waste and the oxidizing nature of the nitric acid waste solutions being processed (Personal Communication with Schindler 1998b). Recently, several continuous samples of the ICPP stack have been taken using the charcoal iodine samplers, which also collect mercury. The results of this sampling was summarized in memos by R. Schindler (1997, 1998a). The monitoring method used was not an EPA-approved method but Schindler concluded that the measurements were reasonably accurate because the concentrations on mercury on the charcoal (14 ppm) is far below saturation and also because the measurements agree with measurements reported by Hohorst in 1993 and 1995, taken using a different sampling method. [Records of the sampling done by Hohorst were not obtained in Phase I. We have requested, but have not yet obtained, copies of relevant reports authored by Hohorst]. The sampler was downstream from the particulate filters so would not measure mercury on particles in the effluent. Mercury emissions from the NWCF, based on the charcoal sampling, were estimated to be 7 kg for June 25 through August 27 and 11 kg for August 27 through December 23. The total emission for June 25 through December 23, which was said "to cover almost all of 1997 NWCF hot operation…" was 18 kg, which equates to about 1.45% of the total mercury fed into the calciner for that time period. The average mercury concentration in the stack for the 63 days sampling was done was 28 μg/m^3.

Mercury Used for the ANP Program

From 1951—1961, the ANP Program conducted Heat Transfer Reactor Experiments (HTREs). The HTRE test assemblies consisted of a core test facility and a nuclear reactor. The components were mounted on a steel dolly and transported over a four-rail track and was moved from the TAN/Technical Services Facility and the IET facility at the north end of TAN. In March 1986, a health physics survey found mercury on the dolly and ground. A deteriorated polyethylene bottle was also found and 6 pounds of mercury were recovered from the bottle. Thirteen pounds were recovered from the area immediately surrounding the bottle using a special vacuum. Samples of the IET railroad track beds taken in May 1987 detected mercury (Alexander 1988). The soil was removed in 1995.

The mercury spill area at TAN was described in a DOE/IDEQ newsletter as being "contaminated in 1958 by a large mercury spill from the HTRE-III engine. A removal action was done in 1995, and the area was backfilled with clean soil."(DOE 1998). Other documents described a very small spill on the railroad tracks used for the IET. Small and large are relative terms. The spill was small compared to the large amount of mercury used for the project, but it was large enough to require cleanup 30 years later. The volume, size, and nature of the spill is uncertain and estimates of the amount of mercury that evaporated from the spill could not be made with any certainty. Incomplete drainage of lines seems to be a likely cause (Personal

Communication with Horan 1997) but does not explain the bottle of mercury found in 1986. In the course of investigating a database entry indicating mercury had been disposed of in a trench at the RWMC in 1962. We found Hiaring et al. (1991), which documented interviews with 24 people who worked on the ANP Program in the 1950s and 1960s. The report briefly summarizes the history of mercury used for the testing of the D102A turbojet engine reactor system at the IET facility. Liquid mercury was used as a gamma shield. The shielding allowed personnel to access the idled reactor. During reactor operation, water was used for shielding. When personnel shielding was required during reactor shutdown, the mercury was pumped into the outer primary shield tank of the reactor. Approximately 55,000 lb or 25,000 kg (27.5 tons) of mercury was required to fill the shield tank. Mercury was also present in the piping system and the IET storage tank. According to Hairing et al. (1991), those interviewed estimated as much as 50 tons of mercury was used during the ANP Program. A one- page memo located at Oak Ridge and found on the Internet by C.M Wood, CDC, discussed the transfer of 1316, 100,000-lb flasks of mercury to the ANP Program (Armstrong 1956). This supports a 50-ton estimate for the quantity of mercury used for the ANP Program.

When the ANP Program was canceled the mercury was surveyed for contamination and according to project engineers interviewed in 1990 and 1991, the mercury was not contaminated or activated and was not sent to the RWMC. Personnel recalled seeing bottles, flasks, and cans of mercury stored just west of Building 607 at TAN. Sometime after the ANP Program was stopped, General Electric declared the mercury as excess and it was probably made available to other government agencies. Several of the people interviewed emphatically believed that the mercury was not sent to the RWMC but was excessed to government agencies. An unknown amount of remaining material was offered for sale to private individuals. ANP workers recalled that when the ANP Program ended, the mercury, was placed into containers and sold as surplus to a buyer in Utah (Personal Communication with Horan 1997). No mercury vapor was detected in any of the soil gas samples taken at the trench and magnetic studies did not indicate that mercury was present (Hiaring et al. 1991).

Investigators in 1991 noted that more than 1000 flasks would have been required to bury 50 tons of mercury and they felt someone interveiwed would have remembered the shipping and burial, which would have taken some time. The investigation report included a write-up of a computer model developed to predict the transport of liquid mercury in soils at the INEEL. This was a *hypothetical* exercise to predict the rate of downward and lateral movement of a hypothetical plume through RWMC soil. Mercury was not found in the trench, and paper records indicate mercury was never buried at the RWMC.

Thiesen (1993) described treatment of a decontamination solution used to wash the HTRE-3 reactor shield tank before the HTRE-3 was sent to be displayed at the EBR-I museum. The background section of this report says that the reactor was designed as a part of the airplane engine program and the reactor shielding was provided by an “approximately 1,500-gal shield tank filled with mercury.” The tank had been drained long before, but the wash solutions generated in 1993 contained about 7 mg/L of mercury, which exceeded the RCRA limits and required removal by ion exchange (Thiesen 1993).

There is not enough information available to determine how much mercury may have evaporated from the shield tank and during transfers of mercury to and from the tank. Historical records for other DOE sites suggest that at the time, mercury was not treated carelessly because it was very expensive.

Mercury at CFA

Simulated calcine was discharged to the CFA-674 pond from the chemical engineering laboratory that operated from 1953 to 1965. Sampling was conducted in 1989, 1993, and 1994 indicated that mercury exceeded the RCRA regulatory level. A risk assessment was performed and a time-critical removal action was completed in 1994 to remove mercury contamination that was above the occupational risk levels allowed. Approximately 2345 m^3 of mercury-contaminated soil was removed, which included calcine, soil contaminated by calcine, and soil contaminated by liquid effluent discharges. Pond sediments remaining contained up to 223 mg/kg mercury (McCormick et al. 1996).

Findings for mercury: We have been unable to find enough information about losses of mercury from the ANP Program to develop a reasonably accurate source term. Assuming all 50 tons of mercury could have been released would be unreasonable. We know that at least 6 kg were released. We will attempt to locate more documentation on mercury use and release during the ANP Program during the course of the Task Order 6 document review.

A source term for mercury released from the calciner from 1963 to 1997 could be derived from the mercury content of the feed, the feed rate, and a more in-depth analysis of the effects of HEPA filters and silica gel absorbers on reducing mercury in the off-gas (the forms of mercury released from the calciner). It seems unlikely that the amount of mercury released, which may have ranged from 5 to 2500 g/day based on the limited amount of information we have reviewed, would have reached concentrations to have caused adverse health effects through inhalation. A calculation for the potential receptor at U.S. Highway 20/26, just south of the ICPP, using the air dispersion value of 5.67×10^{-8} s/m^3 that we used for the screening and the highest release estimate, would result in an mercury concentration estimate of 1.64×10^{-3} μg/m^3. This concentration is less than 1 % of the RfC and suggests that concentrations of health significance were not attained at the highway. The area around the INEEL is desert and with no prominent lakes, ponds, or fishing holes that might have been affected by atmospheric deposition or surface water runoff to an extent to cause mercury accumulation in fish.

Nickel

A screening ratio of 0.019 was calculated for nickel compounds. Nickel is an allergen and nickel dust causes lung and nasal cancer. Like lead, much of the nickel reported in the inventory may have been in solid form and not easily dispersed into the air. No information suggesting that notable amounts of nickel were released to the air has been found.

Nitrogen Oxides

Because various forms of nitrogen oxides can occur together in the air and many are chemically convertible, nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), and nitric acid (HNO_3) are collectively termed oxides of nitrogen, abbreviated NO_x. Much of the NO_x initially produced is nitrous oxide, but it is usually rapidly oxidized to nitrogen dioxide. Nitric oxide and nitrogen dioxide are chemically reactive and of public health interest.

Inhaled nitrogen dioxide effects the lungs, possibly decreasing pulmonary protective mechanisms at relatively low levels. It does not appear to be a carcinogen. In general, studies on humans suggest that levels less than 1 ppm do not cause significant changes in pulmonary function in normal healthy adults. Inhaled nitric acid reacts in the upper respiratory tract. Exposure to nitric acid may exacerbate lung diseases like asthma.

Oxides of nitrogen were released from facilities that process nitric acid and nitrates. Operating of the NWCF has resulted in large emissions of nitrogen oxides. Nitrogen oxide releases from the INEEL were said to be minimal when the NWCF was not operating (DOE 1995). Most of the nitrogen oxides, primarily nitrogen dioxide, were formed by decomposition of nitrates in the waste solution that was calcined.

WCF and the NWCF effluent was exhausted to the ICPP main stack. The stack was described in the 1995 air emissions inventory as a 250-ft tall, 6.5-ft diameter stack with an air flow of about 100,000 to 150,000 cfm resulting in a velocity of about 61 ft/sec up the stack. The effluent was continuously monitored for nitrogen oxides and radionuclides, although the NO_x monitor appears to have been out-of-service often in the mid-1980s and it was often not run when the NWCF was not operating (DOE 1995).

Emissions Estimates

Stack exhaust concentrations and calculated ground level concentrations have been routinely measured, observed (by color/opacity) or calculated since the mid-1980s.

In a WCF safety analysis report from 1963, nitrogen oxides were said to make up about 2.5% of the process off-gas sent to the ICPP stack. At the top of the stack, the NO_x concentration averaged approximately 210 ppm. At ground level, the concentrations was predicted to be as high as 18 ppm under looping weather conditions. Usually, the ground level concentration was thought to have been less than 1 ppm (1.8 mg/m^3) (Lakey and Bower 1963). For comparison, the occupational standard (threshold limit value) is currently 1 ppm (NIOSH 1995). Concentrations greater than 200 ppm may be fatal (Lakey and Bower 1963).

A safety analysis for the electrolytic dissolver included material balance flowsheets that gave the percent nitrogen dioxide in the off-gas and diluted off-gas. Dissolution of EBR-II clad pins in cans, bare pins, and ingots and skull oxide in cans all had 35% nitrogen dioxide values in dissolver off-gas and 1.3% in diluted off-gas. The material balance for dissolution of the EBR-II fuel assemblies had 41% nitrogen dioxide values in the off-gas and 2% in the diluted off-gas (Denney 1974).

Simpson (1978) predicted the calciner off-gas would contain 12,000 to 24,000 ppm oxides of nitrogen in a 0.248 standard m^3/sec effluent. This assumed all of the nitrates in the waste would be converted to NO_x. The concentration was predicted to be 150 to 300 ppm at the stack after being combined with the fuel reprocessing plant off-gas and diluted with plant air. The author acknowledged that the dissolver off-gas would also contain NO_x, but did not attempt to estimate how much.

An earlier evaluation to determine whether projected NO_x releases would be within federal and State standards was provided in Wenzel and Fernandez (1981). NO_x from the ICPP during operation of the WCF had been about 60% NO_2 and 40% NO, but 80% NO_2 was assumed to be conservative. The concentrations of NO_x at the stack discharge point were said to vary considerably depending on the waste feed rate to the calciner, the amount of nitrate in the waste feed, and the stack flow. The NWCF feed rate was expected to be from 178 to 214 gph while the

WCF feed rate was typically 100 gal/hr. The production of NO_x was expected to increase by a factor of from 1.8 to 2.1. Reasonable minimum flow rates from the stack of 75,000 cfs for the NWCF were predicted. Based on all these assumptions, the concentration of NO_x at the stack discharge point was predicted to be between 370 and 550 ppm. Theoretically, the maximum opacity would be about 55%, in between 40% and 65% (Wenzel and Fernandez 1981).

A measurement of the ICPP stack opacity was included in measurements from Rockwell Hanford Operations. The measurement at the stack was said to agree well with the Exxon Idaho Nuclear Company, Inc. (ENICO) theoretical value (Wenzel and Fernandez 1981). The maximum anticipated release rate for nitrogen dioxide from the NWCF was 33 g/sec. Using MESODIF and assuming the WCF operated 270 days/yr, an annual average concentration at the Site boundary from the ICPP stack was calculated to be 1.2 $\mu g/m^3$, 1.2% of the standard of 100 $\mu g/m^3$. An integrated operability test was performed for the NWCF for 7 days in August 1981 and for a month spanning October and November 1981 using the simulated feed material, cold aluminum nitrate. The data were used to predict that 33 g/sec of nitrogen dioxide would be released from the NWCF. Assuming 270 day/yr operation, the annual average concentration of 1.2 $\mu g/m^3$ at the Site boundary was calculated; with worst-case, Class B looping conditions and a wind speed of 2 m/sec, the concentrations 110–115 m from the stack at ground level would be 10 mg/m^3 for a few seconds before dilution occurs. The concentration of NO_x seemed to be directly related to the feed rate to the calciner. The anticipated gross feed rate was 180–200 gal/hr, corresponding to NO_x releases of 550–550 ppm. The ratio of NO_2 to NO in the releases was 0.92 NO_2 to 0.08 NO. The ratio was predicted to decrease during actual operations using real waste, and total NO_x releases were predicted to be less when zirconium fuel waste was being processed. The most frequent atmospheric conditions at the INEEL were said to be stable Class F and favor fanning of the stack plume. The document says, “the ICPP plume can be seen for several miles stretching across the desert. It is possible, although not probable, that the plume may cross the southern edge of Craters of the Moon National Monument” (Wenzel and Fernandez 1981).

Standards

An opacity limit of 20% was given as a standard in a document about the ICPP from 1978 (Simpson 1978). It seemed that the operators and engineers expected that the standards would be hard for the NWCF to meet. The NO_x emissions from the NWCF were predicted to be “significantly higher than from operation of the old Waste Calcining Facility” in 1982 (Honkus 1982). The EPA’s NAAQS limit the annual arithmetic mean at the facility boundary to 100 $\mu g/m^3$ (0.05 ppm) nitrogen dioxide. The State of Idaho uses the NAAQS standard and limits visible emissions (opacity) to 20% for no more than 3 minutes each hour. Before 1983, a Ringelman #2 (a method of determining opacity) was accepted as the limit for opacity, corresponding to 40% opacity, but a limit of 40% opacity, in 1982, only applied to exempt sources under Idaho regulations. The NWCF opacity was expected to be about 58%. Site reports concluded that the nitrogen dioxide concentration at the Site boundary was predicted to be 1.2% of the NAAQS or Idaho limits. However, the opacity at the stack was predicted to be three times the State limit, and it was possible that the nitrogen dioxide plume could cross the Craters of the Moon Area where the EPA had determined visibility to be important. Honkus (1982) recommended that a program be initiated to limit releases to conform to limits or that steps be taken to obtain an exemption from the regulations. The latter appears to have been done in 1983. The 1983 Environmental

Report said that the NWCF at the ICPP was operating under a variance for visible emissions due to NO_x. Visual determination of opacity was routinely made twice a week. All of the observations for 1983 were below the 60% opacity specified in the variance. The ICPP monthly reports and annual environmental and effluent monitoring reports for the Site and the ICPP seem to agree that from 1983 to 1987 a variance limiting opacity to 60% was in place (ENICO 1984; WINCO 1985a, 1985b, 1986). In 1988, a new limit of 1700 ton/yr and 388 lb/hr was imposed (Krivanek 1988a). In 1994, the IDEQ imposed a stricter permit limit of 472 lb/hr and 1700 ton/yr (Personal Communication with Wenzel 1997). In recent years, releases were regulated by the ICPP NO_x Sources Permit to Construct issued by the State of Idaho (Mitchell et al. 1996).

Table 12 provides the cumulative total releases of NO_x from the main ICPP stack, reported for each calendar year in the ICPP effluent monitoring reports.

Table 12. Cumulative Total Releases of Nitrogen Oxide from the Main ICPP Stack

Year	Total NO_x released (ton/yr)
1987	336
1988	725
1989	10.8[a]
1990	74.6
1991	521.1
1992	14.4
1993	458

[a] The total NO_x releases in 1989 were said to have been low because the NWCF did not run hot and only ran cold for a few days in June.

An operations history of the WCF and NWCF through the end of 1997 was provided to us by Maria Dumas at the ICPP. The approximate time periods of operation for the NWCF were

- Cold Run I: 10/28/81–11/20/81
- Cold Run II: 5/19/82–6/17/82
- Hot Run-1: 8/28/82–1/31/83, 3/14/83–3/15/83, 3/19/83–10/11/83, 1/13/84–3/17/84, and 4/17/84–6/17/84
- Hot Run-2: 9/14/87–3/4/88, 3/25/88–5/5/88, 5/23/88–6/11/88, 6/26/88–10/7/88, 11/28/88–11/30/88, 12/1/88–12/3/88, 12/7/88–12/9/88, and 6/18/89–6/24/89
- Hot Run-3: 12/1/90–1/26/91, 3/11/91–3/18/91, 3/29/91–3/30/91, 4/1/91–8/6/91, 8/16/91–8/29/91, 1/11/92–1/19/92, 1/8/93–1/9/93, 1/24/93–1/28/93, and 3/14/93–11/3/93
- Hot Run-4: 6/5/97–9/27/97, 10/21/97–12/4/97, and 12/15/97.

The WCF operated from 12/63–10/64, 03/66–03/68, 8/68–6/69, 8/70–1/71, 9/71–5/72, 5/73–7/74, 6/75–1/77, 9/77–9/78, and 6/79–3/81 (Personal Communication with Dumas 1998). The amount in gallons and the type of waste processed for each campaign can be obtained from monthly reports.

Pollution control measures used over the years would need to be better characterized and understood if process throughput data were to be used to reconstruct releases. For example, dissolver off-gases were sent to the gas plant to remove contaminants before cryogenic distillation to recover krypton and xenon. Some of the oxides of nitrogen were removed by the caustic scrubber, and nitrous oxide was dissociated to nitrogen and oxygen on a fixed rhodium catalytic unit (Dickey et al. 1972). In 1971, the silica gel absorbers used to treat the ICPP off-gas were bypassed for one week to see the effects on cesium and ruthenium removal. The concentrations of nitrogen oxides in the stack were 225 ppm and were said to be unchanged by the bypassing experiment (Buckham et al. 1972). Simpson (1978) reviewed and summarized a literature study to evaluate potential methods for removing NO_x from the off-gas. After a lengthy analysis of many different pollution control equipment options, a catalytic reduction of NO_x by ammonia using zeolite was recommended (Simpson 1978). Some of the NO_x generated was converted to nitric acid and essentially all the nitric acid was recovered from the off-gas (Buckam et al.1972), but it was not clear how significant this was relative to the total NO_x discharged.

The calciner resumed operations in the summer of 1997, and people traveling on U.S. Highway 20/26 could see a yellow/orange/brown nitrogen dioxide plume coming from the main stack of the ICPP from the calcining operation. A continuous stack monitor was put in place.

The stack releases of NO_x from the ICPP were probably best characterized by the stack measurements taken in the 1980s and in 1997. The emissions measurements and estimates done during times when aluminum fuel waste was being processed could probably be applied to the entire time period of NWCF operations. A good understanding of the calciner processing runs for the aluminum fuel raffinate and feed rates would need to be obtained from the monthly reports and campaign reports. A thorough review of the NO_x monitor operations and a compilation of all ambient air monitoring results would also be needed.

Nitrogen oxide releases from combustion sources might best be derived from recent air emissions inventories and the operating permit application submitted to IDEQ in 1995. The annual reports from the late 1980s say, “Nitrogen oxide emissions are routinely monitored at the NWCF. Sulfur dioxide, nitrogen oxides and carbon oxides are monitored at the CFSGF. Emissions of nitrogen oxides from fuel are calculated using emission factors developed by the EPA and the amount and type of fuel burned at each facility as reported in INWMIS.” No other reports of effluent monitoring were found in monthly or other ICPP reports.

Whether further analysis of the NO_x releases is justified is a difficult question to answer. Although visible, several studies have calculated the concentrations at the Site boundary based on stack measurements and determined they were far below air quality standards. The distance and dilution seems great enough so that the amount releases would not present a health hazard.

Atmospheric modeling, presumably similar to modeling that would be performed for a dose reconstruction, has been done for the NO_x emissions by INEEL Site personnel. The highest concentration at the ground next to the stack under atmospheric conditions that would maximize exposures were calculated to be 10 mg/m^3. Concentrations at the Site boundary, based on a dispersion of 5.0×10^{-8} s/m^3 were predicted to be 1.2 μg/m^3. A calculation for the potential receptor at U.S. Highway 20/26, just south of the ICPP, using the air dispersion value of 5.67×10^{-8} s/m^3 that we used for the screening, would result in an estimate of 1.36 μg/m^3. All of these estimated values are well below the occupational and ambient air standards.

Ambient Air Monitoring

In 1983, RESL published a 20-page ambient nitrogen dioxide monitoring plan for the INEL. Sources of nitrogen oxides mentioned were the WCF, heating oil combustion, and vehicle emissions. The program combined monitoring data and atmospheric dispersion modeling to predict concentrations over a large geographical area. Continuous monitoring equipment was placed at the corner of U.S. Highway 20/26 and Van Buren Blvd. The station began operations in October 1982 (RESL 1983). Ambient air monitoring data were reported in the annual environmental reports and are summarized in Table 13. *Calculated* estimates of emissions were often called effluent and environmental monitoring, most of which appears to have been calculated using fuel consumption and EPA's AP-42 values, rather than monitoring data.

Ambient NO_x was also measured at the Experimental Field Station, a location thought to be situated where maximum concentrations of materials released from the ICPP stacks might be predicted.

Table 13. Nitrogen Oxide Emissions and Ambient Air Concentrations Reported in Annual Reports

Year	Annual ambient air concentration at the Experimental Field Station (μg/m^3)	Annual ambient air concentrations at Van Buren and U.S. Highway 20/26 (μg/m^3)	Total estimates emissions from all facilities in metric tons
1989	3.6	5.5	Not made
1990	8.7	3.7	189
1991	7.2	5.2	566
1992	12.5	4.9	147
1993	36	9.4	598
1994	15.4	4.9	102
1995	4.0	3.8	Not made

The highest onsite concentration reported was 36 μg/m^3 in 1993. The highest concentration reported at Highway 20/26 was 9.4 μg/m^3. These concentrations can be compared to a NAAQS of 100 μg/m^3 for nitrogen dioxide.

In May 1992, new samplers were said to have been established at CFA and the Craters of the Moon National Monument as part of the National Park Service Interagency Monitoring of Protected Visual Environments (IMPROVE) network. IMPROVE data for subsequent years was reported for particulates in the annual reports. Although NO_x monitors were once part of the proposed plan, NO_x were not monitored by these stations once the program was implemented (Personal Communication with Chew 1997). A letter report with results of NO_x monitoring for the Van Buren and Experimental Field Station has been sent to IDEQ each quarter since the late 1980s. These reports could be obtained from IDEQ, Air Quality Bureau and examined for unusual spikes and to verify that quarterly data matches annual data. Such an analysis did not seem warranted at this time, based on the preliminary assessment presented here.

Findings for NO_x: Nitrogen dioxide emissions from the ICPP were visible and visible emissions have crossed U.S. Highway 20/26. Calculated average concentrations were about 1.2 $\mu g/m^3$ at the closest Site boundary. Measured onsite concentrations have been less than ambient air and occupational standards. Given that offsite concentrations would be expected to also be less than the standards, a more detailed analysis and reconstruction for NO_x releases do not seem warranted.

Sulfuric Acid

A screening ratio of 0.0189 was estimated for sulfuric acid. The inventory amounts for sulfuric acid were very conservative. Sulfuric acid is a very corrosive chemical; however, it is not carcinogenic. Sulfuric acid in the atmosphere dissolves in rain and contributes to the formation of acid rain. Sulfuric acid would not be expected to be persistent in the environment. Because it seems unlikely that sufficient amounts of unreacted acid could have traveled offsite, sulfuric acid has not been evaluated further.

Sulfur Dioxides

Sulfur dioxide was released from the power and steam generation facilities. These releases were reported in annual reports based on coal and fuel oil consumption and approximate sulfur content of the fuel. The annual and monthly reports containing data on sulfur dioxide emissions should be entered into the database and the magnitude and potential health impact resulting from the releases should be assessed. The annual NAAQS standard for sulfur dioxide is 80 $\mu g/m^3$. Using the formula for the screening ratio, about 4.46×10^7 kg of sulfur dioxide would have had to have been released to produce this air concentration. It seems unlikely that such a large amount could have been released.

Sulfur dioxide was released from combustion sources, especially coal and fuel fired boilers, open burning, diesel generators, and other engines. The CFSGF at the ICPP has been in operation since 1984. Annual records have been kept of the total yearly shipments of coal and ash disposal (Phase I Interview with Chesnover MC 501).

Four auxiliary boilers within the EBR-II complex at ANL-W provide central heating for the ANL-W area. The combustion off-gas is discharged from 80-ft tall stacks. The sulfur dioxide content of the flue gas was monitored periodically to determine compliance with air quality standards. In the early 1970s, the fuel oil was switched from No. 5 to No. 2 to help reduce sulfur dioxide emissions. For the year 1972, 70,000 lb (31,820 kg) of sulfur (presumably sulfur dioxide) was calculated to have been released based on the amount of fuel burned (ANL-W 1973). EBR-I, shutdown before 1973, also had a boiler that burned fuel oil and would have released flue gas (ANL-W 1973).

The NRF site uses steam heat that is generated by burning No. 1 fuel oil. The steam plant is placed in standby when ambient temperature is greater than 38°F (Phase I Interview with Schreck MC 26570)

Waste oils and solvents were disposed of by dumping and covering in the CFA and other landfills or by burning in open pits. Some of the oil was used as dust suppression treatments for dirt roads and some was used for fire training (Commander 1971b). Several fire training areas were located at the CFA, which burned several hundred gallons of waste oil and fuel and flammable chemicals each year since about 1958 (McCormick et al. 1996). Commander (1971b) estimated that about 2500 gallons of waste oil were used each year for fire training. The Site was said to generate 19,000 to 24,000 gallons of waste lubricating oils each year (Commander 1971b). WRRTF burn pits were described in a newsletter from DOE, EPA, and IDEQ on TAN Superfund work as four pits in operation from 1958 to 1975. These pits burned solid and liquid wastes. The Technical Support Facility burn pit at TAN burned waste from 1953 to 1958 (DOE, EPA, IDEQ 1998). Burning produces sulfur dioxide. Estimates of the amounts of waste solvents burned were very uncertain, but they could be used to estimate sulfur dioxide emissions using AP-42 emissions factors.

In 1971, waste solvent from the solvent extraction processes at ICPP was disposed of by burning and the unfiltered off-gas was discharged through the ICPP main stack. After 1972, according to the Safety Analysis for the Atmospheric Protection Project, the waste solvent was to be routed to the WCF and burned in the calcining vessel. The calciner off-gas was scrubbed and filtered (Nelson et al. 1972). Before 1972, it seems that radioactively contaminated extraction solvent (tributyl phosphate and kerosene) from the solvent extraction process was subjected to steam stripping to decontaminate it, then vaporized in a column countercurrent to steam flow to deposit most of the radionuclides onto the column packing. The solvent was then burned using a “common household-type oil burner.” Off-gas from the burner was discharged to the stack (Dickey et al. 1972).

A source term for sulfur dioxide releases from combustion sources could be derived for recent years and be used to calculate a release estimate for earlier years based on the amount and type of fuel burned. The operating permit application and air emissions inventories could be used to determine the number and capacity of coal and fuel oil fired boilers, diesel engines and generators, and open burning areas operating in the 1990s and these could be related to combustion that occurred at various times during the history of the Site.

The air emission inventory for 1989 estimated that a total of 120 tons was emitted from all sources (Ecology and Environment 1994). This is about 400 times the release required to result in a air concentration equal to the NAAQS using the conservative dispersion factor for a potential receptor on U.S. Highway 20/26, south of the ICPP.

Ambient air quality monitoring conducted for sulfur dioxide was presented in the annual reports and is summarized for 5 years in Table 14.

Table 14. Sulfur Dioxide Ambient Air Concentrations Reported in Annual Reports

Year	Annual ambient SO_2 concentrations at Van Buren and U.S. Highway 20/26 ($\mu g/m^3$)	Total estimated SO_2 emissions from all facilities (metric tons)
1990	0.4	122
1991	0.0	135
1992	0.8	117
1993	1.8	139
1994	2.7	188

The 1987 report said, “ Sulfur dioxide, nitrogen oxides and carbon oxides are monitored at the CFSGF. Emissions of sulfur dioxide from heating oil are calculated from sulfur content and the amount of fuel used.” The total amount of sulfur dioxide estimated to have been released was 174 metric tons in 1987. The annual average ambient air concentration at the Van Buren station was 0.82 μg/m^3 (Chew and Mitchell 1988). In 1992, RESL also calculated the maximum concentration at the Site boundary using the INWMIS discharges and the MESODIF air dispersion model. In 1992, the total sulfur dioxide released was estimated to be 177 metric tons and the maximum concentration at the southern Site boundary, where MESODIF predicted the highest concentration was 0.2 μg/m^3, compared to a NAAQS of 80 μg/m^3 (Hoff et al. 1993).

Findings for SO_2: Calculations of the amount of sulfur dioxide estimated to be released from boiler operations and other combustion sources suggest that concentrations at the Site boundary have been well below the NAAQS. Ambient air monitoring suggests that concentrations at Van Buren and the U.S. Highway 20/26 are less than 4% of the NAAQS. Offsite concentrations would be expected to be less than this. There seems to be no justification for including sulfur dioxide in a dose reconstruction study.

1,1,1-Trichloroethane

1,1,1-Trichloroethane has been used extensively as a solvent and degreaser since the 1980s, replacing more toxic solvents like tetrachloroethylene, trichloroethylene, and carbon tetrachloride used in the 1950s and 1960s in many industries. 1,1,1-Trichloroethane can cause nervous system and liver damage. Trichloroethane is very volatile and most of the trichloroethane used or released would have evaporated into the air where it persists for several years.

In 1991, the area surrounding the RWMC was monitored to establish baseline values in anticipation of future cleanup activities. The periphery was monitored for dusts with sorbed radionuclides. To obtain baseline measurements, Sisson and Porro (1992) recommended the air monitoring program (which is for radionuclides) include four VOCs found in groundwater: carbon tetrachloride, 1,1,1-trichloroethane, trichloroethylene, and chloroform. These four VOCs and tetrachloroethylene have been detected in soil gas samples. In discussions of modeling that might be used, the Industrial Source Complex model was suggested. The model has been used to determine the annual average VOC concentrations at the INEEL southern boundary and along U.S. Highway 20 from the vapor vacuum extraction process air emissions. The carcinogenic risk from concentrations based on uncontrolled extraction stack release estimates was found to be below acceptable criteria at both locations. The EPA Screen Model was used to evaluate exposure concentrations to the general public and workers and these concentrations were found to be within acceptable levels. The stack concentrations, exposure concentrations at the two locations, and the health risks were not given. Another risk assessment prepared for the Subsurface Disposal Area by McCellan et al. (1991) was cited as finding noncarcinogenic and carcinogenic effects due to chlorinated solvents were less than the level of concern for the air pathway (Sisson and Porro 1992).

Findings for trichloroethane: There are few records about the use and release of trichloroethane. The large inventory amount of 45,000 kg seems to have been totaled from many small amounts used for a variety of uses all over the Site. Determining how each facility may have used and released trichloroethane would involve interviewing many employees at many facilities. When all of the trichloroethane reported in storage was assumed to have been released into the air at the same time, the screening ratio was 0.13, which predicts the maximum concentration at the receptor location was 10 fold less that the threshold toxic concentration. The amount used probably does not justify a reconstruction or trichloroethane releases.

Other Solvents

Other chlorinated solvents were included in the screening. Although they have been contaminants of groundwater and were present in buried waste, we have found no evidence that large amounts of other toxic solvents, such as carbon tetrachloride, trichloroethylene, or tetrachloroethylene, were used at the INEEL in ways that would have resulted in large amounts being released to the air.

In 1971, Commander published a study of waste solvent generation. Commander (1971a) indicated that records about waste solvent generation had not been kept and information on the quantities generated were obtained by interviews with personnel and limited procurement records. More than 90% of the solvent procured in 1970 was kerosene. Four percent was hydrocarbon cleaning solvent. Less than 10 gal of carbon tetrachloride and 666 gallons of trichloroethylene were procured and trichloroethane was not listed. The ICPP used 550 gal/yr of hexone in 1970. The waste solvent generated in 1970 was estimate to total 440 gal/yr, an amount that was much less than Commander (1971a) expected. The volume was much less than the amount of solvent waste generated at DOE production facilities where solvent degreasing of nuclear fuel and target assemblies or products was done on a large scale.

Other Chemicals

Hydroxylamine Sulfate

Little additional information on the use and release of hydroxylamine sulfate was found in the record review. A technical progress report for the ICPP for 1974 discussed efforts to improve decontamination at the WCF. Two of the decontamination solutions being considered contained 0.3 M hydroxylamine sulfate. These were to be tested in the decontamination studies. Whether they were used extensively was unknown (Buckham and Bower 1975). Hydroxylamine sulfate is a white crystalline material that is very corrosive and can cause severe burns, ulceration, and sensitization reactions. There is a lack of toxicity information for this material. Although specific environmental fate data on this chemical are also lacking, it is a reactive chemical and would not be expected to persist in the environment in sufficient amounts to have been a concern offsite.

Slimicides

Slimicides were used to treat water and inhibit the growth of bacteria and algae in equipment at all of the facilities onsite. Details on the types of slimicides used have been found in interviews, technical reports, and operating procedures. Betz chromium-based and hexavalent chromium/phosphate based water treatment chemicals and Dianodic 194 corrosion inhibitors were used from startup until at least 1973. The interview notes for RL Batten (Phase I Interview with Batten MC 1763) read,

> 'Betz 40P'; "low" chromium about 1975-1979 Dianodic 2 (Part I) corrosion inhibitor 4.Nalco calcium phosphate; non heavy metal; used from 1973-1975 5.Dianodic II is Betz 20K- corrosion inhibitor; Betz 22K- dispersant; phosphate-based system Dianodic II used from 1979 to current. pH control: sulfuric acid added since day 1. microbiological control: slimicides are developmental toxins. chlorine gas- used from old days until 1985. oxidative biocides- bromine/chlorine donors; 'Aquabrom'; used in 1987-current non oxidative biocides- early days, don't know; later used C-30, C-30A, C-41, C-41A boiler feed water- only four chemicals used: from day 1 until 1986, hydrazine (35% solution) as an oxygen scavenger, from 1976-1986, morpholine (40% solution) for pH control from 1986-now, (1) Nalco 'Eliminox'- a carbohydrazide oxygen scavenger; works better at low temperatures; (2) Nalco 7270- blended amine for pH control auxiliary boilers- phosphate-based 'AGel' used for last 20 years, sodium sulfite, 'Liquimine.'

This suggests that a wide variety of chemicals were used for water treatment at various times.

The NRF prototypes' circulating water systems used chemicals to control pH (sulfuric acid), algae growth (chlorine initially, then other biocides), and corrosion (originally chromates and subsequently phosphate-based compounds). NRF began processing primary coolant discharged to these ponds through charcoal filters in 1973 (Phase I Interview with Borror MC 26568).

An operating procedure found as an attachment to a packet of information having to do with RCRA compliance issues at ANL-W contained information about Betz compounds, Dianodic, HEDP, and tolytriazole (chemicals listed in the inventory for which use, formulation, and toxicity information was not available). A description of water treatment says that Dianodic-II was added to prevent oxygen corrosion. Orthophosphates and polyphosphates, were also used for corrosion control. Betz-20K, the solution containing the poly- and orthophosphates was continually injected into the system at 11–15 ppm. Calcium phosphate precipitation from this treatment was prevented by another treatment of BETZ 2020, which contained a polyacrylic acid that dispersed salts. Betz-20K also contained HEDP, which inhibits the precipitations of scale (calcium carbonate), and a chemical called tolytriazole, which inhibits corrosion of copper alloys. The BetzE Dianodic-II chemicals were received in bulk quantities and stored in two 2000-gal polyethylene tanks and were piped to the injection tanks by gravity flow. The tank and supply line were heated to prevent freezing (ANL-W 1987). This helps confirm that these chemicals were used and suggests that the ANL-W inventory for Betz compounds provided a upper end inventory amount to use for screen sodium tolytriazole and dionodic. We have found no indication that these compounds were released into the air in sufficient amounts to be of concern for this study.

The majority of the slimicides used were chlorine based. With the exception of chromium (in BETZ E-194 or dianodic) which is a carcinogen and persistent, the water treatment chemicals would not have been released in quantities that warrant inclusion in a dose reconstruction study. The amounts used were large, but these compounds were mixed into large amounts of water and there was no indication that large amounts would have been released to the air.

Asbestos and PCBs

No additional information was found subsequent to the screening that would suggest that asbestos or PCBs should be included in a dose reconstruction study. The INEEL has an asbestos control program that established mandatory standardized requirements for any work involving asbestos. Also, a database called HAZ CAD is being implemented at the INEEL to track asbestos-containing material, as required by federal regulations (DOE 1997a). PCBs and PCB-containing equipment has been tracked by the Power Management organization at the INEEL. Small amounts of PCBs and asbestos, supposedly from asbestos-tiling that was disposed of as construction debris, was found in the CFA pond (McCormick et al. 1996). This asbestos was in solid materials, in sludge, or underwater and has probably not been subject to dispersion. Other RCRA or CERCLA monitoring and site characterization has provided no evidence of undocumented PCB burials or any large releases that should be considered in a dose reconstruction.

Additional Chemicals

The selection of chemicals to evaluate in the feasibility study was an ongoing process throughout the study. As documents were reviewed, information regarding the amounts of chemicals used and released were noted and we continually assessed whether evidence warranted adding chemicals to those that were selected. As yet, no chemicals have been added to the chemicals of concern, although several have been considered. These are discussed briefly below.

Explosive Residues

Before 1949, the Navy conducted aerial bombing practice, naval artillery testing, explosive storage bunker testing, and ordinance disposal over a large part of what is now the INEEL. Between 1942 and 1950, approximately 1650 guns were tested at the Naval Proving Ground. Mass detonation tests were also conducted, where hundreds of thousands of pounds of explosives in land mines, smokeless powder, and bombs were placed in storage bunkers or open areas and detonated to determine the effects on the bunkers or other facilities being tested. In 1950, the Naval Proving Ground was transferred from the Navy to the Atomic Energy Commission. In 1968, the Naval Ordnance Test Facility was established at the south end of the former Naval Proving Ground and was used by the Navy to test 16-in. guns (Sherwood et al. 1997). Unexploded ordinance and contaminated soil resulting from these activities are now being addressed. The soil was contaminated with explosive residues like trinitrotoluene (TNT) and Research Development Explosive or cyclotrimethylene trinitroamine) (RDX), that can cause cancer. As a part of the cleanup, hundreds of ordinance items were detonated and several hundred yards or more of soil contaminated with more than 440 mg/kg TNT and 180 mg/kg RDX were removed for offsite incineration (DOE-ID 1995). As a result of these activities, many projectiles, explosive materials, pieces of explosives and debris remain in the area. Unexploded ordnance and explosive waste in soils have been removed in many sites during removal actions in 1993, 1994, 1995, and 1996. A brief description of each site and a risk assessment for explosive risk and risk from the contaminants RDX; TNT; 1,3,5-trinitrobenzene (TNB), and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetraxocine (HMX) was described in Sherwood et al. (1997). There was no evidence that the residues were being resuspended or dispersed by the wind. The extent of the contamination and the amounts of explosive residues in the soil do not warrant inclusion of these compounds in the dose reconstruction.

Hexone

Additional information on the amounts used and potential evaporation of hexone was found in an Phase I interview with M. Croson in August of 1993 (Phase I Interview with Croson MC 26983). The second and third cycle extractions used hexone (methyl isobutyl ketone [MIBK]) to further separate the uranium from residual fission and transuranic materials. M. Croson provided SC&A with an estimate of hexone releases to the environment during the 42 fuel processing campaigns performed at the ICPP between 1953 and 1985. In addition to the estimate of hexone released, Mr. Croson also provided his assumptions, pathway of release to the environment, and upper and lower boundaries of quantities released. The summary of his hand-written estimates entered in the database as interview notes reads,

> Upper end estimate of hexone releases to environment. Assumptions 1.42 Campaigns = 42 2nd/3rd Cycle Runs - Use 50 to include R&D. 2.1-2 months - operating time is generally less than one month with cold testing and flushing; but later runs have moved the average up. Use two operating months, because I'm not sure. 3.Hexone use rate = 1,000 gal./month. Measured makeup has been 600 - 1,000 gal. per operating month. Use 1,000 to account for ground spills or sloppiness. 4.Release: I estimate 50 percent volatilizes and 50 percent stays soluble in aqueous wastes and eventually burned in the calciner. If you say 100 percent is volatilized, you have an upper bound. (50) (2) (1000) = 100,000 gal. hexone with 100 percent of makeup being released. Probably closer to (50) (1) (1000) (50%) = 25,000 gal. To clarify, the units of calculation are: (# of campaigns)(operating months per campaign)(hexone use per operating month)(percent of hexone used which volatilizes)".

This suggests that about 25,000 gallons of hexone was released each month. The amount of hexone used for the screening was 7.6×10^4 kg (Commander 1971; DOE 1995), which corresponds to about 2.0×10^4 gallons. The screening ratio for this amount was well below one, at 5.67×10^{-6}. Using an assumption of 100% volatilized and an upperbound of 100,000 gal, or about 3.8×10^5 kg/month or 4.6×10^6 kg/yr released would result in a ratio of 3.4×10^{-4}, well below 1.

Cyclohexamine

The INEL Site Environmental Report for Calendar Year 1992 reported the release to the percolation pond of a corrosion inhibitor used to treat steam condensate at ICPP, containing cyclohexylamine. After discovering the toxicity of this material, it was replaced with a new corrosion inhibitor. How much was released was not described (Hoff et al. 1992), but it seems to have been used for a short time.

Gasoline and Diesel Fuels

Gasoline and diesel fuel have been used in large amounts at the INEEL. Thousands of personnel have been bused from Idaho Falls and Pocatello to the Site. The 1989 Air Emissions Inventory conservatively estimated total VOCs from gasoline transfer operations at the Site in 1989. A total of 95,783 gal of gasoline were estimated to have been transferred from bulk storage to distribution trucks. Using an emission factor from the EPA’s AP-42 of 0.005 lb/gal, an emissions estimate of 479 lb was calculated for the year. A Total of 345,430 gal of gasoline was estimated to have been transferred from storage tanks to consumers. Using an emission factor from the EPA’s AP-42 of 0.011b/gal, an emissions estimate of 3800 lb was calculated for the year.

An inventory amount of 5.0×10^6 kg was derived from the SARA Title III reports (DOE 1993a). This resulted in a screening ratio of 1.0×10^{-4}, well below 1. Combustion of gasoline and fuels release exhaust containing sulfur dioxide and oxides of nitrogen, pollutants also addressed in this feasibility study.

CONCLUSIONS

In assessing the feasibility of performing a chemical dose reconstruction study at the INEEL, we thought two questions should be answered for each chemical under consideration (1) could a dose reconstruction be done for this chemical? Is there enough information available to estimate a source term, characterize environmental degradation, and fate and transport and calculate an exposure concentration with a reasonable uncertainty? and (2) should a dose reconstruction be performed? Does the preliminary information collected suggest that the amounts released might have reached members of the public? Do the potential for health effects justify a study?

To conduct a dose reconstruction for any chemicals at the INEEL, it seems clear that a more more directed series of interviews with knowledgeable people would need to be done for the chemicals under study. There does not appear to be enough information available to reconstruct releases for hydrazine, slimicides, hydroxylamine sulfate and lead; however, there is also no indication that large amounts of these chemicals were released to the air.

Calculated maximum cadmium concentrations in air from suspension of all of the cadmium potentially in the ICPP percolation ponds were less than health risk-based screening concentrations. Chromium released to the air from cooling tower operations appears to have been less than levels of concern. The potential for chromium to have been suspended from TRA pond sediments was calculated using EPA-approved suspension rate constants and conservative estimates of the amount of chromium in the pond. Predicted concentrations in air were less than screening levels used by the EPA.

The information needed to evaluate mercury releases from the ANP Program is lacking. Although several kilograms of mercury was known to have been spilled, large amounts of mercury do not seem to have been spilled or buried or dumped on onsite waste areas. Mercury was released from the dissolution of aluminum fuels and from calcining of waste from aluminum fuel processing at the ICPP. The releases could be reconstructed using information on processing, campaigns, pollution control, and recent monitoring and special sampling done in the 1980s. The information does not seem to be accurate enough and the mercury releases are not large enough to estimate releases using a mass balance approach. Site estimates of mercury concentrations at ground level and our estimates of predicted mercury concentrations at Highway 20/26 (based on site emission estimates), were less than health-based regulatory standards. Mercury releases from the ICPP could be estimated but concentrations in areas accessible to the public were probably very low.

Nitrogen dioxide releases from combustion sources, especially the powerhouses, can be estimated from data on the type and amount of fuel burned and the emission factors that apply to that fuel. Nitrogen dioxide emissions from the ICPP processes can be based on NO_x monitoring conducted since the mid-1980s. The Site has made emissions estimates for operating permits and air quality compliance requirements Calculated air concentrations at the Site boundary and at U.S. Highway 20/26 have been well below NAAQS for oxides of nitrogen.

Sulfur dioxide releases from combustion sources, especially the powerhouses, could be estimated from data on the type and amount of fuel burned and the sulfur content. The Site has made emissions estimates on this basis and has calculated that Site boundary concentrations should be well below NAAQS. Ambient air concentrations measured onsite at the intersection of Van Buren and U.S. Highway 20/26 have also been well below regulatory standards and levels of concern.

A summary of the findings is compiled in Table 15.

Table 15. Assessing the feasibility of conducting a historical dose reconstruction For selected chemical releases.

Chemical	Could a Dose Reconstruction Study be done? Is there sufficient data?		Should a Dose Reconstruction Study be done? Was the amount likely to have been released sufficient to justify a study?	
	YES	NO	YES	NO
Beryllium		■		■
Cadmium	■			■
Chromium	■			■
Hydrazine		■		
Hydroxylamine Sulfate		■		■
Lead		■		■
Mercury (ANP)		■		
Mercury (ICPP)	■			■
Nickel	■			■
Nitrogen dioxide	■			■
Slimicides		■		■
Sulfuric Acid	■			■
Sulfur dioxides	■			■
Trichloroethane		■		■

There is sufficient documentation and information about most of the chemicals evaluated in the feasibility study to allow reconstruction of releases and estimate of exposure concentrations to be made. However, none of these chemicals appear to have been released in quantities sufficient to warrant a dose reconstruction and assessment of past health risk offsite. It seems unlikely that the air concentrations of these pollutants would have been high enough at the Site boundary or at U.S. Highway 20/26 to have caused health effects.

REFERENCES

Abbott, Michael J. 1991a. Letter to J.T. Case. TRA Evaporation Pond Dose Assessment at U.S. Highway 20/26. MLA-08-91. April 8, 1991. INEEL Task Order Database MC Number 95000.

Abbott, Michael J. 1991b. Engineering Design File. Radiological Impacts for the CFA Evaporation Pond – Environmental Assessment and NESHAP Analysis. Project File Number SEM-ROU-91-024. July 22, 1991. INEEL Task Order Database MC Number 95001

Abbott, Michael J. 1991c. Letter to J.R. Mitchell. Transmittal of Non-Radiological Impact Analysis for Airborne Releases from the CFA Laundry Evaporation Pond. MLA-16-91. July 31, 1991. INEEL Task Order Database MC Number 95002.

Abbott. M. 1997. Advisory Scientist. Lockheed Martin Idaho Technologies Company. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. Regarding modeling of the atmospheric dispersion of pond sediments. INEEL Task Order Database MC Number 70710.

Abbott, Michael J. 1998. Advisory Scientist. Lockheed Martin Idaho Technologies Company. Communication with M. J. Case, consultant to *Radiological Assessments Corporation*. Regarding modeling of the atmospheric dispersion of pond sediments. INEEL Task Order Database MC Number 70710.

Alexander, T.G. 1988. *Groundwater Monitoring Plan for TSF HTRE-III Mercury Spill Area*. EGG-ER-8061. April. INEEL Task Order Database MC Number 50962.

Alexander T.G. and S. Saint-Louis. 1988. Closure Plan and Sampling and Analysis Plan for ARA-1 Chemical Evaporation Pond. EGG-WM-7699. INEEL Task Order Database MC Number 51041.

Allied Chemical Corporation. 1973a. *Idaho Chemical Programs Annual Technical Report Fiscal Year 1972*. ICP-1022. National Reactor Testing Station. INEEL Task Order Database MC Number 51042.

Allied Chemical Corporation. 1973b. ICPP Monthly Report for March. National Reactor Testing Station. April.

Allied Chemical Corporation. 1976. *Idaho Chemical Programs Annual Technical Report Fiscal Year 1975*. ICP- 1086. National Reactor Testing Station. INEEL Task Order Database MC Number 51040·

ANL-W (Argonne National Laboratory-West). 1989. *Hazardous Chemicals and Extremely Hazardous Substances Inventory*. Intralaboratory Memo. January. INEEL Task Order Database MC Number 50963.

ANL-W. 1989. *ANL-W Hazardous Chemical Inventory*. Intralaboratory Memo. INEEL Task Order Database MC Number 50964.

ANL-W. 1987. *EBR-II Standard Operating Procedure XIII, C Main Cooling Tower Water Treatment.* Revision Bulletin 1603. November 11. INEEL Task Order Database MC Number 95003.

ANL-W. 1973. Facility Waste Descriptions. DRAFT. December 14. INEEL Task Order Database MC Number 50965.

Armstrong, R.C. 1956. *Mercury Shipment.* Memo. Y/IIG-0541. Atomic Energy Commission. Oak Ridge, Tennessee. INEEL Task Order Database MC Number 50947.

ATSDR (Agency for Toxic Substances and Disease Registry). 1989–1996. *Toxicological Profiles*. Atlanta, Georgia.

ATSDR. 1995. “List of Hazardous Substances in the Soil, Sediment and Groundwater at the INEL.” Given to C.M Wood, Centers for Disease Control and Prevention, Radiation Studies Branch, by ATSDR, Health Assessments Group, Atlanta, Georgia.

Bartholomay, R.C., B.R. Orr, M.J. Liszewski, and R.G. Jensen. 1995a. *Hydrologic Conditions and Distribution of Selected Chemical Constituents in Water, Snake River Plain Aquifer, INEL, Idaho 1989–1991*. U.S. Geological Survey Water-Resources Investigations Report 95-4175, DOE/ID-22123. INEEL Task Order Database MC Number 50932.

Bartholomay, R.C., L.M. Williams, and L.J. Campbell. 1995b. *Radionuclides, Stable Isotopes, Inorganic Constituents and Organic Compounds in Water from Selected Wells and Springs from the Southern Boundary of the INEL to the Hagerman Area, Idaho, 1994*. U.S. Geological Survey and Idaho Department of Water Resources Open File Report 95-718, DOE/ID-22124. October. INEEL Task Order Database MC Number 50934.

Beller, J.M. and R.A. Bessent. 1991. *TRA Warm Water Waste Pond at the INEL Sediment Treatment Feasibility Study Phase I*. EGG-WM-10000. November. INEEL Task Order Database MC Number 95004.

Buckham, J.A. and J.R. Bower. 1974*. Idaho Chemicals Programs Annual Technical Report Fiscal Year 1973*. ICP-1047. Allied Chemical Corporation. January. INEEL Task Order Database MC Number 51033.

Buckham, J.A. and J.R. Bower. 1975*. Idaho Chemicals Programs Annual Technical Report Fiscal Year 1974*. ICP-1063. National Reactor Testing Station. INEEL Task Order Database MC Number 51030.

Buckham, J.A., C.B. Amberson, B.C. Musgrave, J.R. Bower, and B.R. Wheeler. 1972. *Idaho Chemical Programs Annual Technical Report Fiscal Year 1971*. ICP-1006 Allied Chemical Corporation. National Reactor Testing Station. INEEL Task Order Database MC Number 51032.

Burns, S.M., K.M. Ludi, M.J. Spry, C.K. Hardy, and S.N. Stanisich. 1990. *Sampling and Analysis Plan for the TRA Chemical Waste Pond (COCA Unit TRA-06).* EGG-WM-8827. INEEL Task Order Database MC Number 51029.

Chew, E. 1997. U.S. Department of Energy Idaho Operations Office Environmental Programs, DOE Point of Contact for the INEEL Dose Reconstruction Feasibility Study. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. Regarding many different subjects and several conversations in 1997 and 1998. INEEL Task Order Database MC Number 95105.

Chew, E.W. and R.G. Mitchell. 1988. May. *1987 Environmental Monitoring Program Report for the Idaho National Engineering Laboratory Site.* DOE/ID-12082(87). INEEL Task Order Database MC Number 50966.

Commander, J.C. 1971a. *Nonradioactive Waste Solvent Disposal Study*. CI-1221. Idaho Nuclear Corporation. April. INEEL Task Order Database MC Number 50950.

Commander, J.C. 1971b. *Nonradioactive Waste Oil Disposal Study*. CI-1212. Idaho Nuclear Corporation. February. INEEL Task Order Database MC Number 51026.

Coward D.D. 1972. *Nonradioactive Beryllium Handling*. Memo to G.R. Allred. ATR106, Aerojet Nuclear Company Interoffice Correspondence COW-37-72. April 26. INEEL Task Order Database MC Number 95013.

Creighton, P. 1999. Occupational Health and Safety, INEEL. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. Regarding beryllium surveillance in workers at the INEEL. May. INEEL Task Order Database MC Number 95026.

Denny, R.D. 1974. *Addendum-Safety Analysis Report for the ICPP Electrolytic Dissolution Process*. ACI-141. Allied Chemical Corporation. INEEL Task Order Database MC Number 51050.

Depperschmitt, J. and M. Bennett. 1997. U.S. Department of Energy Idaho Operations Office, Idaho National Engineering and Environmental Laboratory. Communication with P.D. McGavran, consultant *to Radiological Assessments Corporation* about the INEL Groundwater Monitoring Plan and similar projects. October. INEEL Task Order Database MC Number 70709.

Dickey, B.R., W.F. Holcomb, Lt. Lakey, R.D. Modrow, and C.M. Slansky. 1972. *Plan for the Management of Radioactive Wastes at the ICPP.* ACI-123. Allied Chemical Corporation. INEEL Task Order Database MC Number 51027.

DOE (U.S. Department of Energy). 1980. Transuranic Elements in the Environment. DOE/IC-2280. INEEL Task Order Database MC Number 95005.

DOE 1988. *Environmental Survey Preliminary Summary Report of the Defense Production Facilities*. DOE/EH-0072. September. INEEL Task Order Database MC Number 50958.

DOE. 1989. *SARA 312 Report for the INEL Site Facilities. Calendar Year 1988*. DOE Idaho Field Office. March. INEEL Task Order Database MC Number 95006.

DOE. 1991a. *Idaho National Engineering Laboratory Historical Dose Evaluation, Volume 1*. DOE/ID-12119. August. INEEL Task Order Database MC Number 51061.

DOE. 1991b. *SARA 312 Report for the INEL Site Facilities. Calendar Year 1990*. DOE Idaho Field Office. March. INEEL Task Order Database MC Number 50931.

DOE. 1992. *Remedial Investigation and Feasibility Study Final Work Plan Industrial Waste Ditch for the Naval Reactors Facility, Idaho Falls, Idaho*. September. INEEL Task Order Database MC Number 51057.

DOE. 1992b. Track 1 Sites: Guidance for Assessing Low Probability Hazard Sites at the INEL, Rev. 1, DOE/ID-10340. INEEL Task Order Database MC Number 95007.

DOE. 1993a. *SARA 312 Report for the INEL Site Facilities. Calendar Year 1992*. DOE Idaho Field Office. March. INEEL Task Order Database MC Number 50917.

DOE 1993b. *INEL Groundwater Monitoring Plan*. Excerpts and INEL Site-Wide Contaminant Source Survey Draft Materials. DOE/ID-10441, June 1993. INEEL Task Order Database MC Number 51043.

DOE. 1994a. “Proposed Plan for the Naval Reactors Facility Industrial Waste Ditch and Landfill Area.” *INEL Environmental Restoration Program Newsletter*. April. INEEL Task Order Database MC Number 51106.

DOE. 1994b. *Department of Energy Programmatic Spent Nuclear Fuel Management and INEL Environmental Restoration and Waste Management Programs Draft Environmental Impact Statement*. DOE/EIS-0203-D. INEEL Task Order Database MC Number 50944.

DOE. 1994c. Track 2 Sites: Guidance for Assessing Low Probability Hazard Sites at the INEL, Rev. 6, DOE/ID-10389. INEEL Task Order Database MC Number 95008.

DOE. 1995. *Comprehensive Remedial Investigation and Feasibility Study Final Work Plan. Waste Area Group 8 Naval Reactors Facility*. October. INEEL Task Order Database MC Number 51058.

DOE. 1997a. *Final Work Plan for Waste Area Group 5, OU 5-12, Comprehensive Remedial Investigation/Feasibility Study, Draft*. DOE/ID-10555. May. INEEL Task Order Database MC Number 51047.

DOE. 1997b. *SARA 312 Report for the INEL Site Facilities. Calendar Year 1996*. DOE Idaho Field Office. March. INEEL Task Order Database MC Number 95006.

DOE. 1997c. *Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to Their Environmental Consequences*. Office of Environmental Management. Washington DC. January.

DOE. 1999. *Proposed Plan for Operable Unit 4-13A Interim Action.* INEEL Environmental Restoration Program . August. INEEL Task Order Database MC Number 95012.

DOE-ID (U.S. Department of Energy-Idaho Operations Office). 1995a. *Update*. Fact Sheet, Community Relations, INEL Environmental Restoration Program. March

DOE-ID. 1995b. *Air Emissions Inventory for the INEL-1995 Emissions Report*. DOE/ID-10537. June. INEEL Task Order Database MC Number 51063.

DOE, EPA, and IDEQ (U.S. Department of Energy, U.S. Environmental Protection Agency, and Idaho Department of Environmental Quality). 1998. *"Proposed Plan for WAG 1–TAN at the INEEL*.". *INEL Environmental Restoration Program Newsletter*. February. INEEL Task Order Database MC Number 51062.

Dumas. M. 1988. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. Regarding operation of the WCF and NWCF at the ICPP. March. INEEL Task Order Database MC Number 95016.

Ecology and Environment. 1994. *Toxic Air Pollutant Emission Inventory of the INEL for Calendar Year 1989. Volumes 1 and 2.* INEEL Task Order Database MC Number 51067.

EG&G (EG&G Idaho, Inc.). 1988. *Groundwater Monitoring Plan for TSF HTRE-III Mercury Spill Area*. EGG-ER-8061. April. INEEL Task Order Database MC Number 50961.

EG&G. 1990. *Closure Plan for the PBF Corrosive Waste Sump and the PBF Evaporation Pond.* EGG-WM-8996. May. INEEL Task Order Database MC Number 51021.

Eisler R. 1986. *Chromium Hazards to Fish, Wildlife and Invertebrates: A Synoptic Review.* Patuxent Wildlife Research Center, Laurel, MD. US Fish and Wildlife Service, US Department of Interior. Biological Report 85(1.6). January.

ENICO. (Exxon Nuclear Idaho Company, Inc.).1984. *ICPP 1st, 2nd, and 3rd Quarter Effluent Monitoring Report*. ENICO-1116. INEEL Task Order Database MC Number 51095 – 51098.

EPA (U.S. Environmental Protection Agency). 1996. Region Nine Preliminary Remediation Goals. August.

EPA (U.S. Environmental Protection Agency). 1988. *Compilation of Air Pollutant Emission Factors. Volume 1: Stationary Point and Area Sources. 4th edition*. AP-42. Research Triangle Park, North Carolina.

EPA 1985. Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites. EPA/600/8-85/002.

Hiaring, C.M., N.E. Josten, D.J. Kuhns, and M.D. McKenzie. 1991. *Radioactive Waste Management Complex Trench 27 Mercury Investigation.* EGG-WM-9730. INEEL Task Order Database MC Number 51020.

Herbst, A.K. 1979. *Mercury Concentrations in the Effluent Streams of the Idaho Chemical Processing Plant*. M.S. thesis. University of Idaho, Moscow, Idaho. INEEL Task Order Database MC Number 51049.

Hilmas, D. 1999. Technical Director for the Oak Ridge Associated Universities Beryllium Surveillance Project. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. Regarding beryllium surveillance in workers at the INEEL. May. INEEL Task Order Database MC Number 95025.

Hoff, D.L., E.W. Chew, and R.L Dickson. 1984. *1983 Environmental Monitoring Program Report for the Idaho National Engineering Laboratory Site.* DOE/ID-12082(83). May. INEEL Task Order Database MC Number 50930.

Hoff, D.L., E.W. Chew, and R.L Dickson. 1985. *1984 Environmental Monitoring Program Report for the Idaho National Engineering Laboratory Site.* DOE/ID-12082(84). May. INEEL Task Order Database MC Number 50949.

Hoff, D.L., E.W. Chew, and S.K. Rope. 1986. May. *1985 Environmental Monitoring Program Report for Idaho National Engineering Laboratory Site.* DOE/ID-12082(85). INEEL Task Order Database MC Number 50946.

Hoff, D.L., E.W. Chew, and S.K. Rope. 1987. *1986 Environmental Monitoring Program Report for the Idaho National Engineering Laboratory Site.* DOE/ID-12082(86). May. INEEL Task Order Database MC Number 50956.

Hoff, D.L., R.G. Mitchell, and R. Moore. 1989. *The INEL Site Environmental Report for Calendar Year 1988*. DOE/ID-12082(88). June. INEEL Task Order Database MC Number 50938.

Hoff, D.L., R.G. Mitchell, G.C. Bowman, and R Moore. 1990. *The INEL Site Environmental Report for Calendar Year 1989*. DOE/ID-12082(89). June. INEEL Task Order Database MC Number 50936.

Hoff, D.L., R.G. Mitchell, R. Moore, and R.M. Shaw. 1991. *The INEL Site Environmental Report for Calendar Year 1990*. DOE/ID-12082(90). June. INEEL Task Order Database MC Number 50937.

Hoff, D.L., R.G. Mitchell, R. Moore, and L. Bingham. 1992. *The INEL Site Environmental Report for Calendar Year 1991*. DOE/ID-12082(91). September. INEEL Task Order Database MC Number 50951.

Hoff, D.L., R.G. Mitchell, R. Moore, and L. Bingham. 1993. *The INEL Site Environmental Report for Calendar Year 1992*. DOE/ID-12082(92). June. INEEL Task Order Database MC Number 59014.

Holcomb, W.F. and A.P. Larick. 1974. *Effective Water Utilization at the NTRS Test Area Reactor.* ACI-159. Allied Chemical Corporation. INEEL Task Order Database MC Number 50957.

Honkus, R.J. 1982. *Evaluation of ICPP Nitric Oxides (NOx) Emissions*. ENI-198. April. INEEL Task Order Database MC Number 51072.

Horan, J. 1997. Health Effects Subcommittee member and former Director of Health and Safety Division of the Atomic Energy Commission at the INEL. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. INEEL Task Order Database MC Number 70702.

Hull, L.C. 1989. *Conceptual Model and Description of the Affected Environment for the TRA Warm Waste Water Pond.* EGG-ER-8644. October. INEEL Task Order Database MC Number 51054.

Krivanek, K.R. 1988a. *ICPP Environmental Monitoring Report CY-1986*. WINCO-1052. February. INEEL Task Order Database MC Number 51085.

Krivanek, K.R. 1988b. *ICPP Environmental Monitoring Report CY-1987*. WINCO-1055. June. INEEL Task Order Database MC Number 51086.

Krivanek, K.R. 1989. *ICPP Environmental Monitoring Report CY-1988*. WINCO-1071. August. INEEL Task Order Database MC Number 51088.

Kunze, J. 1999. Dean of Engineering at Idaho State University in Pocatello. Telephone Communication with P. D. McGavran consultant to *Radiological Assessments Corporation*.

Regarding Beryllium and Mercury Use and Release from the ANP Project. May. INEEL Task Order Database MC Number 95017.

Lakey, L.T. and J.R. Bower. 1963. *ICPP Waste Calcining Facility Safety Analysis Report*. IDO-14620. Phillips Petroleum Company. December 1. INEEL Task Order Database MC Number 50960.

Layton D.W., B.J. Mallon, D.H. Rosenblatt and M.J. Small. 1987. “Deriving allowable Daily Intakes for Systemic Toxicants Lacking Chronic Toxicity Data.” *Regulatory Toxicology and Pharmacology*. 7:92-112.

Lee, S.D., M.J. Rohe, A.S. Rood, and I.E. Stephan. 1997. *Comprehensive Remedial Investigation/Feasibility Study for ANL-W Operable Unit 9-04 at the INEEL (DRAFT), Volume 1*. W7500-0000-ES-01. June. INEEL Task Order Database MC Number 50967.

Liable, E. 1997. Safeguards Unit, Material Control and Accountability, Technical Operations, Lockheed Martin Idaho Technologies Company. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. October. INEEL Task Order Database MC Number 95018.

Mann, L.J. and L.L. Knobel. 1988. *Concentrations of Nine Trace Metals in Ground Water at the INEL, Idaho*. U.S. Geological Survey Report 88-332. DOE/ID-22075. May. INEEL Task Order Database MC Number 50955.

Martin-Lewis, S., P.O. Sinton, M.J. Condran and J.W. Gordan. 1992. *Remedial Investigation Report for the Test Reactor Perched Water System (OU-2-12)* Volume 1. EGG-WM-10002. INEEL Task Order Database MC Number 51039.

Mason, L. 1999. Retired ANP Project Engineer. Telephone Communication with P. D. McGavran consultant to *Radiological Assessments Corporation*. Regarding Beryllium and Mercury Use and Release from the ANP Project. May. INEEL Task Order Database MC Number 59019.

McCormick, S.H., P.J. Jessmore, J.M. McCarthy, and S.M. Rood. 1996. *Work Plan for WAG-4, OU 4-13, Comprehensive Remedial Investigation/Feasibility Study DRAFT*. DOE/ID-10550. INEEL Task Order Database MC Number 51048.

McGavran, P.D. and J.E. Till. 1997. *Selection of Chemicals of Concern for Assessing the Feasibility of Performing a Chemical Dose Reconstruction at the INEEL, Draft*. *Radiological Assessments Corporation*, Neeses, South Carolina. December.

McGavran, P.D. and J.E. Till. 1997. *Criteria, Methods and Exposure Pathways Considered for Selection of Chemicals of Concern for Assessing the Feasibility of Performing a Chemical Dose Reconstruction Study at the INEEL, Draft*. *Radiological Assessments Corporation*, Neeses, South Carolina. July.

Mitchell, R.G. 1994. *INEL Site Environmental Report for Calendar Year 1993*. DOE/ID-12082(93). Environmental Science and Research Foundation. July. INEEL Task Order Database MC Number 50941.

Mitchell , R.G., D. Peterson and D.L. Hoff. 1995. *INEL Site Environmental Report for Calendar Year 1994*. DOE/ID-12082(94). Environmental Science and Research Foundation. July. INEEL Task Order Database MC Number 50939.

Mitchell, R.G., D. Peterson, and D.L. Hoff. 1996. *INEL Site Environmental Report for Calendar Year 1995.* DOE/ID-12082(95). Environmental Science and Research Foundation. August. INEEL Task Order Database MC Number 50940.

Morris. 1994. *Radioecology and Ecology Publications of the Idaho National Engineering Laboratory: 1974 - 1994.* Environmental Science and Research Foundation. Idaho Falls, Idaho. ESRF-003. November. INEEL Task Order Database MC Number 50935.

Morris, B. K. 1998. Occupational Safety and Health Representative on the INEELHES, Oil, Chemical and Atomic Workers International Union Local 2-652. Communication with P. D. McGavran consultant to *Radiological Assessments Corporation*. Regarding Beryllium, Trichloroethylene and Mercury Use and Release. INEEL Task Order Database MC Number 95024.

Nebeker, R.L. and L.T. Lakey. 1970. *A Study of Possible Improvements in Liquid Waste Management at the NRTS Test Reactor Area. Idaho Nuclear Corporation*, CI-1173. National Reactor Testing Station, Idaho Falls, Idaho. April. INEEL Task Order Database MC Number 1473.

Neff, J.K. 1992. *ICPP Environmental Monitoring Report CY-1990*. WIN-340. May. INEEL Task Order Database MC Number 51091.

Neff, J.K. 1992. *ICPP Environmental Monitoring Report CY-1991*. WINCO-1102. July. INEEL Task Order Database MC Number 51092.

Neff, J.K. 1993. *ICPP Environmental Monitoring Report CY-1992*. WINCO-1128. July. INEEL Task Order Database MC Number 51093.

Nelson, P.I., W.A. Freeby, and R.D. Modrow. 1971. *Design Criteria for an Atmospheric Protection System at the ICPP.* ACI-112. Allied Chemical Corporation. November. INEEL Task Order Database MC Number 51056.

Nelson, P.I., G.E. Bingham, and W.A. Freeby. 1972. *Preliminary Safety Analysis Report for the Atmospheric Protection System.* ACI-126. Allied Chemical Corporation. September. INEEL Task Order Database MC Number 51060.

NIOSH (National Institute of Occupational Safety and Health). 1993. *Preliminary Draft Report of the Cohort Mortality Study at the INEL.* Cincinnati, Ohio.

NIOSH. 1995. *NIOSH Pocket Guide to Chemical Hazards.* Centers for Disease Control and Prevention. Department of Health and Human Services. Cincinnati, Ohio.

Oil, Chemical and Atomic International Union Center for the Biology of Natural Systems. 1998. Former Worker Medical Surveillance Program at Idaho National Engineering and Environmental Laboratory. Phase I: Needs Assessment. Queens College, University of Massachusetts Lowell. October. INEEL Task Order Database MC Number 95014.

Orr, B.R. and L.D. Cecil. 1991. *Hydrologic Conditions and Distribution of Selected Chemical Constituents in Water, Snake River Plain Aquifer, INEL, Idaho 1986-1988.* U.S. Geological Survey Water-Resources Investigations Report 91-4047. DOE/ID-22096. INEEL Task Order Database MC Number 50932.

Phillips Petroleum Company. 1953a. *Idaho Chemical Processing Plant Monthly Progress Report*. IDO-14288. Atomic Energy Division, Idaho Operations Office. October.

Phillips Petroleum Company. 1953b. *Idaho Chemical Processing Plant Monthly Progress Report*. IDO-14290. Atomic Energy Division, Idaho Operations Office. November.

Phillips Petroleum Company. 1953c. *Idaho Chemical Processing Plant Monthly Progress Report*. IDO-14291. Atomic Energy Division, Idaho Operations Office. December.

Phillips Petroleum Company. 1954a. *Idaho Chemical Processing Plant Monthly Progress Report*. IDO-14296. Atomic Energy Division, Idaho Operations Office. January.

Phillips Petroleum Company. 1954b. *Idaho Chemical Processing Plant Monthly Progress Report*. IDO-14297, Atomic Energy Division. Idaho Operations Office. February. INEEL Task Order Database MC Number 50056.

Phillips Petroleum Company. 1954c. *Idaho Chemical Processing Plant Monthly Progress Report*. IDO-14298; Atomic Energy Division. Idaho Operations Office. March

Phillips Petroleum Company. 1954d. *Idaho Chemical Processing Plant Monthly Progress Report*. IDO-14302. Atomic Energy Division. Idaho Operations Office. April.

Phillips Petroleum Company. 1954e. *Idaho Chemical Processing Plant Monthly Progress Report*. IDO-14308. Atomic Energy Division. Idaho Operations Office. June.

Phillips Petroleum Company. 1955. *CPP Production Weekly Reports No. 91 to No. 116.* PPC-1131. Atomic Energy Division. Idaho Operations Office. July 3 to December 31.

Phillips Petroleum Company. 1956. *Idaho Chemical Processing Plant Monthly Progress Report*. PTR-163. Atomic Energy Division. Idaho Operations Office. December.

Phillips Petroleum Company. 1957. *Idaho Chemical Processing Plants Monthly Reports*. PTR-182. Atomic Energy Division. Idaho Operations Office. January.

Pittman, J.R., R.G. Jensen, and P.R. Fischer. 1988. *Hydrologic Conditions at the INEL 1982 to 1985.* U.S. Geological Survey Water-Resources Investigations Report 89-4008. DOE/ID-22078. INEEL Task Order Database MC Number 50918.

RESL (Radiological and Environmental Sciences Laboratory). 1979. *1978 Environmental Monitoring Program Report for the Idaho National Engineering Laboratory Site.* IDO-12082(78). U.S. Department of Energy Idaho Operations Office. May. INEEL Task Order Database MC Number 50925.

RESL. 1980. *1979 Environmental Monitoring Program Report for the INEL Site.* IDO-12082(79). U.S. Department of Energy Idaho Operations Office. May. INEEL Task Order Database MC Number 50926.

RESL. 1981. *1980 Environmental Monitoring Program Report for the INEL Site.* IDO-12082(80). U.S. Department of Energy Idaho Operations Office. May. INEEL Task Order Database MC Number 50927.

RESL. 1983. *1982 Environmental Monitoring Program Report for the INEL Site.* IDO-12082(82). U.S. Department of Energy Idaho Operations Office. May. INEEL Task Order Database MC Number 50929.

RESL. 1983. *Ambient Nitrogen Dioxide Monitoring Plan for the INEL*. February. INEEL Task Order Database MC Number 51071.

Ritter, Paul D. 1998. Communication with M. J. Case, consultant to *Radiological Assessments Corporation*. Regarding modeling of the atmospheric dispersion of pond sediments. April. INEEL Task Order Database MC Number 95010.

Rood, A.S. 1994. *GWSCREEN: A Semi-Analytical Model for Assessment of the Groundwater Pathway from Surface or Buried Contamination: Theory and Users Manual Version 2.0.* EGG-GEO-10797. INEEL Task Order Database MC Number 95009.

Rood, A.S., R.C. Arnett, and J.T. Barraclough. 1989. *Contaminant Transport in the Snake River Plain Aquifer: Phase I, Part 1: Simple Analytical Model of Individual Plumes*. EGG-ER-8623. INEEL Task Order Database MC Number 95010.

Sagendorf, J.F. 1996. *Atmospheric Transport and Diffusion Modeling for Short Term Releases from INEL Facilities.* National Oceanic and Atmospheric Administration. Idaho Falls, Idaho. INEEL Task Order Database MC Number 95011.

Sax, N.I. 1993. *Dangerous Properties of Industrial Materials*. New York: New York: Van Nostrand Reinhold Co.

SC&A (Sanford Cohen and Associates, Inc.). 1993. *Phase I Report. Inventory Values Reported from B&W. 1993: Specific Manufacturing Capability Project Hazards Assessment, Draft.* BWI-1333.

SC&A. 1994. *Identification, Retrieval and Evaluation of Documents and Data Pertinent to a Historical Dose Reconstruction at the INEL. Final Report*. Prepared by Sanford Cohen and Associates, Shonka Research Associates, and Woodward-Clyde Consultants for the Centers for Disease Control and Prevention. December 21.

Schindler, R.E. 1998a. *NWCF Atmospheric Mercury Emission*. Memo to J.P. Law. LMITCo. February. INEEL Task Order Database MC Number 51073.

Schindler R. E. 1998b. Chemical Engineer , ICPP, Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. Regarding mercury monitoring at the ICPP. March. INEEL Task Order Database MC Number 70703.

Schindler R.E. 1997. *NWCF Atmospheric Mercury Emission: Stack Mercury Emissions for NWCF Operation from June 25, 1997 through September 27, 1997*. Memo to J.P. Law. Schi-23-97. October. INEEL Task Order Database MC Number 51104.

Schindler, R., Sherwood, J.A., D.E. Ebersole, H.E. Clayton, R.J. Hover, and R.G. Peatross. 1997. *Summary Report for Operable Unit 10-03 Ordnance*. DOE/ID-10566. March. INEEL Task Order Database MC Number 51081.

Simpson, G.G. 1978. *Abatement of Nitrogen Oxides Effluent from a Commercial Waste Calcining Facility*. ACI-352. Allied Chemical Corporation. June. INEEL Task Order Database MC Number 51034.

Sisson, J.B. and I. Porro. 1992. *Baseline Monitoring for the Air Pathway at the RWMC.* EGG-ERD-10482. September. INEEL Task Order Database MC Number 51055.

Staiger, D. 1997. Advisory Engineer, Lockheed Martin Idaho Technologies Company. Communication with P.D. McGavran, M.J. Case, and K.R. Meyer, consultants to *Radiological Assessment Corporation*. Subject: Idaho Chemical Processing Plant. INEEL Task Order Database MC Number 70695.

Stanisich, S.N., K.J. Poor, M.J. Spry, G.A. Barry, and D.W. Lodman. 1992. *Final Remedial Investigation Report for the ARA Chemical Evaporation Pond (OU 5-10).* EGG-WM-10001. INEEL Task Order Database MC Number 51045.

Suckling D. 1999. Retired ANP Project Engineer. Telephone Communication with P. D. McGavran consultant to *Radiological Assessments Corporation*. Regarding Beryllium and Mercury Use and Release from the ANP Project. May. INEEL Task Order Database MC Number 95021.

Thiesen, B.P. 1993. *Processing Results of 1,800 gallons of Mercury and Radioactively Contaminated Mixed Waste.* EGG-WM-10630. INEEL Task Order Database MC Number 50913.

Tkachyk, J.W., J.M. Welch, and J.T. Case. 1990. *NESHAPs 40 CFR 61.93 Monitoring Requirements for Radiological Emission Sources at INEL.* DOE/ID-10310. INEEL Task Order Database MC Number 50945.

Utterback, D. 1998. Research Industrial Hygienist. National Institute for Occupational Safety and Health. Cincinnati, Ohio. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. Regarding worker studies at the INEEL. April. INEEL Task Order Database MC Number 95022.

Villarreal R. 1986. Intralaboratory Memo and data enclosure to R.J. Teunis and L.C. Witbeck, Argonne National Laboratory-West. Memo subject: A Study of the Chemistry of Chromates in the ANL-W Industrial Waste Pond. IWP Analyses Data Enclosure: A Study of the Chemistry of Chromates in the ANL-W Industrial Waste Pond; analysis for metallic impurities. December 9. INEEL Task Order Database MC Number 51087.

Volpe, J.J. 1987. *SARA Title III, Emergency Planning and Community 'Right-to-know Act of 1986' Notification to the State of Idaho.* Westinghouse Idaho Nuclear Company. May 15.

Warren, R. 1997. Environmental Science and Research Foundation. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. Regarding research on wildlife and bioaccumulation of toxic metals at the INEEL. October. INEEL Task Order Database MC Number 95023.

Wenzel, D.R. 1997. Idaho Chemical Processing Plant. Communication with P.D. McGavran, consultant to *Radiological Assessments Corporation*. Regarding ICPP operations, stack releases and documents. INEEL Task Order Database MC Number 70701.

Wenzel, D.R, and S.J. Fernandez. 1981. *Evaluation of NOx Releases from the ICPP Stack*. June. INEEL Task Order Database MC Number 51068.

WINCO (Westinghouse Idaho Nuclear Company, Inc.). 1984. *ICPP 4th Quarter 1983 Effluent Monitoring Report.* WINCO-1002. February. INEEL Task Order Database MC Number 51099.

WINCO. 1985a. *ICPP Quarterly 1984 Effluent Monitoring Reports*. WINCO-1002. INEEL Task Order Database MC Number 51082.

WINCO. 1985b. *ICPP First Quarter 1985 Effluent Monitoring Report*. WINCO-1002. June. INEEL Task Order Database MC Number 51083.

WINCO. 1986. *ICPP Environmental Monitoring Report Fourth Quarter CY-1985*. WIN-181. March. INEEL Task Order Database MC Number 51084.

WINCO. 1991. *ICPP Environmental Monitoring Report CY-1989.* WINCO-1085. January. INEEL Task Order Database MC Number 51089.

Witbeck, L.C. 1990. *SARA Title III Inventory Reporting of Hazardous Chemicals (for ANL-W).* Intralaboratory Memo ANL-WW-SSS-90-03. INEEL Task Order Database MC Number 50964.