92183R03
2ND COPY

DRAFT

THE ROCKY MOUNTAIN ARSENAL PILOT EXPOSURE STUDY[1,2]

PART 1: ANALYSIS OF EXPOSURE TO ARSENIC AND MERCURY

Theodora A. Tsongas[1]

John S. Reif[2]

Jane Mitchell[1,2]

Thomas J. Keefe[2]

John D. Tessari[2]

Linda Metzger[1]

From the Disease Control and Environmental Epidemiology Division, Colorado Department of Health, Denver, CO[1] and the Department of Environmental Health, Colorado State University, Fort Collins, CO[2]

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE 05/00/92	3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
THE ROCKY MOUNTAIN ARSENAL PILOT EXPOSURE STUDY, PART 1: ANALYSIS OF EXPOSURE TO ARSENIC AND MERCURY

5. FUNDING NUMBERS

6. AUTHOR(S)
TSONGAS, T.; REIF, J.; KEEFE, T.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
COLORADO. DEPT. OF HEALTH
DENVER, CO

8. PERFORMING ORGANIZATION REPORT NUMBER
92183R03

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
COLORADO STATE UNIVERSITY. DEPT. OF ENVIRONMENTAL HEALTH
FORT COLLINS, CO

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
A PILOT EXPOSURE STUDY WAS UNDERTAKEN IN COMMUNITIES SURROUNDING THE RMA. THE OBJECTIVES OF THE STUDY WERE: (1) TO DETERMINE WHETHER ARSENIC AND MERCURY LEVELS IN URINE WERE GREATER AMONG RESIDENTS OF COMMUNITIES ADJACENT TO THE RMA THAN AMONG RESIDENTS OF COMPARISON COMMUNITIES LOCATED 12 TO 15 MILES FROM THE RMA AND PRESUMED TO BE EXPOSED. (2) TO DETERMINE WHETHER EXPOSURE TO ARSENIC AND MERCURY WERE ASSOCIATED WITH PROXIMITY TO THE RMA.

14. SUBJECT TERMS
HEALTH EFFECTS, EXPOSURE PATHWAYS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED			

ARSENAL STUDY 1989 CSU
BIORAD LYPHOCHEK URINE METAL CONTROL
HIGH SPIKE MERCURY QA/QC
DL = 5 PPB BIORAD RANGE 20.5-40.5 MEAN = 30.5 PPB

REPLICATE NUMBER	CSU'S (PPB)	MEAN	UCL	UWL	LWL	LCL
1	31.9	32.04	37.26	35.52	28.56	26.82
2	30.5	32.04	37.26	35.52	28.56	26.82
3	33.8	32.04	37.26	35.52	28.56	26.82
4	29	32.04	37.26	35.52	28.56	26.82
5	33.8	32.04	37.26	35.52	28.56	26.82
6	33.8	32.04	37.26	35.52	28.56	26.82
7	33	32.04	37.26	35.52	28.56	26.82
8	30.5	32.04	37.26	35.52	28.56	26.82

8 AVG = 32.0375
S = 1.739926

UWL = 35.51735 UCL = 37.25728

LWL = 28.55765 LCL = 26.81772

ARSENAL STUDY 1989 CSU
BIORAD LYPHOCHEK URINE METAL CONTROL
LOW SPIKE MERCURY QA/QC
DL = 5 PPB BIORAD RANGE 2.8-7.6 MEAN = 5.2 PPB

REPLICATE NUMBER	CSU'S (PPB)	MEAN	UCL	UWL	LWL	LCL
1	10	10.11	12.26	11.433	8.679	7.96
2	10.9	10.11	12.26	11.433	8.679	7.96
3	11	10.11	12.26	11.433	8.679	7.96
4	9.5	10.11	12.26	11.433	8.679	7.96
5	10.2	10.11	12.26	11.433	8.679	7.96
6	9.2	10.11	12.26	11.433	8.679	7.96
7	11	10.11	12.26	11.433	8.679	7.96
8	9.2	10.11	12.26	11.433	8.679	7.96

8 AVG = 10.1125
S = 0.716655

UWL = 11.43331 UCL = 12.26246

LWL = 8.679191 LCL = 7.962536

→ Bill Thomas

Colorado Department of Health
Disease Control and Environmental Epidemiology Division

MEMORANDUM

FROM: Michael P. Wilson, Ph.D.
Chief, Environmental Toxicology Section

DATE: April 29, 1992

SUBJ: The Rocky Mountain Arsenal Pilot Exposure Study
Part 1: Analysis of Exposure to Arsenic and Mercury

Please note that the advance draft report which you are being provided under this cover is subject to change and may differ from the draft for public comment to be released May 7, 1992. The attached draft is for your information only and I request that you not release it publicly.

Thank you.

RMA 92-0927 1/2

CORRECTION

THE FOLLOWING CHANGES HAVE BEEN MADE TO THE RMA PILOT EXPOSURE STUDY REPORT:

Page 53 (conclusions) #5, middle of the paragraph

...although the differences between area 2 and area 3 were small and unlikely to be of biological significance. After adjustment...

Page 55, # 3; should read

Although the levels of arsenic and mercury in urine were generally not high enough to be of clinical concern, followup evaluation of arsenic and mercury levels in locally produced milk and beef...etc.

ROCKY MOUNTAIN ARSENAL
PILOT EXPOSURE STUDY

Table of Contents

DISCLAIMER

Mention of the name of any company or product does not constitute endorsement by the Agency for Toxic Substances and Disease Registry, the Public Health Service, the U.S. Department of Health and Human Services, or the Colorado Department of Health.

ABSTRACT

A pilot exposure study was undertaken in communities surrounding the Rocky Mountain Arsenal (RMA) in order to determine whether exposures to several chemicals were greater among persons who resided there than among residents of a comparison area. Areas 1 and 2 were adjacent to the RMA and considered potentially exposed; area 3 was 12-15 miles from the RMA. Following a census and selection of a stratified random sample, 469 persons were interviewed and urine samples were obtained. Arsenic was detected and quantified in urine from 43 of the 469 persons (9.2%), and mercury in 32 persons (6.9%). Non-quantifiable ("trace") levels of arsenic were found in 184 (39.2%) of persons sampled; non-quantifiable levels of mercury were found in 80 (17.1%) persons.

Neither the frequency of detection, the arithmetic mean nor the geometric mean values for urine arsenic and mercury were found to be statistically different when areas 1 and 2 were each compared with area 3. The geometric mean values for urine arsenic in areas 1, 2, and 3 were 1.43, 1.55 and 1.77 ppb, respectively. The geometric mean values for urine mercury were 0.31, 0.51 and 0.44 for areas 1, 2, and 3. No statistically significant increases in urine arsenic and mercury were found for residents of areas 1 and 2 in age and gender specific analyses. However, the frequency of detection and arithmetic mean for those with quantifiable urine mercury were higher in area 2 than in area 3, although the differences were small. After adjustment for confounding in multivariate analyses, residence in area 2 remained associated with risk of quantifiable urine mercury among children and adults. None of these differences was statistically significant.

Persons who consumed well water or used well water on their gardens in area 2 had an increased risk of having a quantifiable level of urine mercury. The consumption of locally produced beef and milk in the total study population was associated with an increased risk of having a quantifiable level of urine arsenic .

Logistic regression analyses were conducted to evaluate the risk of arsenic and mercury exposure associated with variables included in the interviews while controlling for confounding. Among adults, persons less than 40 years of age, those of hispanic origin or non-white race and those employed in a hazardous occupation had a significantly increased risk of having a quantifiable level of urine arsenic. Consumption of red wine or fish in the previous week was associated with risk of exposure to arsenic. Women, persons of hispanic origin or non-white race and those who worked in electroplating, welding or battery manufacture had a significantly increased risk of having a quantifiable level of urine mercury. Adults who had completed less than 12 years of education had a lower risk of exposure to mercury. None of the activities directly involving the RMA were significantly associated with urine arsenic or mercury.

I. INTRODUCTION

The Rocky Mountain Arsenal (RMA) is a hazardous waste site on the National Priorities List (NPL) near Denver, Colorado. It is unique in terms of its large size, levels of contaminants and the complex mixture of chemicals documented in various media on-site. Contaminants have been measured in soil, water and air in the adjacent communities (ESE, 1989b). Human exposure to volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), organochlorine pesticides, heavy metals and products associated with the manufacture of chemical warfare agents is believed to have occurred via air, water and soil exposure pathways (Colorado Department of Health, 1989).

a. Rationale and Objectives

In response to evidence of chemical concentrations offsite, known pathways of exposure, presumed exposed populations, a substantial amount of subjective information indicating that acute adverse health outcomes have taken place, and risk estimates predicting an increased risk of cancer if exposure has occurred, we undertook an exposure study in communities surrounding the RMA.

The analytes chosen for screening included arsenic and mercury, four organochlorine pesticides (dieldrin, endrin, aldrin and isodrin) and DIMP, a by-product of nerve agent manufacture produced at the RMA by the United States Army.

This report (Phase I) presents the results of the arsenic and mercury analyses. Arsenic and mercury are excreted relatively rapidly from the body. Thus, their presence in tissues and fluids represents recent exposure, rather than historical exposure. This study used a cross-sectional approach; the determination of urine arsenic and mercury was made at a single point in time. Therefore, the potential effects of seasonal factors on exposure to arsenic and mercury could not be evaluated.

Specific hypotheses concerning potential exposure to arsenic and mercury were developed. Questionnaire responses were used to evaluate the contributions of exposures to air, soil, ground water, home garden produce, and locally produced foodstuffs. The roles of occupation, hobbies, lifestyle factors and activities relevant to the RMA which might have influenced exposure to arsenic and mercury were evaluated. Population subgroups which might have increased risk for exposure to arsenic and mercury were considered in the analysis. Women and children might have had additional opportunity for exposure if they spent more time at home or engaged in activities which increased potential for contact with local soils. Therefore, the effects of age, gender, socioeconomic status, race and education on the risk for exposure to arsenic and mercury were evaluated. Exposure was defined by the results of biomonitoring.

The investigation was conducted collaboratively by the Colorado Department of Health (CDH) and the Department of Environmental Health at Colorado State University (CSU). Laboratory analyses were conducted by the Colorado State University, Department of Environmental Health Analytical Laboratory.

The study objectives were:

1. To determine whether arsenic and mercury levels in urine were greater among residents of communities adjacent to the Rocky Mountain Arsenal (RMA) than among residents of comparison communities located 12 to 15 miles from the RMA and presumed to be unexposed;

2. To determine whether exposures to arsenic and mercury were associated with proximity to the RMA; and,

3. To test _a priori_ hypotheses regarding specific pathways of exposure for arsenic and mercury.

II. BACKGROUND

a. Site History

The Rocky Mountain Arsenal (RMA) is located in Adams County, Colorado and encompasses approximately 27 square miles (figure 1). The RMA is bordered on the west by residential and commercial properties of Commerce City, on the north and east by rural residential and agricultural properties and on the south by Stapleton Airport and residential and commercial properties of the City and County of Denver (figure 2) (ESE, 1989b).

The United States Army has owned the Rocky Mountain Arsenal since 1942 and has used the site to manufacture, assemble, test and demilitarize chemical and incendiary munitions including nerve gases, mustards and rocket fuels. Colorado Fuel and Iron Corporation manufactured chlorinated benzenes and p,p'-dichlorodiphenyltrichloroethane (DDT) for a period during the 1940s. Julius Hyman and Company manufactured several pesticides at the Arsenal during the 1940s and 1950s. Shell Chemical Company manufactured the pesticides dibromochloropropane (DBCP), dieldrin, aldrin, endrin, isodrin and others through 1978 (Colorado Department of Health, 1989).

Since about 1970, work at the RMA has consisted primarily of disposal of the products produced and stockpiled in previous years. This disposal has included TX anti-crop agent, mustard agent, explosive components, the nerve agent GB (Sarin) and related munitions casings. Industrial waste effluents generated at RMA were routinely discharged to unlined evaporation basins. Solid wastes have been buried at various locations throughout the RMA. Unintentional spills of raw materials, process intermediates, and end products have occurred within the manufacturing complexes at RMA. Contaminants from these sites have entered mobile media (ground water, surface water, air, and wildlife) and have been transported off the RMA site (ESE, 1987). Over 88 on-post sites have been identified as potentially contaminated with hazardous wastes (ESE, 1988b).

Off-post contamination from the site was first detected in 1954. Since 1974, investigations have found contaminated ground water crossing the west, northwest and north boundaries of the RMA. Contaminants have included chlorinated solvents, DBCP, and DIMP. Interim response actions taken have included three groundwater treatment systems on the north, west and northwest boundaries and a system to treat trichloroethylene contamination of the South Adams County Water and Sanitation District (ATSDR, 1988).

Environmental sampling of air, soil and water has identified approximately 80 compounds off-site. These compounds include DIMP, dieldrin, aldrin, endrin, organosulfur compounds, a variety of volatile organic compounds including benzene, carbon tetrachloride, chloroform, trichloroethylene, tetrachloroethylene, 1,2-dichloroethane, and arsenic, mercury, chromium, fluoride, cadmium, DBCP, and others (Appendix A, ESE, 1988a).

b. The Basin F Episode, 1988

In May, 1988 the Army began the excavation of Basin F, a 93-acre surface impoundment located in the northwest corner of the RMA. Basin F contained free-standing liquids. Originally the basin had an asphalt liner that was found to be leaking, resulting in contamination of ground water. Samples of plumes of contamination moving off-site from Basin F were found to contain DIMP, aldrin, dieldrin, and other compounds. The excavation was conducted in an effort to isolate liquid and solid hazardous wastes and to cease further degradation of the environment (Colorado Department of Health, 1989).

The activity at Basin F involved draining the liquids from the impoundment and placing approximately four million gallons in tanks to be stored at the RMA; five to six million gallons which could not be accommodated by the tanks were placed in Pond A, a 4.8 acre, 8.5 million gallon capacity open pond. Five feet of overburden found under the Basin F liquid and six inches of underburden beneath the liner were to have been excavated. As the excavation progressed, noxious odors and volatile and semivolatile compounds were released into the air, causing area residents to the north, northwest, west and south to complain, particularly residents of the Irondale Trailer Park located approximately 1 mile west of Basin F (US Army and Tri-County Health Department, Appendix B). The excavation of Basin F was discontinued in December 1988 because of the number and intensity of the complaints and after consultation with , EPA, and the State Health Department. The Basin F floor has been covered with 6 inches of soil and clay. The 16-acre waste pile containing approximately 500,000 cubic yards from the excavation has been covered with a synthetic cover (Colorado Department of Health, 1989).

c. Potential Exposure Pathways

Air and Soils:

Air monitoring was instituted by the Army during July-August, 1988 in response to complaints from nearby residents. Chemicals of greatest concern, in addition to the semi-volatile pesticides, were volatile organic compounds, including benzene, trichloroethylene, perchloroethylene, chloroform, and methylene chloride, and metals, particularly arsenic, chromium and mercury.

On the basis of meteorological information, air monitoring results obtained at a sampling station one mile north of Basin F were assumed to represent air levels one mile to the northwest, the location of the Irondale Trailer Park at the northwestern boundary of the RMA. The Irondale Trailer Park is comprised of approximately 45 residences and about 100 persons. Additional residences along the west, northwest, and north boundaries of the Arsenal may have been subject to similar airborne levels of these toxicants. Complaints of odors and a variety of symptoms were received from a number of these residents and from commercial establishments (Tri-County Health Department, unpublished).

Air monitoring was initiated in November 1988 at the Irondale Trailer Park and at a residence north of the RMA by the Tri-County Health Department. Aldrin and dieldrin were found at levels greater than those observed by the Army in samples taken one mile north of Basin F, increasing concerns about potential adverse effects of exposure to these chemicals (Tri-County Health Dept, Appendix C).

In December 1988, CDH collected tap water, soil, and air samples in and near the Irondale Trailer Park, with particular emphasis on sampling during temperature inversions which were thought to enhance the air emissions and potential exposures from Basin F. Air, water, and soil sample results are summarized in Appendix D.

Surface and Groundwater:

There is current and prior evidence indicating surface and groundwater contamination by a number of toxic compounds in the area to the north and northwest of the Arsenal. For example, diisopropylmethylphosphonate has been detected in wells drawing on the alluvial aquifer as far away as the South Platte River (figure 3) (ESE, 1989b). During the late 1970's, groundwater plumes containing organic solvents and DBCP were identified to the west of RMA. The Irondale Boundary Containment System was installed in 1981 to remove organic contaminants such as dibromo-chloropropane (Colorado Department of Health, 1989). A CDH initiative undertaken in 1990 provided bottled water to many of the residences north of the RMA which were using wells for domestic purposes or for feeding livestock because of contamination of the shallow aquifer with DIMP.

Other Pathways:

There are a number of additional potential pathways for human exposure. Studies of wildlife on the Arsenal have shown contamination of prairie dogs, waterfowl, raptors, carnivores, and fish, primarily with dieldrin (Thorne, 1979; ESE, 1989a). In addition to the possibility for a direct toxic effect on wildlife, the potential exists for food chain contamination and human exposure through consumption of wild game which migrates off the Arsenal. Additional pathways include dermal absorption from soil contact, ingestion of fruits and vegetables grown in proximity to the RMA, ingestion of meat and milk from domestic animals raised in the area, ingestion of fish from the RMA lakes and surface water flowing through the RMA and direct contact with soil and water contaminated as the result of onpost activities. The degree to which these potential pathways contributed to human exposure to arsenic and mercury is described below.

d. Health Effects Evaluated In Prior Studies

The Basin F episode in 1988 lead to the initiation of a series of pilot health studies aimed at determining the prevalence of adverse health effects resulting from the activities surrounding basin F and the more general question of long term effects associated with residence around the RMA.

In 1988, residents of the trailer park and surrounding neighborhoods complained of a variety of symptoms such as eye irritation, runny nose, sore throat, nausea, and shortness of breath. These symptoms were enumerated in a health survey administered to individuals complaining of adverse health effects (Tri-County Health Department, unpublished, December, 1988).

Physical examinations were conducted on a limited number of residents by physicians from the Rocky Mountain Poison Control and Drug Center. Examinations included a general physical exam and laboratory analyses including complete blood counts, a general screen of liver and kidney function and electrolytes. No definitive pattern of abnormalities could be discerned from the results of these studies (Colorado Department of Health, unpublished, 1989).

Because of concerns about the potential for exposure of residents to a number of toxic chemicals in air, quantitative cancer risk estimates were calculated by CDH using data from 24-hour air samples collected on the Arsenal during July/August, 1988 one mile north of Basin F. A cancer risk estimate using EPA potency factors (slope factors) for a two-month exposure to the seven carcinogens, methylene chloride, benzene, chloroform, trichloroethylene, tetrachloroethylene, aldrin and dieldrin, was calculated to be 2.29 x 10^{-6}. A revised cancer risk estimate, using aldrin and dieldrin sampling results obtained by the Tri-County Health Department for December 1, 1988, was calculated by CDH at 1 x 10^{-4} for a six-month exposure to the seven carcinogens. In addition to potential cancer risks, concerns were previously raised about the potential for other chronic effects such as reproductive, developmental, and genetic toxicity, neurotoxicity and liver and kidney disease which might result from exposure to these chemicals (Colorado Department of Health, unpublished, 1989).

e. Environmental Contamination with Arsenic and Mercury

Limited data exist with which to evaluate the offsite contamination with arsenic and mercury at the RMA, particularly on a site-specific basis. For example, data for mean soil values for the areas sampled during this exposure study were not available. Additional characterization of environmental contamination with arsenic and mercury could have contributed to the design and evaluation of this study. However, analyses of environmental samples for arsenic and mercury in the study areas selected was beyond the scope of this exposure study.

Arsenic

Arsenic is one of three heavy metals that have been detected in offpost groundwater samples at concentrations exceeding health-based criteria set forth in the EPA Superfund Public Health Evaluation Manual (1986). The highest level detected was 5.8 ug/l in alluvial groundwater, compared to the health-based recommended maximum level of 0.0032 ug/l. Arsenic contamination has been associated with RMA onpost activities, including the production of arsenical pesticides and as a component of the raw materials and by-products of lewisite, a blistering agent manufactured at the RMA (ESE, 1989b).

Between 1942 and 1978, it is estimated that 21 million cubic yards of pesticide and chemical warfare wastes were disposed of in Basin A, an unlined evaporation pond located roughly in the center of the RMA complex, just north of the Shell Chemical Company facility. Dozens of pesticides have been identified in soil and groundwater in the vicinity of the Shell facility. In 1986, Basin F, a 96-acre asphalt basin, was constructed for the transfer and disposal of these pesticide and chemical warfare wastes. This site was also used for deep-well injection of similar wastes from 1962 until 1967. Wastes are known to have seeped into the alluvial groundwater from a leak in the asphalt at Basin F (ESE, 1987). In the 1970's, contaminated groundwater was found to be moving off-site in a north and northwesterly direction, towards the South Platte River Basin. Two boundary containment and groundwater treatment systems were installed to trap and treat these contamination plumes, but it was subsequently discovered that these systems had been bypassed. Arsenic is known to be present along the north pathway, directly north of the North Boundary Containment System (NBCS). The distribution of arsenic in groundwater is similar to that for diisopropylmethylphosphonate (DIMP) (fig 3) (ESE, 1989b).

Environmental monitoring for arsenic offpost has been limited, but it is suspected that potential for exposure to surrounding residents exists via air, soil and soil dust, as well as via contaminated groundwater (shallow wells used for domestic, livestock and agriculture), and foodchain pathways.

Mercury

Mercury has been identified in several media including air, soils, sediments, water and plant and animal biota, on- and off-post at the RMA. Air monitoring during 1988 detected concentrations of mercury of at least 0.43 ug/m^3 (Appendix B) one mile north of Basin F on the RMA. Other air monitoring data for mercury are sparse. Levels of mercury have been detected on the RMA in soils which could adversely impact the health of populations using the RMA in the future. Thus, mercury has been designated one of 20 contaminants of concern which have been detected at levels exceeding health based criteria by a significant margin in the South Plants area and in the North Central area of the RMA (Ebasco et al., 1990).

Environmental monitoring for mercury, as with arsenic, has been limited, both on- and off-post. It is suspected that the potential for exposure to surrounding residents exists because of levels found in soils, lake sediments, and air on the RMA, and in biota on and off the RMA in nearby areas.

f. <u>Arsenic and Mercury Toxicity</u>

Arsenic

Inorganic arsenic occurs primarily in the trivalent and pentavalent forms, with the trivalent being the more soluble and toxic of the two forms. A number of sulfhydryl-containing proteins and enzyme systems are altered by trivalent arsenic. Inorganic arsenic compounds are known to interfere with DNA repair mechanisms and can replace phosphorus in the DNA chain. An increased frequency of chromosomal aberrations has been found among workers exposed to arsenicals (Casarett and Doull, 1986). Airborne arsenic is largely in the form of trivalent arsenic oxide.

Arsenic trioxide is an important compound in industrial production and is used in the manufacture of insecticides, herbicides, wood preservatives, glass, ceramics, dyestuffs and semiconductors, and as an additive in alloys. Arsenical pesticides were manufactured on the RMA site from 1947 to 1982. Arsenic is also known to be a component of the raw materials and by-products of lewisite, a blistering agent that was manufactured and later incinerated at the RMA. Other common sources of environmental arsenic are smelting and combustion of fossil fuels. Seafood is considered the main source of dietary arsenic. Shellfish in particular has been shown to elevate urine arsenic in study subjects. Natural contributors to environmental arsenic include geothermal wells and weathering of bedrock and soil substrates. (Clarkson, 1988)

Arsenic trioxide is a soluble compound which is absorbed rapidly from both the respiratory and the gastrointestinal tract. Absorbed arsenic is cleared rapidly from the blood and excreted primarily via the kidney (ATSDR, 1989). Chronic exposure to inorganic arsenic via inhalation and ingestion is known to affect many human organ systems, including the skin, nervous system, liver, cardiovascular system, hematopoietic system and respiratory tract (Vahter, 1988).

Arsenic has been classified by the U.S. EPA as a Group A carcinogen based on evidence of excess risk for skin and lung cancers in humans exposed to inorganic arsenic compounds (U.S. EPA, 1984). Recent studies have also shown a strong association between arsenic ingestion and liver, kidney, lung and bladder cancer (Chen et al., 1986).

The major source of occupational exposure to arsenic in the United States has been from the manufacture of pesticides, herbicides and other agricultural products (Landrigan, 1981). Epidemiologic studies have implicated inorganic arsenic compounds as pulmonary carcinogens in pesticide production workers and vineyard workers, as well as in smelter workers (Hayes, 1982). Both Ott (1974) and Mabuchi (1979) have shown an increase in lung cancer mortality among workers engaged in the production of arsenic-containing pesticides. Ambient exposure to airborne arsenic has also been considered a cause of lung cancer. Four epidemiologic studies of nonworker populations living near point source emissions of arsenic in ambient air have shown increases in lung cancer mortality, although these studies are not considered to be definitive due to limited exposure data (Pershagen, 1981).

Epidemiologic studies in Europe, Argentina, Chile and Taiwan have suggested an association between chronic exposure to high levels of arsenic in drinking water and the occurrence of a variety of skin disorders, including skin cancer (Tseng et al., 1968; Arguello et al., 1939; Borgono et. al., 1977). The Taiwan study (Tseng et al., 1968) showed an association between skin cancer and arsenic-contaminated drinking water and was based on over 40,000 study participants. Studies in the U.S. of drinking water supplies with lower arsenic levels and smaller study populations, however, have not confirmed the association with skin cancer (Harrington et al., 1978; Morton et al., 1976; Southwick et al., 1981).

Mercury

Mercury occurs in the environment in three valence states which influence its distribution and toxicity; as inorganic and organic complexes and as the elemental metal. Metallic or elemental mercury volatilizes at ambient air temperatures and may result in human exposures by inhalation (Casarett and Doull, 1986). Metallic mercury may be oxidized to inorganic divalent mercury, particularly in aquatic environments. Bacterial action in soil and water may convert divalent mercury to a methylated form which is released to the atmosphere, returns to the earth through rainfall, may be bioaccumulated by fish and eventually consumed by humans.

Absorption of mercury can occur via the lungs, gastrointestinal tract or skin. Mercury vapor is fairly readily absorbed from the respiratory system. Gastrointestinal absorption is variable but is over 90% for methyl mercury, the most toxic form of the metal (Taylor, 1984). Mercury is excreted from the body through urine and through bile release to the feces.

Occupational exposures to mercury occur primarily by inhalation of inorganic mercury, particularly in the electrical appliance, pulp and paper, pharmaceutical and paint industries. The general population is exposed to organic mercury primarily through the food chain. Humans may be exposed by ingestion of contaminated fish which have bioaccumulated agricultural pesticides or inorganic mercury converted by bacterial action to organic mercury (ATSDR, 1989). Recently, the potential for mercury exposure through dental amalgams has received considerable attention (Patterson, 1985).

Mercury has been detected in the environment in air, water, soil and feedstuffs and is a frequent contaminant at NPL sites (ATSDR, 1989). Exposure to mercury at Superfund sites is likely to involve mercury salts in contaminated water or soils, metallic mercury vapor close to spills of metallic mercury, or metallic mercury in soil that is contaminated. Exposure to organic mercury compounds can occur at sites such as the RMA that have been contaminated with organic mercury compounds from agricultural fungicides.

The toxicology of mercury exposure in humans depends upon the form of the metal involved. Chronic exposure to inorganic mercury vapor results in a triad of symptoms; excitability, muscular tremor and gingivitis, recognized historically in workers in the fur, felt and hat industry where the term "mad as a hatter" was coined (Casarett and Doull, 1986).

Occupational exposures to mercury vapor resulting in levels of mercury in urine exceeding 200 ug/l have produced neuromotor effects such as increased tremor and poor hand-eye coordination (Williamson et al, 1982). Increases in tremor frequency, reaction time and reduced hand-eye coordination have been reported in workers exposed to inorganic mercury. (Smith et al., 1970; Miller et al., 1975; Verberk et al, 1986). Memory function is frequently reduced in occupationally exposed persons such as chloralkali workers. An association between urine mercury levels and performance on memory tests has been described by several investigators (Vroom and Greer, 1972; Smith et al., 1983; Piikivi et al., 1984). Inorganic mercury exposure is associated with renal damage as well as neuropathy. Proteinuria, tubular necrosis and an immune-mediated glomerular disease are seen following chronic mercury exposure.

The effects of exposure to organic mercury at relatively high doses were first recognized in modern times during the episode known as "Minimata Disease" which occurred in Japan in 1955 following the ingestion of methylmercury contaminated fish (Tamashiro et al., 1984). The neurological syndrome was characterized by parathesias, impaired peripheral vision, slurred speech, incoordination, irritability, memory loss, depression and insomnia. An acute episode of neurological disease occurred in Iraq and involved over 6,000 persons who were hospitalized and 459 deaths associated with central nervous system failure after the ingestion of contaminated bread made with wheat treated with a methylmercury fungicide (Bakir et al., 1973).

Low dose mercury exposure to pregnant women consuming contaminated wheat flour in the large-scale poisonings in Iraq was followed by developmental defects and mild psychomotor abnormalities among the children exposed prenatally (Marsh et al., 1980). Mercury is likely to exert its main effect through neurotoxic damage to the unborn fetus. Intrauterine mercury toxicity was also observed following unintentional poisoning with mercury-contaminated grain in Sweden (Engelson, 1952) and in the Minimata Bay episode in Japan (Matsumoto et al., 1965) where severe brain damage occurred in 22 infants whose mothers had consumed methylmercury contaminated fish. However, dietary intake of methylmercury was recently associated with low birth weight in Greenland (Foldspang and Hansen, 1990), suggesting a direct effect on the developing fetus.

III. METHODS

a. Selection of Study Groups

Three study areas were defined. Two of these areas were adjacent to the RMA and putatively exposed; a third area served as a comparison population (figure 4).

Exposed Subgroup (Area 1)

Area 1 contained residents to the north and northwest of the RMA, including the Irondale Trailer Park and adjacent neighborhoods (figures 5,6). This group consisted of persons who were thought most likely to have been exposed to chemicals from the RMA by residential exposure pathways, i.e., soil, water or air. The largest number of complaints during the 1988 Basin F excavation at the RMA was recorded among residents of this area. Many residents of area 1 used private wells for domestic water.

This population lived in an area directly adjacent to the north and northwest boundaries of the RMA. This area was bounded on the east by the RMA and a line extending north from Buckley Road, on the north by 104th avenue, on the west by the Union Pacific railroad tracks, and on the south by 80th Avenue and the RMA. Area 1 residents were completely enumerated by a house-to-house census. All dwellings in the area were identified and the inhabitants queried. Following the census, all persons who had been resident in the area for at least one year and who were two years of age or older on January 1, 1988 were initially considered eligible for participation. Participants were then selected by stratified random sampling based on age and sex from the pool of eligible persons.

Exposed Subgroup (Area 2)

A second exposure group (Area 2) consisted of persons who lived directly to the west of the arsenal (figure 6). Due to the direction of the prevailing winds, airborne exposure to RMA contaminants was considered less likely than for area 1. This area was directly west of the South Plants (approximately 2.5 miles to the nearest residence). Domestic water was supplied by the South Adams County Water and Sanitation District for the majority of households in this area. The boundaries of area 2 included RMA on the east, Oneida street on the west, 64th Avenue on the south and 80th Avenue on the north.

Area 2 was densely populated (fig 6). Therefore, one third (15/46) of the blocks in area 2 were selected randomly from among all blocks for census enumeration to provide an adequate sampling frame (shaded black in figure 6). Following selection of target blocks, a house to house census of residents was conducted and eligibility criteria applied as above. The sampling strata were group matched to the age and gender composition of area 1. Potential participants were stratified by age groups (2-5, 6-14, 15-39, 40-64, ≥65) and gender. The age and gender composition for area 1 was used to determine the number of individuals needed for each cell in area 2. Selection of potential participants was conducted by using computer generated random numbers.

Unexposed Subgroup (Area 3)

A comparison group consisted of persons presumed to have no exposure to the RMA (Area 3). This comparison area was 12 to 15 miles north and northeast of the RMA, presumably unexposed to the site. Its boundaries were defined to include areas that qualitatively matched the semi-industrial and agricultural characteristics of the exposed areas proximal to the RMA (figure 7 a&b). Socioeconomic, demographic and ecologic characteristics of area 3 resembled those of areas 1 and 2. The comparison area was not near a hazardous waste site, nor a currently or historically active pesticide formulating plant.

Persons in area 3 were selected for interview and biological monitoring following a two-stage sampling design similar to that described for area 2. Sixty percent (24/30) of blocks in area 3 were selected randomly for a house-to-house census to provide an adequate sampling frame for group matching. Following enumeration of eligible participants through the census, participants were selected by age and sex stratified random sampling as described for area 2.

b. Census Procedures

A door-to-door census was conducted as described above in each of the three exposure subgroups for the purpose of enumerating eligible residents. The census was completed using a block survey form listing each family household on a block as well as vacant dwellings and invalid addresses, such as commercial properties (Appendix E). Vacancies were confirmed with neighbors and commercial properties were visited to ascertain that they were not also residences. Houses were visited at least four times on different days and at different hours, if needed, to establish contact with residents. Census takers were trained and the census forms were pilot-tested. The census form tracked the number of attempted contacts with residents and was used initially to determine eligibility criteria. The census was also used as a means to introduce the study to neighborhood residents.

c. Interview Procedures

Participant Consent:

Eligible persons were telephoned or visited and asked to participate. Informed consent was obtained according to NIH guidelines. Approval of CDH and CSU Human Subjects Review Boards (HSRB) was obtained before beginning the study. Any changes which became necessary in the consent form, interview format or fact sheet, or in the study protocol involving human subjects were approved by the CDH HSRB. A separate consent form was used for each participant person and a copy with a fact sheet were left with each household (Appendix F).

Minor Assent:

If a parent/guardian consented to blood and/or urine testing of a minor aged 8 years or older, these procedures were performed if the minor child verbally assented. Interviewers read the consent form to each participant or the child's parent/guardian and obtained signed consent before samples were collected.

Interview Process:

The interview was administered by a trained interviewer using a standardized procedure. Interviewers participated in 10 hours of training by project personnel prior to the field work. Training included familiarization with techniques to administer questions in a neutral manner, practice interviews, and providing field staff with sufficient knowledge of the study to be able to explain the purpose of the study to those being interviewed. Interviewers used a prepared fact sheet to explain the purpose of the study to participants consistently. Interviewers were assigned to interview subjects from each of the three study areas in order to further reduce bias.

Interview:

A standardized interview procedure was developed to determine exposure status for a variety of variables. The interview collected basic demographic data, residential history, water supply and use patterns, data on consumption of home grown fruits and vegetables, occupational history, information on previous and current exposures to pesticides and other organic and inorganic compounds and potential exposure pathways. Information on potential confounders and modifiers including education, housing characteristics, smoking, alcohol consumption, diet, play habits, hobbies and activities was collected. An adult household member was asked to provide information on household characteristics and on habits and daily activities for children under the age of 15. Recent work history was compiled, with special attention to occupations with possible chemical or pesticide exposures. Limited data on past medical history were gathered in order to be able to assess pre-existing chronic disorders that could have affected metabolic status or detoxification capability through hepatic or renal mechanisms and thereby influence the levels of contaminants found in biological assays. Other health measures (outcomes) were not included since this was an exposure study.

The interview forms and procedures were pre-tested to judge their overall adequacy, clarity, feasibility and appropriateness of items and revised before being administered to the participants. Four separate interview instruments were used; adult, child (6-14), (toddler 2-5) and household (Appendix G).

d. Procedures for Biological Specimens

Biological specimens consisted of venous blood and urine specimens. For the Phase I report, only urine mercury and arsenic values have been considered. Specific gravity and creatinine were determined for each urine specimen to control for variation in urine concentration among subjects.

First morning voided urine samples were collected by participants at home in 50 ml plastic cups and transported to the CDH laboratory in refrigerated containers by project personnel. In the laboratory, the total urine volume was divided into two aliquots. The fraction for arsenic and mercury analysis was acidified by the addition of 0.5 ml of nitric acid, stored in 50 ml plastic tubes and frozen at -4 degrees centigrade. The urine samples were then transported to the CSU laboratory in refrigerated containers and stored there at -4 degrees centigrade.

Aliquots of unacidified urine were sent to a commercial laboratory for determination of creatinine and specific gravity. Urine was held at -4 degrees centigrade prior to transport to the laboratory.

e. Analytical Methods for Urine Arsenic and Mercury

The methods used for analysis of mercury and arsenic followed the basic EPA "Methods for Chemical Analysis of Water and Wastes" (1983) and those described by Voth-Beach (1985). These analytical methods are for water samples; however, the following modifications were made to adapt them to urine samples.

A microwave digest of urine was prepared by combining 20 ml of urine, 10 ml hydrochloric acid and 2 ml nitric acid. Twelve digestions were prepared at one time and microwaved for 6 minutes at 65% power followed by 9 minutes at 60% power. After cooling, the resulting digest was divided into equal portions for Hg and As analysis.

Mercury Analysis

The digest portion for mercury analysis was added to 90 ml distilled water in a BOD bottle and prepared as stated in the operating manual (Coleman Instruments). The analysis was completed within 2-3 hours of digestion. The analytical range was 5ppb to 90 ppb. The detection limit was 5 ppb.

Arsenic Analysis

The digest portion for Arsenic analysis was diluted 1:1 with HCl and divided into two portions. One was analyzed from 1-14 days later; the other was reserved. All standards were made by adding a known amount of analyte to a control urine. Urea and potassium iodide were added to the arsenic digest before analysis. A Varian Spectra-40 atomic absorption spectrophotometer using a VGA-76 vapor generation unit was the analytical instrument. Analytical range was 10 ppb to 80 ppb. The detection limit was 10 ppb.

f. Chain of Custody

Established documentation methods were used to preserve the chain of custody and safeguard against tampering with samples or records. These methods included chain of custody forms indicating dates of collection and subject identification numbers (Appendix H). Each specimen was assigned a unique identification number to allow appropriate identification, using a hierarchic system that uniquely described the study, the person, the specimen matrix, and the aliquot number.

All biological specimens were personally carried by study team members from the time of collection to the time of delivery to the Colorado State University Laboratory. Laboratory transfer sheets contained signatures and dates of the analysts who received the specimens and who recorded how much specimen was used and whether the specimen was compromised in any way in the laboratory. Any departures from the collection, storage, or shipping protocol were to be noted, but none were observed with the exception of one broken vial of urine.

g. Quality Assurance, Quality Control

External standards were used for quality control samples for both arsenic and mercury. These were purchased (Bio-Rad) at two concentrations. The samples were lyophilized urine to be reconstituted with distilled water. During the study, 8 low level samples and 8 high level samples were interspersed with regular samples and analyzed.

Internal quality control consisted of a high level and a low level urine spike. Each contained both organic and inorganic mercury and organic and inorganic arsenic. These spikes were added to a pooled urine sample and then frozen in 20 ml aliquots. A total of 18 high spikes and 18 low spikes were analyzed interspersed with regular samples throughout the study.

In addition to the above controls, QC samples were analyzed to verify the Coleman Mercury Analyzer calibration each time it was operated. The National Institutes of Standards and Technology standard for mercury in water was used for verification. An EPA Quality Control sample for metals in water was added to a control digest and analyzed with each arsenic calibration curve as verification. QA/QC data are presented in Appendix J.

h. Participant Convenience, Privacy and Notification

Participant Convenience

The voluntary nature of the survey was explained to every potential participant, and flexible appointment hours were scheduled. Special arrangements were made to pick up urine specimens at the convenience of individual participants and their families from their homes.

Confidentiality

This report, as well as all reports made available to the public, does not contain laboratory results or findings in association with any individual subject or person and reports only aggregate data. All records were maintained to prevent unauthorized visual observation, accidental loss, or theft. Confidential records will continue to be kept out of sight of unauthorized persons, stored in locked cabinets or locked rooms when not being used, and copied only when absolutely necessary. Statistics derived from such confidential data will be reported without inadvertent disclosure about particular study subjects.

Individual Notification

The study team reviewed all results of arsenic and mercury analyses. Individual results were transmitted by letter to the adult subjects and to parents/guardians of the child subjects by CDH. For each analyte, participants were provided the means and range for all study subjects. A sample letter to participants is found in Appendix I. CDH personnel were available for additional consultation with study participants or their health care provider if so desired.

Findings of Immediate Significance

In cases where a test revealed a finding of potential significance to a person's health, that person or that person's parent or guardian was notified by telephone or in person by CDH and additional questions regarding exposures were asked. Subjects were offered the opportunity to provide another sample. All subjects contacted in this manner provided an additional urine sample for validation of test results. The investigators offered to speak with their health care provider, but all participants elected to communicate the information with their physician directly. Arsenic values in excess of 30 ppb adjusted or unadjusted were considered notifiable; the value for mercury was 20 ppb for adults and 10 ppb for children. These values were based on toxicology profiles, additional references and consultation with Dr. Philip Landrigan (Personal Communication, 1990).

i. Data Entry and Management

Data obtained from interviews were coded and entered into a data management system (dBase III Plus). Interview sheets were visually inspected by two different reviewers for completeness and consistency of responses before the field data collection phase was completed. Internal consistency was checked by cross-tabulating each interview item. Checks for out of range values were performed. Questionnaires from a 10% sub-sample were recoded in order to detect coding and data entry errors. Results of laboratory analyses were entered into another dBase file with the participant identification number used to merge files. The dBase file was read directly into SAS (Statistical Analysis System 6.04, Cary, NC) using PROC DBF.

j. Adjustment for variation in urine concentration and urine flow rate

In order to adjust the concentrations of urine arsenic and mercury for differences in urine concentration and urine flow rate, four separate analytical approaches were taken: (1) the data were examined unadjusted (2) the values were corrected for urine specific gravity to a standard of 1.024 (3) the values were corrected to urine creatinine on a ug/g creatinine basis and (4) the data were corrected simultaneously for specific gravity and urine creatinine concentration. (see discussion)

Urine arsenic was corrected for urine specific gravity, using an established standard of 1.024, by the formula (shown for arsenic):

$$\text{UrAsSP (ng/ml)} = \frac{(\text{UrAs ng/ml})\ (1.024 - 1)}{(\text{UrSP} - 1)}$$

where
UrAsSP = Urine arsenic corrected to urine specific gravity,
UrAs = Urine arsenic uncorrected, and
UrSP = Urine specific gravity.

Urine mercury was similarly corrected to urine specific gravity.

Urine arsenic and urine mercury were also adjusted to a per gram creatinine basis by the following formula (shown for arsenic only):

$$\text{UrAsCr (ug/g of creatinine)} = \frac{\text{UrAs (ng/ml)}}{\text{UrCr (mg/dl)}} \times 100$$

where

UrAsCr	=	Urine arsenic adjusted to urine creatinine,
UrAs	=	Urine arsenic unadjusted, and
UrCr	=	Urine creatinine.

In the above equation, the concentration of the solute of interest is factored by the concentration of creatinine to more accurately calculate urine concentration and remove the effects of known age and gender-related differences.

The means for unadjusted, specific gravity and creatinine-adjusted values were compared among the two exposure areas and the comparison area.

k. Data Analysis Methods

Statistical analyses were performed using SAS for the personal computer. Analytical techniques typical for stratified cross-sectional study designs were conducted to determine whether persons living in areas 1 and 2 had higher concentration or frequency of arsenic or mercury in urine than persons residing in the comparison area. Analyses included descriptive statistics for each analyte, specifically, the mean, median, standard deviation and range. Mean levels of contaminants for each exposure group were compared to means for the comparison group by Student's two sample t test and the differences between means calculated. The ratios between means for the exposure and comparison areas were also calculated with the confidence intervals around the ratios.

Age and gender-stratified analyses between exposure groups were performed and the effects of stratification analyzed. Analysis of variance (ANOVA) was used to compare mean analyte levels among the three exposure groups.

As is typical of such values, the natural logarithm of the urine arsenic and mercury levels were more normally distributed than the non-transformed values; thus, statistical analyses were performed using the log-transformed values. Geometric mean values were calculated from the log-transformed values for urine arsenic and urine mercury as well as arithmetic means.

A large proportion of the laboratory results for urine arsenic and mercury were found to be non-quantifiable (trace) values. Therefore, the analyses were repeated with four different approaches: (1) means for the areas were compared using trace values set to one half the detection limit and zero for no detectable analyte; (2) means were compared setting all values below the detection limit to one half the detection limit; (3) the analysis was repeated using values only at and above the detection limit for each area; (4) odds ratios and 95% confidence intervals were calculated for the frequency of detection of trace values in areas 1 and 2 compared with area 3. In addition, the distributions of detectable values, trace or non-quantifiable values and nondetectable values for the three exposure groups were compared using a chi square test to assess the potential effect of the trace values on the comparison of mean analyte levels among areas.

The relationship between various exposure variables (risk factors) and the presence of arsenic and mercury in urine was assessed by calculation of odds ratios with their 95% confidence intervals for the variables included in the interview. Exposures among children (ages 2 to 14) were treated separately from those reported for adults (persons 15 and older), corresponding to the structure of the interviews. In general, exposure variables were treated as dichotomous variables (yes/no). For those factors where the exposure was a continuous variable (e.g., number of hours spent outdoors in the summer), the median value was used to dichotomize the variable. Where data were adequate to permit stratification, additional analyses were conducted by separating the exposure into tertiles and examining each stratum independently with the non-exposed group serving as the reference category.

Initially, the values for urine arsenic and mercury were treated as dichotomous values, above and below the detection limit for each analyte. In the initial analyses of interview data on exposure variables, persons with "trace" values were excluded due to the inherent analytic uncertainty and to avoid introducing misclassification. Thus, the analyses reported in tables 24 to 47 compared the odds of exposure to the risk factor among those with a quantifiable level of arsenic or mercury with the odds of exposure among those with no evidence of the metal in urine. The odds ratio provided an estimate of the risk for having quantifiable arsenic or mercury in urine among those with the risk factor compared to those without the risk factor. Ninety-five percent confidence intervals were calculated for the odds ratios. Confidence intervals can be used as a form of significance testing; however, they are more appropriately used to provide information about the precision of risk estimates, especially when sample size is small and associations are weak.

In subsequent analyses, the effect of exclusion of persons with "trace" levels of arsenic and mercury in urine was evaluated further. Persons with trace levels were compared to those with no detectable arsenic and mercury in urine in a series of screening analyses on approximately 10 variables. The results of these screening analyses suggested that persons with "trace" values had essentially the same pattern of risk for exposure to arsenic and mercury as persons with quantifiable levels of these analytes. Therefore, further analyses were conducted with the addition of persons with "trace" values to those with quantifiable levels of arsenic and mercury (tables 48-55), thereby increasing power and the precision of the risk estimates.

In the univariate and multivariate analyses of exposure factors for urine arsenic and mercury, subjects were pooled without consideration of exposure area in order to examine potential exposure pathways. The number of study subjects with quantifiable urine arsenic and mercury was small. Restricting the evaluation to areas 1 and 2 would have lead to additional imprecision, particularly among children. However, for several exposure variables which were directly related to the exposure area (water supply, locally produced food) additional analyses of exposure in areas 1 and 2 were conducted. Theses analyses were intended to provide insight regarding pathways for exposure across study groups.

The risk factors which showed some evidence of association in univariate analyses for arsenic and mercury were included in multivariate models for the estimation of risk while controlling for potential confounding effects of the other variables. Logistic regression analyses were used to obtain the maximum likelihood estimates of the odds ratios. In the analyses for children, all variables chosen were forced into the logistic regression models since the numbers of observations for exposed persons was extremely small. Variables chosen for inclusion in the models were those for which the univariate odds ratios were 2.0 or greater (or 0.5 and below) and where there were at least two persons with quantifiable urine arsenic or mercury among those exposed to the risk factor.

In the analyses for adults, those variables with an odds ratio of 2.0 or greater (or 0.5 and below) based on at least two persons with quantifiable urine arsenic or mercury among those exposed to the risk factor were initially eligible for inclusion in the logistic regression models. A forward selection procedure was used to choose variables for inclusion in the final model with a probability value of 0.3 used for inclusion. Age, gender, race and residence area were included in all models.

IV. RESULTS

a. Census

The census enumerated age, gender, and race for a total of 3393 people, of which 2552 (75%) met the initial eligibility criterion of having lived at their current residence for a minimum of one year (table 1). There were 11 refusals and 12 residences for which no contact was made, a participation rate for the entire census of over 99%. The age and gender distribution for the 2,552 eligible residents in the census population is shown in table 1 by area.

In area 1, the census was complete; each structure was identified and all occupants were enumerated. Due to larger populations in areas 2 and 3, blocks were chosen at random for the census and study participant selection. Within the randomly chosen blocks, a complete enumeration as described for area 1 was performed.

b. Random Sample

In the next step, a stratified random sample of the census population was chosen. Areas 2 and 3 were frequency matched to area 1 on the basis of age and gender distributions. The random sample contained 376, 469 and 612 residents in areas 1, 2 and 3, respectively. The sample sizes used in the random selection were based on anticipated participation rates for each area. The age-gender distribution for the random sample is shown in table 2 for each of the three areas. Note that the age distribution presented in tables 1 and 2 is based on 10 year intervals and differs from the broader strata used to determine the sampling scheme (2-5, 6-14, 15-39, 40-64, ≥64). Therefore, the numbers of males and females in each age stratum of table 2 are not identical across areas.

c. Final Sampling Algorithm

Because the census identified a greater than anticipated number of available study subjects in area 1, it was possible to apply a more stringent residency requirement (having lived at one's current residence since January 1, 1988, approximately two years), in order to be eligible to participate in the study. In area 1, 330 of the 376 people selected by the random sample, (88%) met the two year residency requirement; in area 2, 437 of the 469 selected (93%) met the two year eligibility, and in area 3, 544 of the 612 selected (89%) met this requirement (table 3).

Additional eligibility requirements of having to spend at least 5 days per week and 9 months per year at one's residence to be able to participate in the study were then applied; 321 persons in area 1, 428 in area 2 and 536 persons in area 3, 536 persons met the additional eligibility requirements (table 3). People in area 3 were also asked whether they had lived within one mile of the Rocky

Mountain Arsenal in the past 10 years. Eighteen of the 536 persons who met the other eligibility requirements had previously lived near the Arsenal and were excluded to avoid potential exposure misclassification (table 3).

When initial appointment-setting calls indicated a participation rate significantly higher than anticipated, a phone survey was conducted to more closely estimate the number of participants in each area that met the above eligibility requirements. This phone survey provided a more precise estimate of anticipated participation rates in each of the three study areas.

During the telephone survey, 66 people in area 1, 104 in area 2 and 186 people contacted in area 3 indicated that they would refuse to participate in the study if they were selected and recontacted to set up an appointment. These persons were not contacted further. The participants were then randomly selected from age and gender strata as described above to develop the final study sample. In area 1, 188 people were called and asked to participate, 30 of whom refused to participate, although they had indicated willingness to participate during the phone survey. In area 2, 26 of the 204 people contacted refused to participate, and in area 3, 41 of the 193 people called for appointments subsequently refused. The contacts in area 2 included 23 persons who were contacted and tested prior to the telephone survey, and who represented an oversampling of two blocks in area 2. Analysis of the characteristics and exposure status of these individuals suggested that they were similar in all respects to the rest of the area 2 sample; hence, they were retained in all analyses. The age and gender composition of the study participants are shown in figures 8 and 9.

d. <u>Participation Rates</u>

The flow of contact and participation is shown in table 3. The participation rate was calculated by combining persons who refused during the telephone survey, and those who refused to participate during the appointment setting phase. "No contacts" were also treated as nonparticipants. Thus, the proportions of persons who participated (or indicated willingness to participate but were not asked to do so) as a fraction of the total eligible persons were 68% in area 1, 68% in area 2, and 56% in area 3.

A total of 472 participants was interviewed and provided either a blood sample, a urine sample (n=469) or both. Three persons provided blood samples but not urine. Table 4 shows age and gender distribution, by area, for all study participants. As can be seen from tables 1, 2 and 4, the census, random sample and final study samples from areas 1, 2 and 3 were generally similar in age and gender distribution. The age strata used in the sampling scheme were broader than those presented in table 4. This difference, as well as the effects of non-participation, account for the differences seen among areas in table 4.

Although neither the census nor the study group was stratified by ethnicity, ethnicity was evaluated as a potential confounder and modifier. As shown in table 5, approximately 70% of people enumerated in each area in the census, random sample and the study group reported themselves to be White- Non-Hispanic, approximately 25% were Hispanic, and less than 5% were of other ethnicity (Black-Non-Hispanic , Asian or Pacific Islander, Native American/ Alaska native or other).

Additional selected demographic and lifestyle data are shown in summary form in table 6. The study participants came from 314 households. Length of residence was similar among areas (11.7-13.7 years). The mean years of residence included the data for 88 children; therefore, the average duration of residence for adults was actually greater than that shown in the table. The population contained large segments from lower socioeconomic strata as shown by the high proportion of individuals who did not complete 12 years of education (36-42%). Current alcohol consumption and smoking frequencies were generally similar among areas. A history of employment at RMA within the previous 10 years was also similar among area residents.

e. Non-participants

The gender and ethnic composition of eligible participants who refused to participate were analyzed by area; 50% of all refusals in area 1 were male and 50% were female. In area 2, 53% of all refusals were male and 47% female and in area 3 54% were male and 46% female. Refusals in each area closely approximated the gender composition for participants who agreed to participate in the study. Ethnicity of refusals in areas 1 and 2 was similar to that for study participants, with 75% of all refusals in area 1 being White-Non-Hispanic, 20% Hispanic and 5% of other ethnicity. In area 2, 73% of all refusals were White-Non-Hispanic, 23% Hispanic and 4% of other ethnicity. In area 3, persons who refused were more likely to be Hispanic, with 36% of all refusals being Hispanic and 64% White-Non-Hispanic.

f. Findings of Clinical Significance

In general, the levels of urine arsenic and mercury in this population were within the reference range for the general population and were not indicative of acute toxicity. Four persons had levels considered notifiable and were recommended for re-testing. Two adults had urine arsenic values above 30 ppb; both resided in area 3. One of these two individuals had a history of employment at the RMA; the second worked in the electrical industry and reported a history of liver disease and diabetes. One adult resident of area one had a urine mercury value above 20 ppb; she had no other notable risk factors. One 5 year old child had a urine mercury above 10 ppb (the value used in children to report elevated findings to individuals); she resided in area 2 and had no other notable risk factors.

g. Descriptive Statistics for Urine Arsenic and Mercury

The frequency distributions for detection of arsenic and mercury in the 469 study subjects who provided a urine sample are presented in tables 7 and 8. Arsenic was detected and quantified in urine from 43 of the 469 persons (9.2%) at the detection limit of 10 ppb. Non-quantifiable (trace) levels of arsenic were detected in an additional 184 (39%) of the individuals sampled and 242 (52.2%) had no evidence of urine arsenic at the detection limit of 10 ppb.

The frequency of mercury detection in urine was lower than that for arsenic. Mercury was quantified at or above the detection limit of 5 ppb in 32 persons, 6.9% of the sample. Trace values for mercury were found in 80 (17.1%) persons sampled; 357 (76%) persons had no evidence of mercury exposure.

Five study subjects, all of whom resided in exposure areas 1 and 2, had detectable and quantifiable levels of both arsenic and mercury in their urine.

Oversampling of area 2 occurred when 23 extra urine samples were collected from blocks 429 and 435. These 23 persons were in excess of the anticipated sample size of 150 for area 2 due to better than anticipated participation rates during the initial sample collection. Analyses were conducted to compare summary statistics with and without the 23 extra samples collected to see if frequency of detection or mean urine arsenic or mercury levels were different for the extra samples in these two blocks than for the rest of the study population. As shown in tables 9 and 10, the frequency of detection of arsenic and mercury was virtually identical with and without the 23 individuals. Further, there was almost no change in either mean arsenic or mean mercury for area 2 when the 23 persons were included. Therefore, results for these 23 extra samples have been included in all analyses.

The central question for this exposure study is addressed in tables 11 and 12 in which the unadjusted arithmetic and geometric means for urine arsenic and mercury with their standard deviations and are compared for areas 1, 2, and 3. As shown in table 11, the arithmetic and geometric mean values for urine arsenic are higher in the comparison area (3) than in either area 1 or area 2. The arithmetic mean values for urine arsenic for areas 1, 2, and 3 were 3.0, 3.4 and 3.8, respectively. Trace values were set at one half the detection limit with non-detects set at zero. The mean values were compared statistically with analysis of variance (ANOVA); no statistically significant differences were found among areas, nor were the mean values for areas 1 and 2 statistically different from the mean for area 3. The mean values for quantifiable urine arsenic were also not statistically different.

As shown in table 12, the arithmetic and geometric mean values for urine arsenic were higher in area 2 and lower in area 1 than in area 3, the comparison area. The arithmetic mean values for urine mercury for areas 1, 2 and 3 were 0.8, 1.1 and 0.9, respectively (table 12). However, there were no significant differences among the three areas when tested with ANOVA, nor were the means of areas 1 and 2 statistically different from the mean of area 3. The mean values for quantifiable urine mercury were also not statistically different ($p > 0.05$).

As a further check on the differences found among areas for urine arsenic and mercury, the ratios of the geometric means for areas 1 and 2 to the geometric mean for area 3 were compared. As previously described, statistical analyses of arsenic and mercury levels in urine were appropriately based on logarithmic transforms; consequently the geometric mean provides a more appropriate measure of central tendency than the arithmetic mean. Similarly, rather than a difference in mean levels, the ratio of the geometric mean for each exposure area to the geometric mean for the comparison area provides a measure of relative exposure not unlike the ratio of odds (ie, the odds ratio) for a dichotomous variable. The lower and upper limits of the corresponding 95% confidence interval were obtained by dividing and multiplying, respectively, the computed ratio of geometric means by the exponential of the following quantity

$$t\, s \sqrt{\frac{c_i}{n_i} + \frac{c_3}{n_3}}$$

where n_3 denotes the sample size for the comparison area (Area 3), n_i denotes the sample size for the exposure area of interest (Area 1 or Area 2), $c = (1 + 1/GM)^2$, s denotes the pooled standard deviation obtained in the t-test using the log-transformed values, and t is the value from Student's t-distribution corresponding to the 95% confidence level:

Urine Analyte	Area	Geom. Mean	Area 3 Geom. Mean	Ratio	(95% CI)
Arsenic	1	1.435	1.773	0.81	(0.47,1.39)
	2	1.552	1.773	0.88	(0.50,1.51)
Mercury	1	0.314	0.438	0.72	(0.33,1.55)
	2	0.511	0.438	1.17	(0.58,2.34)

As shown above, the ratios for the geometric means for arsenic in areas 1 and 2 compared to area 3 were both below 1.0. The ratio of the geometric mean for mercury in area 2 to the geometric mean for area 3 is slightly above one, but the confidence intervals were wide and included 1.0.

Tables 13 and 14 provide geometric means and standard deviations for quantifiable levels of arsenic and mercury in urine by the method of adjustment for urine concentration. Urine mercury and arsenic values were adjusted by three methods: for urine specific gravity, for urine creatinine and for specific gravity and creatinine. These two parameters of renal function measure two different physiological mechanisms; therefore, the effects of adjustment for each of these two variables were assessed. In addition, the effect of adjusting for both parameters simultaneously was evaluated. The latter technique is analogous to a simultaneous adjustment for both age and gender in an epidemiologic analysis where confounding may affect risk estimates. These adjustment procedures were evaluated to determine whether differences in renal function among study participants could have affected the mean values for the analyte in each area. Adjustment for creatinine produced a consistent decrease in the geometric mean values for urine arsenic and mercury.

One-way analysis of variance (ANOVA) with multiple comparisons was used to compare geometric mean values of urine arsenic and mercury among the three exposure areas. The unadjusted geometric mean values, creatinine-adjusted, specific gravity-adjusted and specific gravity-creatinine adjusted mean values were compared among areas, and no statistically significant differences were detected. Area 1 and Area 2 were compared to Area 3; no significant differences were found (tables 15-16). Since no significant differences among areas were detected for any of the three methods of adjustment, a decision was made to use unadjusted values for urine arsenic and mercury in all further analyses.

The unadjusted arithmetic mean values for arsenic $\geq$ 10 ppb are shown in figure 10 for each area. The mean urine arsenic for area 3 was greater than for either area 1 or area 2. The difference was not statistically significant ($p > 0.05$). The unadjusted arithmetic mean values for mercury $\geq$ 5 ppb are shown in figure 11 for each area. The mean urine mercury for area 1 and area 2 were both slightly higher than the mean for area 3 but the difference was not statistically significant ($p > 0.05$).

The distributions of quantifiable and trace values of urine arsenic and mercury are shown in figures 11 and 12 and in tables 15 and 16. Since the study hypothesis was that exposure among persons living in proximity to the RMA was higher than among persons in the comparison area, the frequency of detection and mean value for each analyte was compared between each exposure area and the comparison area.

The frequency of quantifiable detection of urine arsenic in areas

1, 2 and 3 was 7.4%, 10.5% and 9.5% respectively. No significant difference in the frequency of detection for urine arsenic was found when area 1 and area 2 were each compared with area 3 (table 15).

Geometric mean urine arsenic levels for areas 1, 2, and 3 were 1.43, 1.55 and 1.77 ppb., respectively. Means were compared using a Student's t test for area 1 vs. area 3 and for area 2 vs. area 3 and no significant differences were found ($p > 0.05$) (table 15).

The frequency of quantifiable detection of urine mercury in areas 1, 2 and 3 was 6.0%, 8.7% and 5.4% respectively. When the frequencies of quantifiable detection of mercury for area 1 and area 2 were each compared with area 3, area 2 was seen to be higher in frequency of detection, although no statistically significant differences were found (table 16).

Geometric mean urine mercury levels for areas 1, 2 and 3 were 0.31, 0.51 and 0.44 ppb., respectively. Areas 1 and 2 were each compared to area 3 using Student's t test. No statistically significant differences ($p > 0.05$) in mean urine mercury between the exposure areas and the comparison area were found although the geometric mean level for urine mercury is higher in area 2 than in area 3 (table 16).

Trace values for arsenic and mercury were found frequently. For urine arsenic, 184 of the 469 (39.2%) persons sampled had a level that was detectable but non-quantifiable; for urine mercury, the frequency of trace values was 80 of 469 (17.1%). For both arsenic and mercury, the frequency of detection at the trace level was substantially higher than that for values above the detection limit (figures 12 and 13). Therefore, comparisons of mean values between areas are shown in tables 15 and 16 for the total population sampled (with one half of the detection limit used for a trace value) and for only those persons with quantifiable arsenic or mercury separately.

The detection of trace values was evaluated further by calculating unadjusted odds ratios with 95% confidence intervals for their frequencies in areas 1 and 2, each compared with area 3. As seen in table 17, the odds ratios for detecting both quantifiable and trace values of arsenic were at or below 1.0 for areas 1 and 2 (compared to area 3). The odds ratios for detecting trace values for mercury were also below 1.0 in area 1 and area 2. However, the odds ratio for detection of quantifiable mercury was 1.65 (95% CI 0.7-4.0) for area 2 (table 18). This finding is consistent with the elevated ratio for the geometric mean for area 2 compared to area 3 described above.

The data were also examined after stratification by agegroup and gender to determine whether specific subsets of the population (e.g., children, women) might be at increased risk for exposure.

Such an increase might be postulated to be due to more time spent in the vicinity of the home for women or more contact with soil for children. Stratified analyses were conducted for age using three groups: children less than 6, children 6 through 14 years old, and those over 14 years of age.

The results of stratified analyses are summarized in tables 19 and 20. The mean urine arsenic level among children less than 6 years of age was higher for the comparison area than for area 1 or area 2. Overall, mean urine arsenic levels were higher for males than for females ($p < 0.05$). However, stratified comparisons showed no statistically significant differences for mean urine arsenic levels for males or females comparing each gender across the exposure areas (areas 1 and 2) with means for the same gender in the comparison area (area 3). Mean urine arsenic levels were slightly higher for males in the comparison area than they were in either of the exposure areas (table 19). The proportion of persons with quantifiable levels of arsenic was affected by small numbers in the numerators of stratum-specific analyses. Similarly, although the geometric mean urine arsenic was higher in children 6 to 14 years of age in area 1 and in area 2 than in area, 3 the means were based on small numbers of exposed children and were not significantly different. For example, in area 1, the value for 6-14 years is based on a single child with quantifiable urine arsenic.

The frequency of detection of urine mercury was higher in each age stratum for area 2 than in the corresponding stratum in area 3. However, no statistically significant differences in urine mercury levels were found for any of the age and gender strata examined when residents of area 1 and area 2 were each compared to residents of area 3. As was the case for arsenic, no differences in mean urine mercury values were found by Student's t test when comparing mean values for each sex between the exposure and comparison areas (table 20).

For urine arsenic, there was a statistically significant difference detected by ANOVA, with means being highest in the youngest age group, and lowest in the oldest age group. No differences were detected in mean urine mercury levels by ANOVA in any of the comparisons of agegroups.

In the analyses presented in tables 11 and 12 (arithmetic means) and tables 15-16 and 19-20 (geometric means) trace values were set at one half the detection limit with the non-detects set at zero. To evaluate the effect of this decision on inter-group comparisons of means, the analyses were repeated with <u>all</u> laboratory values less than the detection limit redefined as one half of the detection limit (table 21). The arithmetic mean values for urine arsenic (± standard deviation) for areas 1, 2 and 3 were 5.7 (±2.6), 6.0 (±3.4) and 6.2 (±5.1), respectively and those for urine mercury were 2.7 (±0.8), 2.9 (±1.6) and 2.7 (±1.1) respectively. These mean values were then tested with ANOVA and t test procedures; no statistically significant differences were found among areas ($p > 0.05$).

h. Analyses of Urine Arsenic and Mercury by Date of Sample Collection

The effects of week of sample collection on the frequency of detection of urine arsenic and mercury were evaluated in order to examine seasonal patterns in exposure (table 22). The proportion of subjects with detectable arsenic was significantly higher ($p < 0.003$) during the first three weeks of the study (prior to December 25, 1989). The frequency of arsenic detection for this period was nearly 16 percent, compared with 7 percent after the holiday season. The frequency of mercury detection in the pre-Christmas period was also higher than in the weeks following the holidays, although the difference was smaller and not statistically significant ($p = 0.24$).

The weather in the Denver metropolitan area during the field collection activities was variable (table 23). Examination of the weather data for the period of the study showed some correlation between the frequency of arsenic detection and average daily temperature and snow cover on the ground at Stapleton Airport in the weeks prior to sampling. For example, the highest arsenic detection rate was for the week of December 17, 1989; two weeks previously the average daily temperature was 40 degrees F and there was no snow on the ground.

i. Univariate analyses of Exposure Variables for Arsenic and Mercury.

The precision of the risk estimates was limited by the low proportion of subjects with quantifiable arsenic or mercury in urine after trace values were excluded. Among children, 9 of 34 (26.5%) had quantifiable levels of arsenic, and 7 of 74 (9.5%) had quantifiable levels of mercury. Among adults, 34 of 254 (13.4%) had quantifiable urine arsenic, and 25 of 318 (7.9%) had quantifiable levels of urine mercury.

As a response to this problem, and to assure that data were not being unnecessarily deleted, further analyses were conducted with the addition of persons with "trace" values to those with quantifiable levels of arsenic and mercury as described in section k. This addition had the effect of increasing the sample size for children to 88 of whom 63 had arsenic and 21 had mercury in urine. In the additional analyses of risk factors for adults, there were 384 persons, of whom 164 had arsenic and 91 had mercury in urine. In these analyses, the precision of risk estimates was improved substantially.

Arsenic in Children

The results of univariate analyses for exposure factors to arsenic among children aged 2 to 14 are shown in tables 24 to 27. The confidence intervals around all of the odds ratios in these analyses included 1.0. However, a strong relationship between urine arsenic and gender was found, with male children having approximately five times the risk of that for female children. The risk among hispanics and nonwhites was elevated slightly. None of the other personal risk factors evaluated in table 24 appeared to play a role in arsenic exposure.

Various dietary exposures were examined (table 25). Consumption of more than three glasses of water daily lowered the odds ratio to 0.25. The effect of various behaviors on arsenic exposures was examined (table 26). Spending more time outdoors during the summer, but not during the winter, was associated with an approximate doubling in risk for arsenic exposure. Children who participated in yard and gardening work (table 27) were not at increased risk, nor were those who played on a dirt area (table 26) or ate dirt or grass (table 24). These findings suggest that exposure to soil around the home was not associated with risk of exposure to arsenic among children during the period of the year when the samples were collected.

None of the questions which examined childrens' exposures to the RMA showed a strong or statistically significant association with arsenic. Playing within one mile of RMA had a small increase in risk (OR = 1.6). Residence near the RMA, bicycle riding, or walking near RMA was not associated with exposure. Consumption of foods grown or caught near RMA showed no significant association with exposure.

Arsenic in Adults

Risk estimates for exposure to arsenic among adults are shown in tables 28-31. Age and racial risk factors were associated with exposure to arsenic. Persons less than 40 years of age had an eight fold increase in risk for exposure to arsenic compared to those over 64 years of age. Hispanics and non-whites had an increased risk of exposure to arsenic (OR = 2.6); persons of lower socio-economic status, as measured by level of education attained, showed no evidence of increased risk for arsenic exposure (OR = 0.6) (table 28).

Analysis of the dietary variables included in the adult questionnaire showed little evidence of an effect for arsenic exposure (table 29). The odds ratios for consumption of alcohol and red wine during the previous week were weakly elevated. The risk of exposure to arsenic was elevated among those who did electrical work as a hobby (OR = 2.6) (table 30). The risk estimate for those who did automobile restoration and bodywork was also elevated (OR = 3.1).

Evidence for specific occupational associations with arsenic exposure was found (table 31). Elevated odds ratios were calculated for working in a feed mill (OR =4.5), having sprayed crops (OR =1.5), automobile painting or bodywork (OR = 1.7) and working with inks or dyes (OR = 7.0). In general, questions which examined exposures through activities or pathways associated with the RMA showed no evidence of an association with arsenic exposure. Working at the RMA in the past was found to be associated with a small but imprecise increase in risk (OR = 1.4).

Arsenic - Household Data

Univariate analyses were also conducted for variables in the household interview. Analyses were conducted at the level of the individual; i.e., the individual laboratory result (rather than the presence or absence of an exposed person in the household) was integrated with the household characteristic. (Since the number of persons per household varied from one to three, the probability of finding a person with a quantifiable level of the metal for a given exposure would have depended upon the number of persons sampled in that home).

The results of evaluation of household data on the exposures to arsenic are found in tables 32-33. The findings were generally unremarkable with odds ratios below one found for most variables (table 32). The exceptions were elevated odds ratios for the consumption of locally produced milk (OR = 7.2) or beef (OR =3.4) within the past two years.

There was little evidence that consumption of well water was associated with arsenic exposure for the entire study population (OR = 1.4). In order to evaluate exposure to well water more specifically and test the study hypothesis further, the variables related to water consumption were evaluated in a separate analysis for those persons residing in areas 1 and 2 (table 33). In these analyses, smaller sample size decreased precision of risk estimates. There was no indication that the use of well water increased the risk of arsenic exposure. An increased OR for area 2 was based on one person with quantifiable arsenic. However, when a water filter was added to well water the odds ratio increased (OR = 5.1). When a softener was added to well or city water, the same general effect was noted. Increases in risk for quantifiable urine arsenic associated with the consumption of locally produced milk and beef were found for residents of areas 1 and 2.

Mercury in Children

The results of univariate analyses for exposure factors to mercury among children aged 2 to 14 are shown in tables 34 to 37. A modest increase in risk was found among those older than five (OR = 1.5). Unlike the finding for arsenic, female gender was associated with exposure to mercury (OR = 2.6). Higher daily levels of water consumption were associated with an increased risk for exposure (OR = 2.4, table 35). Other dietary variables showed no evidence of association with mercury exposure. Spending more than 7 hours a day outdoors was associated with a stronger risk estimate for mercury exposure than was true for arsenic (table 36). The risk appeared to extend to the winter months. Playing in an area which was on soil or bare ground also showed some evidence of increased risk for mercury exposure (OR = 4.9). There was little evidence of an association with activities or residence in proximity to the RMA for exposure to mercury among children. A strong association was found for work or play on a farm or ranch (OR = 10.9) (table 37).

Mercury in Adults

Odds ratios for exposure to mercury among adults are shown in tables 38 to 41. As described for arsenic, younger adults had an increased risk for exposure to mercury (OR for persons < 40 = 3.7). Women had more than twice the risk of mercury exposure compared to men; the finding is consistent with that observed for female children. Persons who were hispanic or non-white had an increased risk of exposure to mercury (OR = 1.9), as was the case for arsenic; persons with lower levels of educational achievement had a decreased risk for mercury exposure (OR = 0.4), similar to the result found for arsenic (table 38).

Neither cigarette smoking nor alcohol consumption appeared to be related to mercury exposure. The odds ratios for wine consumption were increased slightly (table 38). The odds ratio for dental fillings within 2 weeks was elevated (OR = 3.0), but was based on a single case. Consumption of tap water appeared to increase the risk for mercury exposure approximately twofold, but there was no evidence of a dose-response relationship. Other dietary factors examined showed little evidence of a relationship with mercury exposure (table 39).

As was the case for arsenic, there was no evidence that outdoor activity was associated with mercury exposure (table 40). Gardening and yard work were not associated with exposure. The odds ratio for auto painting, restoration and bodywork as a hobby was 2.4. Walking/hiking and bicycle riding within one mile of the RMA showed small, imprecise increases in the odds ratios (1.7 and 2.1, respectively).

Several occupations showed some evidence of association with mercury exposure. The increased risk seen for working for a fertilizer company was based on only one person with a quantifiable level of mercury in urine. Small elevations in the risk estimates were found for occupations related to pesticide use, pesticide manufacture, mining, chemical production, glass manufacturing, welding/electroplating and battery work, automobile painting and bodywork, lawn service, and pest extermination (table 41).

Mercury - Household Data

The effects of household exposures on risk for mercury exposure were evaluated in a similar manner, first for the study population as a whole (tables 42-43). Odds ratios above 2.0 were found for growing corn or fruit trees in home gardens, watering the garden with well water, use of central air conditioning and for persistent recognition of chemical odors (table 42).

Consumption of well water in all three study areas was associated with some increase in risk for mercury exposure (OR = 1.9), and consumption of bottled water with a lowering of the odds ratio (OR = 0.5). These findings were not statistically significant. However, when the analyses were restricted to areas 1 and 2 (table 43), there were several interesting findings. The use of well water in area 2 was associated with an eleven-fold increased risk of exposure to mercury, but was based on two exposed persons. Watering the garden from the well also increased risk; the estimate for the two exposure areas was 7.0. In area 1, 3 of 49 persons who watered their garden from a well were exposed; none of nine persons who did not were exposed. In area 2, fewer persons used well water for gardens, but nearly half of those who did had mercury exposure (OR = 32.0). When filtration or water softeners were used in homes where well water was consumed, the risk of mercury exposure appeared to decrease. The consumption of locally produced milk within the past two years in areas 1 and 2 was also associated with increased risk of exposure (OR = 3.5), although based on only one person with quantifiable mercury. No increased risk for beef consumption was suggested.

j. Multivariate analysis.

The risk factors which showed some evidence of association in univariate analyses for arsenic and mercury were included in multivariate logistic regression models for the estimation of risk while controlling for confounding. The analyses for quantifiable levels of arsenic were based on 34 children; those for mercury were based on 74 children, limiting precision. In general, the results were similar to those reported above for the univariate analyses (tables 44-47).

For exposure to arsenic (table 44), risks were elevated among children who were over 5 years of age, male, hispanic or non-white and who drank less than 3 glasses of water daily or spent more than seven hours a day outdoors during the summer. The risk of exposure to mercury was increased among children who were over 5 years of age, female and hispanic or non-white (table 45). Children who played outdoors more than 7 hours a day were at increased risk for mercury exposure, as were those children who lived in a home surrounded by dirt or soil. After controlling for confounding, the risk estimates for mercury exposure for area 1 (OR=4.0) and area 2 (OR=7.4) were elevated. The risk estimates for all of these attributes in children were imprecise, due mainly to the small number of observations.

In the multivariate analyses for adults, a forward selection procedure was used to choose variables for inclusion in the final logistic regression models. Age, gender, race and area of residence were included in all models.

A strong association between exposure to arsenic and age less than 40 was found (OR = 8.1), with a smaller association (OR=4.8) found for those between 40 and 64 years of age compared to the oldest age group (table 46). There was no association between arsenic exposure and gender, but persons who were hispanic or non-white had approximately 3.6 times the risk of arsenic exposure as did whites. Failure to complete at least 12 years of education was associated with a lowering of the odds ratio for exposure to arsenic (OR = 0.48). Residence in area 1 or area 2 had no effect on increasing risk of exposure to arsenic, as was shown in the descriptive analyses of mean urine arsenic levels. There was a weak association with a prior history (within 10 years) of work at the RMA. A history of having worked with electrical components or having sprayed crops was associated with an increase in risk of exposure to arsenic.

In the multivariate analysis for exposure to mercury among adults, a trend for increased risk among those less than 40 years of age was also present, but no risk was found for those between 40 and 64 years of age compared to the oldest age group (table 47). However, unlike the case for arsenic, a strong, statistically significant association was found for gender, with the risk of exposure to mercury among females elevated more than 10 fold. The odds ratio for mercury exposure among persons who were hispanic or non-white was increased (OR = 3.2), similar to the finding for arsenic. Persons with less than 12 years of education showed a decrease in the risk estimate for exposure to mercury (OR = 0.27). Unlike the finding for mercury in children, there was little evidence of an association between mercury exposure and residence in area 1 or area 2. However, the risk estimate for residence in area 2 was elevated (OR = 1.9) for mercury exposure. This finding is compatible with the higher geometric mean level of mercury in area 2 compared with area 3 and with the elevated odds ratio (1.65) found for quantifiable mercury in area 2 compared with area 3.

Elevated risk estimates were found for several occupations i.e; orchard work, mining, smelting or refining, automobile restoration, painting or bodywork and electroplating, welding or battery manufacture. Having worked at the RMA during the past 10 years yielded an odds ratio of 2.4 with wide confidence intervals. The questions asked regarding occupation were set in a time-frame of the past 10 years to evaluate exposure to pesticides; their relevance to the more rapidly excreted metals is unclear. Moderate elevations were also found for persons who drank tap (as opposed to bottled) water, and who worked with pesticide products.

k. <u>Univariate and Multivariate Analyses after Addition of "Trace" Values</u>

As described above, persons with non-quantifiable but detectable levels of urine arsenic and mercury (trace values) were found frequently; 3[illegible]% of persons sampled for urine arsenic and 17% of persons sampled for urine mercury had trace values for the analyte. Although there was no difference in the frequency of detection for trace values when areas 1 and 2 were each compared with area 3, elimination of individuals with trace values decreased sample size and statistical power. Initially, we were concerned that inclusion of these individuals may have lead to misclassification; this was the rationale for their deletion from the series of univariate and multivariate analyses described above.

As a check on the effect of deletion of persons with trace values of urine arsenic and mercury, odds ratios were calculated for a series of approximately 10 variables in screening univariate analyses comparing persons with trace values to those with no detectable urine arsenic or mercury. In these analyses (not shown), persons with trace values had risks which were similar to persons with quantifiable levels; e.g., for age, race, gender etc. Since they appeared to be different from persons with no detectable urine arsenic and mercury, a series of additional analyses was performed which included the major findings from tables 24-47, as well as other risk factors of <u>a priori</u> interest. Univariate analyses were followed by multivariate analyses as described above. The findings from these additional analyses are presented in tables 48-55. Deviations from the results obtained with the analysis of persons with quantifiable levels of urine arsenic and mercury are described in the following section.

Arsenic

Risk estimates for childhood exposure to arsenic are presented in table 48 (for comparison with estimates for quantifiable arsenic see tables 24-27). The strong association seen for male gender in the earlier analysis was reduced by the addition of children with trace values of arsenic (OR = 1.8 vs 5.3). Similarly, the OR for hispanic origin or non-white race was decreased to 1.1. Consumption of home grown fruits and vegetables during the winter was associated with arsenic exposure (OR = 4.9). A tendency for children who spent more time outside in summer to have arsenic in urine was retained, while the association with outdoor activity in winter disappeared.

Analyses of adult risk factors and urine arsenic are shown in table 49 and may be compared with the findings presented in tables 28-33. In general, the earlier findings were supported in the expanded analyses. The risk estimates for older persons decreased further (older people were even less likely to have arsenic in urine); the risk for males was reduced (OR = 1.2). Similarly, the odds ratios for hispanic origin or non-white race and for less than 12 years of education were reduced by the addition of persons with trace levels of arsenic. Household income and education are measures of socio-economic status; both were found to be inversely related to the presence of arsenic in urine. The association between consumption of red wine during the previous week and urine arsenic was strengthened. Consumption of fish was associated with a small increase in risk for arsenic exposure but a dose-response relationship was not demonstrated (table 49).

In general, associations with previously identified hazardous hobbies persisted (table 49). Photography was associated with an increased risk in the expanded analyses (OR= 4.1). Work in any of the list of hazardous occupations increased risk for arsenic exposure (OR = 1.9). The expanded data also confirmed most of the risks previously identified for hazardous occupations. All 8 of the persons who reported work in the chemical industry had detectable urine arsenic (table 49). The risk estimate for having windows open in the house more than 50 percent of the time increased to 1.6.

Risk estimates for several household risk factors were also evaluated for areas 1 and 2 (table 50) and compared with those obtained in earlier analyses of arsenic (table 41). The expanded analyses had additional power to detect associations with the increased sample size available for analysis. In general, the findings were consistent with those described earlier. The estimates for locally produced beef and milk remained elevated but were lower than reported above. The increased risks for well water in area 2 and for the use of a filter on well water were no longer seen.

Mercury

The risk estimates for childhood mercury exposure are shown in table 51 (tables 34-37 for comparison). The association with age ≥6 years was strengthened by the addition of children with trace values (OR = 3.6), but the earlier finding for an increased risk among female children disappeared (OR = 1.1). In this analysis, the elevated odds ratio for spending more time outside in the summer persisted, while that for outdoor activity during the winter decreased. Risk estimates for consumption of more than 2 glasses of water daily, having farm animals as a hobby, and having a dirt or ground play area also decreased. Reporting any of the hobbies listed in table 29 gave an odds ratio of 1.8.

The effects of adding adults with trace levels of mercury are shown in table 52 and may be compared with tables 38-41. The age and gender patterns found in the earlier analysis persisted, with older persons and males having lower risk for mercury exposure. Inverse associations with income and education were seen in this analysis, as described originally and the association with hispanic origin or non-white race was found as well. The odds ratios for tap water consumption were lowered. The findings for hobbies, activities, occupation and household factors were in general agreement with those described in tables 38-41.

In the analysis for household risk factors in areas 1 and 2 (table 53, the risks found were generally lower than those reported in table 43 but were in the same direction. An increased risk associated with use of well water in area 2 persisted (OR=4.7); similarly, the use of well water on a garden in area 2 was again associated with increased risk for mercury exposure (OR=6.7). In addition, the consumption of locally produced beef and milk in area 2 was associated with increased risk for mercury exposure.

Multivariate Analyses

In multivariate analyses for risk of having a detectable level of arsenic in urine (table 54), persons less than 40 years of age had an increased risk compared to those over 64 years of age (OR=3.4). Consumption of fish during the previous week (OR=1.7), and red wine (OR=2.4) were also associated with exposure to arsenic. Employment in any of the hazardous occupations described above increased risk for arsenic exposure by 70 percent. There was no evidence of any association with residence in area 1 (OR=0.8) or area 2 (OR=0.7) after controlling for the effects of other risk factors.

In multivariate analyses for detectable mercury in urine (table 55), persons less than 40 years of age were more likely to have had exposure (OR=4.0). Women were more likely to have had exposure to mercury (OR=1.8) as were persons of Hispanic origin or non-White race (OR=1.7). After controlling for the effects of other risk factors in the model, there was no evidence of an increased risk for mercury exposure with residence in area 1 (OR=0.7) or area 2 (OR=1.0).

1. <u>Laboratory Quality Control</u>

External and internal quality control samples were used for the inorganic metal analyses. External quality control samples for the analyses of arsenic and mercury were obtained from a commercial source (BioRad Laboratories). These control samples consisted of lyophilized urine to be reconstituted with DI water and prepared at two concentrations. The BioRad Lyphochek Urine Metal Control results are given below for high and low levels of mercury and arsenic. The mean values were as follows:

Substrate	No.	Mean (ppb)	Standard Deviation
Mercury (high)	8	32.04	1.74
Mercury (low)	8	10.11	0.72
Arsenic (high)	8	165.62	7.76
Arsenic (low)	8	53.4	2.89

The internal quality control samples were prepared from a spiked sample of pooled urine from Colorado residents. This control sample consisted of a high and low level pool containing both organic and inorganic mercury and arsenic. The Colorado spiked pool results are as follows:

Mercury (High)	18	78.44	4.27
Mercury (Low)	18	10.97	0.66
Arsenic (High)	18	63.87	5.38
Arsenic (Low)	18	23.47	2.22

Individual values for each sample and control charts are shown in appendix B. In addition, the CSU Laboratory reanalyzed ten percent of the original samples as a QA/QC verification. Since there were only 4-7 ml of sample remaining, we analyzed 30 samples for mercury and a different 30 samples for arsenic. Both methods required some modification for the smaller quantity of urine. Results of these analyses are found in appendix B.

Quality control data were plotted comparing ug/l (PPB) vs. replicate analyses. Mean values, upper control levels (UCL), upper warning levels (UWL), lower control levels (LCL) and lower warning levels (LWL) were calculated and plotted. The UWL's and LWL's were calculated from the means plus or minus two standard deviations. The UCL's and the LCL's were calculated from the means plus or minus three standard deviations. As shown in the QA/QC charts, all of the control replicate samples were within the upper and lower control levels.

V. DISCUSSION

Rationale

This exposure study was predicated on the large number of chemicals, including arsenic and mercury, known to exist in various media at the Rocky Mountain Arsenal. Sampling for arsenic and mercury offsite had been relatively limited, but data existed to show that migration of these contaminants into surrounding areas had occurred. Additional environmental monitoring of offsite contamination for arsenic and mercury, including household measurements, would have been useful in interpreting the results but were beyond the scope and objectives of this study. Thus, the proximity of populations residing adjacent to the site formed a portion of the rationale for this study.

Specific *a priori* hypotheses concerning potential exposure to arsenic and mercury were developed. Potential exposure pathways included human exposure via ingestion of contaminated soil or residential dust, inhalation of airborne particulate matter, ingestion of contaminated ground or surface water, uptake of contaminants from fruits and vegetables grown in local gardens irrigated with ground water, ingestion of beef, poultry, milk or other domestic animal products impacted by contaminated ground water, surface water or airborne soil and consumption of plants, wildlife or fish from the RMA. The roles of occupation, hobbies, lifestyle factors and activities relevant to the RMA which might have influenced exposure to arsenic and mercury were evaluated. Population subgroups which might have increased risk for exposure to arsenic and mercury were considered in the analysis. Women and children might have had additional opportunity for exposure if they spent more time at home or engaged in activities which increased potential for contact with local soils. Therefore, the effects of age, gender, socioeconomic status, race and education on the risk for exposure to arsenic and mercury were evaluated. Exposure was defined by the results of biomonitoring.

Limitations of Study Design

The RMA exposure study was designed as a cross-sectional investigation, with the limitations which normally accrue to this approach. Principally, cross-sectional studies are limited in their capacity to integrate exposure and outcome phenomena over time. Biological measurements of arsenic and mercury were made at a single point in time; both chemicals are cleared rapidly from the body. For example, over 70% of trivalent and pentavalent arsenic is excreted in urine within 24 hours in mice, rabbits, swine, dogs and monkeys; excretion rates in humans are similar with approximately 60% excreted in a 24 hour period (ATSDR, 1989). For mercury, excretion is slower, with the half-life of whole body inorganic mercury measured between 42 and 60 days (ATSDR, 1989). After long term exposure, urinary excretion of mercury approaches 60% (ATSDR, 1989) Although the half-life of mercury in blood and plasma is considerably shorter, urine mercury comes from a body pool of mercury as opposed to the glomerular filtrate of the plasma (Cherian et al. 1978). The collection of urine samples from participants in January, February and March can therefore be expected to represent exposure during these months in the case of arsenic, and somewhat earlier for mercury.

Subjects were evaluated simultaneously in all exposure areas in order to avoid introducing bias due to seasonal differences in sampling. However, the possibility that exposures via ingestion of contaminated soil and residential dust, particularly among children, might have been reduced during this portion of the year exists. There is some evidence that frequency of arsenic detection was related to elevated mean daily temperature and lack of snow cover during the period prior to sampling. Additional human monitoring data for this population to include a period when exposures might be expected to be higher (summer months) is indicated before final conclusions regarding exposures can be drawn. The time frame for sampling was selected for administrative reasons, rather than to maximize the probability of detecting arsenic and mercury.

A second limitation was sample size. Although the populations sampled met the original design objectives of the study, the frequencies of quantifiable exposure (9.2% for arsenic and 6.9% for mercury were relatively low). Based on the geometric mean and geometric standard deviation for the comparison group (area 3), this study had statistical power in excess of 80% to detect a 40% increase in the geometric mean for arsenic and a 25% increase in the geometric mean for urine mercury at the 5% level of statistical significance.

The precision of the estimates was limited by the low proportion of subjects with quantifiable arsenic or mercury in urine. After exclusion of subjects with trace values, 34 children remained for the arsenic analysis and 74 for the mercury analysis. The difference in denominators was due to the higher frequency of trace findings for arsenic. Among these groups of children, there were 9 with quantifiable arsenic and 7 with quantifiable mercury. Children with quantifiable arsenic and mercury were apportioned between exposed and unexposed categories of the risk factor resulting in small numbers and imprecise estimates. Among adults, 34 of 254 (13.4%) had quantifiable urine arsenic and 25 of 318 (7.9%) had quantifiable urine mercury after trace values were excluded. The difference in denominators between the arsenic and mercury analyses was again attributable to differences in the proportion of subjects with trace values.

In supplemental analyses, persons with non-quantifiable but detectable levels of urine arsenic and mercury (trace values) were included after a series of screening univariate analyses showed that persons with trace values of arsenic or mercury had risks which were similar to persons with quantifiable levels. The addition of persons with trace values increased sample size, power and precision of risk estimates; however, the findings from these analyses generally yielded lower risks than those for persons with quantifiable levels of urine arsenic and mercury. This suggests that trace values may be due to background exposures in food, rather than to other environmental exposures.

The possibility of introducing selection bias must be considered when participation rates fall below optimal levels. In this study, participation rates of 68% for area 1, 68% for area 2 and 56% for area 3 were calculated. However, these rates include persons who could not be contacted, as well as persons who were asked a screening question regarding participation and indicated that they would be unlikely to participate if asked to. These individuals were not recontacted. To evaluate the effects of non-participation on the potential for introduction of selection bias we examined the demographic characteristics of the participants and non-participants in each of the three study areas. The demographic characteristics of participants generally resembled those of the group which declined to participate with the exception of area 3, where Hispanics were over-represented among non-participants. Data from this group are thus subject to more limited interpretation, although the findings were not stratified according to ethnicity.

Because participation rates when sampling first began were higher than initially anticipated, over-sampling of two blocks in exposure area 2 occurred before the sampling scheme could be adjusted. The result was that 23 more study subjects were tested in area 2 than in areas 1 and 3. A random sample of the over-sampled blocks (blocks 429 and 435) was selected based on the actual participation rate, so that these blocks would not be over-represented and potentially skew the results. Frequency of detects with and without these additional samples were compared using a chi-square test statistic, and means were compared between area 2 and the comparison group (exposure area 3) with and without the additional samples from the over-sampled blocks. Because no differences were found between areas with or without the extra samples, the decision was made to include these 23 study subjects in all analyses in order to fully utilize all available data.

<u>Evaluation of Exposure Variables</u>

In the univariate and multivariate analyses of exposure factors for urine arsenic and mercury, eligible subjects were pooled without consideration of exposure area. Since the descriptive analyses of arsenic and mercury showed no differences in adjusted or unadjusted mean values between the exposure areas and the comparison area, the analyses reported here included all subjects and were intended to provide insight regarding pathways for exposure rather than to examine RMA specific issues. Alternate analytic strategies would have been to examine only residents of the two exposure areas, or to search for associations within the exposure areas and then determine whether the same relationships existed in the comparison area. In view of the similar and low frequencies of quantifiable levels of arsenic and mercury in urine among the three areas and the poor precision of the estimates found for many of the comparisons, especially among children, the best treatment of the data seemed to be to search for exposure patterns rather than to limit precision further in segmented analyses. However, limited attempts at examining site-specific exposure pathways were made, particularly for water.

Trace Values

Approximately 40% of all the laboratory values for each exposure group were reported as trace values (i.e., detectable, but not quantifiable). Methods for including these trace values in the analysis ranging from simple substitution of one half the detection limit to more robust methods, such as probability plots, were considered. Using the trace values to generate a probability plot was rejected because such methods are generally considered unreliable when less than 80% of the data are quantifiable (i.e., values above the detection limit for the analytical method being used). Because simple substitution for such a large number of trace values has the potential to skew the results, four techniques were applied: (1) means for the areas were compared using trace values set to one half the detection limit and zero for no detectable analyte; (2) means were compared setting all values below the detection limit to one half the detection limit; (3) the analysis was repeated using values only at and above the detection limit for each area; (4) ratios of the geometric means for area 1 and area 2 to the geometric mean for area 3 were calculated with the confidence intervals around the ratio. In addition, the distributions of detectable values, trace or non-quantifiable values and nondetectable values for the three exposure groups were compared with odds ratios and chi square tests to assess the potential effect of the trace values on the comparison of mean analyte levels among areas.

Adjustment for variation in urine concentration and urine flow rate

Substantial inter-individual and intra-individual differences in urine flow rate and concentration are expected in any given monitored population, due to differences in diet, body size, body water content, physical activity or diurnal variations. Several strategies exist to adjust measured concentrations of metals in spot urine samples for variations in flow rate and concentration. Adjusted values have been shown to be more accurate than unadjusted ones, with unadjusted dilute samples invariably leading to apparently low results and unadjusted, concentrated samples leading to apparently high results (Elkins, 1974).

Both osmolality and specific gravity have been recommended as appropriate factors to adjust the concentration of solute in spot urine samples for variation in flow rate (Diamond, 1988). In this study, specific gravity, an expression of the density of a solution relative to that of water, was used to make this correction.

The reference standard of 1.024, used for correction of urine specific gravity, was first proposed by Levine and Fahy (1945) following a study of more than 1100 workers in the lead industry; in that study, the group mean specific gravity was found to be 1.024. Elkins et al. (1974) found that this reference standard was still the most consistently used for urinalysis studies, with a range of standards used from 1.016 to 1.024. As many authors have subsequently pointed out, the choice of the reference value can be significant since the individual adjusted metal values will vary in magnitude as a function of the reference value chosen (Diamond, 1988; Berlin, 1985). Comparisons among groups will not be affected so long as each group is standardized to the same reference value.

Group means for urine specific gravity varied from 1.014 to 1.020 for the three areas. Because of the variation inherent in spot urine sampling (vs. 24-hour sampling), we collected first morning void samples. The sample means for specific gravity were not considered to be substantially different from the reference standard of 1.024, and fell well within the reference range for a normal healthy population (ie, 1.003 to 1.030). Should the sample means be a more accurate estimate of a true 24-hour mean specific gravity for the study participants than is the reference standard 1.024 used in the above equation, metal values corrected for specific gravity will represent a slight overestimation of amounts of arsenic and mercury present. Because the 1.024 reference standard has been the one most consistently used for specific gravity corrections in urinalysis, it has the added advantage of allowing for direct comparison with other studies.

Creatinine is a natural waste product discharged from muscle tissue on a relatively continuous basis and then filtered by the renal glomerulus. Creatinine clearance has been used in the past as an estimate of glomerular filtration rate (GFR). However, because creatinine is also dependent on the amount of lean muscle mass in a given study subject, this adjustment has been criticized by some as inappropriate, particularly if there is no data or surrogate available to correct creatinine levels for lean muscle mass. Some authors have concluded that specific gravity is a more appropriate correction. Others have concluded that, while specific gravity adjustments may be adequate for 24-hour samples, a creatinine correction for concentration-dilution effects is particularly important for spot samples (such as single first morning void) and for nonhomogeneous groups (Trevisan, 1990).

Because most metals, including mercury and arsenic, are known to be potent nephrotoxins, the appropriate correction for flow and concentration variation must be considered in the context of the analyte being investigated and the nature of its effect on the kidney itself. Most of the adverse effects to the kidney caused by these metals will be seen in the tubules. Mercury is known to be particularly destructive to tubular cells. In different physiologic states or in disease, marked fluctuations in solute concentration can occur which will then be reflected in the specific gravity for a given urine sample. Creatinine measurements will not be sensitive to the toxic effects on the renal tubules, whereas specific gravity will become unreliable.

The physiological processes regulating creatinine excretion are different from those controlling excretion of the salt and urea components, which primarily determine specific gravity (Elkins, 1974). Alessio et al. (1985) found the correlation between creatinine concentration and specific gravity in the same individual in the general population to be 0.49, indicating that these correction factors only partially explain the same phenomena.

While use of a creatinine correction to adjust individual urine metal concentrations is questionable, it still appears to be an appropriate adjustment to arrive at comparable group average data, and was used in the following analyses for this purpose. Creatinine was assessed for individual results only to screen for over-dilute or over-concentrated samples which would not be appropriate to use in subsequent analyses.

Because of the uncertainties involved with spot urine samples, all urine arsenic and mercury data were analyzed in four forms: (1) unadjusted urine concentration of the analyte; (2) adjusted concentration of analyte to a reference specific gravity of 1.024; (3) adjusted concentration of analyte to a per gram creatinine; and (4) adjusted concentration of analyte to a reference specific gravity of 1.024 and then adjusted to a per gram creatinine. All four forms were analyzed and compared among areas for potential confounding of urine metal results due to individual differences in urine concentration and flow rates. As previously noted, statistical analyses of all adjusted, unadjusted and redefined laboratory values were based on logarithmic (natural) transformed values.

In general, the levels of urine arsenic and mercury in this population were within the reference range for the general population and were not indicative of acute toxicity. However, urinary arsenic levels may not correlate well with clinical toxicity (Borgon et al, 1980). Normal values for urine arsenic are typically in the range of 20 to 50 ug/l, with values of 150 ug/l common in industrially exposed populations (ATSDR, 1989). Urine mercury values for a normal population are up to 20 ug/l (Iyengar, 1988), but are based on small numbers of observations. In this study, four persons had levels considered notifiable (two adults for arsenic, one adult and one child for mercury) and were recommended for re-testing. Upon retesting of three of the individuals, the values for arsenic and mercury were in the normal range.

Exposure to Arsenic

This exposure study provided no evidence that the presence or amount of arsenic in urine was related to the RMA. Frequency of detection was lower in area 1 and approximately the same in area 2 as in area 3. Arithmetic and geometric population mean urine arsenic levels were lower in areas 1 and 2 than in area 3, as was the mean level of quantifiable arsenic. Multivariate analytic procedures showed no evidence of increased risk for arsenic exposure associated with residence in area 1 or area 2.

In children, arsenic exposure was increased among males, persons of hispanic origin or non-white race and children who spent more time outdoors. These findings suggest that some outdoor activities might contribute to arsenic exposure among children, but the specific pathways could not be elucidated from the data gathered.

Arsenic exposure among adults was associated with younger age groups, hispanic origin or non-white race, consumption of fish and red wine during the previous week and certain occupations previously associated with arsenic (ATSDR, 1989a). Socio-economic status was inversely associated with risk for arsenic exposure, a finding without an obvious explanation. Consumption of locally produced beef and milk were also associated with exposure; the biological basis for this finding is unclear.

Exposure to Mercury

The arithmetic and geometric mean and median urine mercury values for area 1 were slightly lower than those for area 3, but the frequency and mean for quantifiable mercury was slightly higher in area 1. There was more evidence that mercury exposure was increased among residents of area 2, although the differences between area 2 and area 3 were small. Arithmetic and geometric mean urine mercury levels were higher in area 2 than in area 3, as were the frequency and means for quantifiable urine mercury. However, none of these differences were statistically significant.

Among children, mercury exposure was associated with the age group over 5, females, hispanic origin or non-white race, spending more time outdoors and living in a home surrounded by dirt or bare ground. Soil contact may be responsible for these findings but the specific pathways of exposure could not be defined. After controlling for confounding in multiple logistic regression analyses, the presence of quantifiable levels of mercury in urine of children was associated with residence in area 1 and area 2.

Mercury exposure among adults was associated with younger (<40) age, female gender, hispanic origin or non-white race, and certain occupations previously associated with mercury (ATSDR, 1989b). Socio-economic status, as determined by both level of educational achievement and income, was inversely associated with risk for mercury exposure; this finding is unexplained for mercury as well as for arsenic. Residence in area 2 was found to increase risk for exposure to mercury, after controlling for confounding.

Exposure to mercury containing fungicides or pesticides in the agricultural environment was suggested by finding elevated risk estimates for some, but not all, agricultural exposure variables. Increased risk associated with consumption of locally produced milk could also be related to soil residues from agricultural practices.

A second pathway which should be considered is ingestion of mercury in water. Increased levels of mercury in water, air and foliage near industries that use mercury have been reported (Lodenius and Tulisalo, 1984, Shaw et al. 1986). In this study, an increased risk of mercury exposure was found for use of well water and for irrigation of gardens with well water in area 2. Area 2 is a semi-industrial environment. Thus mercury may have entered the ground water in this area from localized industrial sources, potentially including the RMA. Increased environmental and human sampling is required to define this exposure pathway more completely.

VI. CONCLUSIONS

1. Arsenic was detected and quantified in urine from 43 of the 469 persons (9.2%). Non-quantifiable (trace) levels of arsenic were detected in an additional 38.6% of the individuals sampled; 52.2% had no evidence of urine arsenic at the detection limit of 10 ppb.

2. The frequency of mercury detection in urine was lower than for arsenic. Mercury was detected and quantified in 32 persons, 6.9% of the sample. Trace values for mercury were found in 17.1% of persons sampled; 76% of the persons sampled had no evidence of mercury exposure at the detection limit of 5 ppb.

3. This exposure study provided no evidence that the presence or amount of arsenic in urine was related to the RMA. Frequency of arsenic detection was lower in area 1 and approximately the same in area 2 as for area 3. Arithmetic and geometric population mean urine arsenic levels were slightly lower in areas 1 and 2 than in area 3, as was the mean level of quantifiable arsenic. Multivariate analytic procedures showed little evidence of increased risk for arsenic exposure associated with residence in area 1 or area 2. None of the differences found were statistically significant.

4. The arithmetic and geometric mean and median urine mercury values for area 1 were slightly lower than those for area 3, but the frequency and mean for quantifiable mercury was slightly higher in area 1 and in area 2 than in area 3. However, differences between the geometric mean values for quantifiable urine mercury were eliminated after correction for creatinine or specific gravity.

5. There was some evidence that mercury exposure was increased among residents of area 2. The frequency of detection and arithmetic mean for those with quantifiable urine mercury were higher in area 2 than in area 3, although the differences between area 2 and area 3 were small. After adjustment for confounding in multivariate analyses, residence in area 2 remained associated with risk of quantifiable urine mercury among children and adults. However, none of these differences were statistically significant.

6. Four independent analyses were used to evaluate quantifiable and non-quantifiable levels of urine arsenic and mercury. There were no statistically significant differences in arithmetic and geometric means among areas irrespective of the method of data analysis employed.

7. In multivariate analyses which controlled for confounding, male gender, hispanic origin or non-white race and spending more time outdoors showed an association with urine arsenic among children. Those children who were over 5 years of age, female, of hispanic origin or non-white race, spent more time outdoors or lived in a home surrounded by dirt or bare ground had an elevated risk estimate for urine mercury. However, none of the risk factors evaluated for children were significantly associated with a quantifiable level of urine arsenic or urine mercury ($p > 0.05$).

8. Among adults, persons who were less than 40 years of age, of hispanic origin or non-white race and those employed in a hazardous occupation had a significantly increased risk of having a quantifiable level of urine arsenic in multivariate analyses. Consumption of fish and red wine in the previous week were also associated with exposure to arsenic.

9. Persons less than 40 years of age, women, persons of hispanic origin or non-white race and those who worked in electroplating, welding or battery manufacture had an increased risk of having mercury in urine. Persons who had completed less than 12 years of education had a lower risk of exposure to mercury.

10. None of the activities directly involving the RMA were significantly associated with urine arsenic or mercury exposure.

11. Persons who consumed well water in area 2 or used well water on their gardens in area 2 had an increased risk of having a quantifiable level of urine mercury.

12. As a group, persons who lived in areas 1, 2 and 3 and consumed locally produced beef and milk had an elevated risk for having a quantifiable level of urine arsenic. This association was also seen for beef and milk consumption and arsenic exposure and for milk consumption and mercury exposure in areas 1 and 2 although some of the risk estimates were imprecise.

VII. RECOMMENDATIONS

1. Additional urine samples from this population should be obtained during the summer months, in order to assure that the winter sampling did not affect the results for arsenic and mercury.

2. The study population should be followed longitudinally to evaluate changes in exposure to arsenic and mercury over time as well as to evaluate the seasonal effects on sampling.

3. Followup evaluation of arsenic and mercury levels in locally produced milk and beef should be undertaken. Tissue levels of arsenic and mercury in locally produced meat and milk should be determined by laboratory analyses. If these are found to be elevated, then further evaluation of local soil conditions, water sources, feed substances and other potential contributors to arsenic and mercury concentrations in animal tissues should be conducted.

4. Evaluation of ground water quality in area 2 should be conducted to assess mercury concentrations.

5. Improved and expanded environmental characterization of contamination in neighborhoods surrounding the RMA should be conducted to evaluate air, soil, surface water, ground water and food pathways for human exposure. As part of the remediation process, ongoing environmental monitoring should be conducted to evaluate offsite contamination, especially during periods of remedial activity.

6. For several classes of contaminants present at the RMA, biomonitoring procedures to evaluate current exposures are technically difficult or impossible to conduct. Furthermore, the exposure study will only evaluate a small proportion of the total number of contaminants present at the site. Therefore, a study of sensitive indicators of health effects in this population should be undertaken. Studies which incorporate the measurement of biomarkers would add important information to that derived from the current pilot exposure study.

REFERENCES

ATSDR (1988) Preliminary Health Assessment for Rocky Mountain Arsenal, Commerce City, Adams County, Colorado. Office of Health Assessment, Agency for Toxic Substances and Disease Registry, U.S. Public Health Service.

ATSDR (1989a) Toxicological Profile for Arsenic. ATSDR, USPHS. Atlanta, /TP/88-02.

ATSDR (1989b). Toxicologic Profile for Mercury. ATSDR, USPHS. Atlanta, /TP-89/16.

Alessio L, Berlin A, Dell'Orto A et al., Reliability of urinary creatinine as a parameter used to adjust values of urinary biological indicators. Int Arch Occup Environ Health 1985; 55:99-106.

Arguello RA, Tello EE, Cenget DD. Cancer and regional endemic chronic arsenicalism. Br J Dermatol 1939; 51:548.

Bakir F, Daluji SF, Amin-Zaki L et al. Methyl mercury poisoning in Iraq. Science 1973;181:230-241.

Berlin A, Alessiio L, Sesana G, Dell'Orto A and Ghezzi I. Problems concerning the usefulness of adjustment of urinary cadmium for creatinine and specific gravity. Int Arch Occup Environ Health 1985;55:107-111.

Borgono JM, Vincent P, Venturino H, Infante A. Arsenic in drinking water of the city of Antofagasta: Epidemiological and clinical study before and after the installation of a treatment plant. Environ. Health Perspect. 1977;19:103-105.

Casarett and Doull. 1986. Toxicology. 3rd ed. Klassen CD, Amdur MO and Doull J, eds. MacMillan Press, New York.

Chen C.J., Chuang Y.C., You S.L., Lin T.M. and Wu H.Y. A retrospective study on malignant neoplasms of bladder, lung, and liver in Blackfoot disease endemic area in Taiwan. Br J Cancer 1986;53:399-405.

Cherian MG, Hursh JG, Clarkson TW et al. Radioactive mercury distribution in biological fluids and excretion in human subjects after inhalation of mercury vapor. Arch Environ Health 1978; 33:190-214.

Clarkson TW, Friberg L, Nordberg GF and Sager PR, eds. 1988. Biological Monitoring of Toxic Metals. Plenum Press, New York.

Coleman Instruments: Operating Manual for Coleman Mercury Analyzer

MAS-50.

Colorado Department of Health. Colorado Disease Bulletin. The Rocky Mountain Arsenal Site History and Update. February 24, 1989; 17:4

Diamond GL. Biological monitoring of urine for exposure to toxic metals. In: Biological Monitoring of Toxic Metals. Clarkson TW, Friberg L, Nordberg GF, and Sager PR, eds. New York: Plenum Press 1985.

EBASCO Services, Inc., Applied Environmental, Inc., CH2M Hill, DataChem, Inc., R.L. Stollar & Assoc. Final Human Health Exposure Assessment for Rocky Mountain Arsenal. Version 4.1, September 1990, Contract No. DAAA15-88-D-0024, RIFS2. Prepared for U.S. Army Program Manager's Office for the RMA Contamination Cleanup.

Elkins HB, Pagnotto LD and Smith HL. Concentration adjustments in urinalysis. Am Ind Hyg Assoc J 1974;35:559-565.

Engelson G, Herner T. Alkyl mercury poisoning. Acta Ped Scand 1952;41:289-94.

ESE (Environmental Science and Engineering, Inc.) Biota Remedial Investigation (2.2) Prepared for Office of the Program Manager, Rocky Mountain Arsenal Contamination Cleanup, 1989a.

ESE (Environmental Science and Engineering, Inc.) et al., Offpost Operable Unit, Endangerment Assessment/Feasibility Study with Applicable or Relevant and Appropriate Requirements. Draft Final Report Version 2.1, vol I, March, 1989b.

ESE (Environmental Science and Engineering, Inc.) Data Assessment and Analysis for the Offpost Feasibility Study with Applicable or Relevant and Appropriate Requirements. Office of the Program Manager, Rocky Mountain Arsenal. Commerce City, Colorado, 1988a.

ESE (Environmental Science and Engineering, Inc). Offpost Operable Unit Remedial Investigation and Chemical Specific Applicable or Relevant and Appropriate Requirements. Final Report (Version 3.1), Volume I-III. Office of the Program Manager, Rocky Mountain Arsenal. Commerce City, Colorado, 1988b.

ESE (Environmental Science and Engineering, Inc). Offpost Assessment Contamination, Contamination Assessment Report, Volume I-III. Draft Final Report. Office of Program Manager, Rocky Mountain Arsenal. Aberdeen Proving Ground, Maryland, 1987.

Foldspang A, Hansen JC. Dietary intake of methylmercury as a correlate of gestational length and birth weight among newborns in Greenland. Am J Epidemiol 1990;132:310-17.

Harrington JM, Middaugh JP, Morse DL, Houseworth J. A survey of a population exposed to high concentrations of arsenic in well water in Fairbanks, Alaska. Am J Epidemiol 1978;108: 377-385.

Hayes W Jr. Pesticides Studied in Man. Williams and Wilkins Co., Baltimore, MD. 1982 pp 41-74.

Iyengar V, Woittle J. Trace elements in human clinical specimens: Evaluation of literature data to identify reference values. Clin Chem 1988; 34:474-481.

Landrigan PJ. Arsenic - State of the Art. Am J Ind Med 1981;2:5-14.

Levine L and Fahy JP. Evaluation of urinary lead determination. J Industr Hyg Tox 1945; 27:217.

Lodenius M, Tulisalo E. Environmental mercury contamination around a chlor-alkali plant. Bull Environ Contam Toxicol 1984; 32:439-444.

Mabuchi K. Lung cancer among pesticide workers exposed to inorganic arsenicals. Arch. Environ. Health. 1979; Sept/Oct. pp 312-319.

Marsh DO, Myers GJ, Clarkson TW et al. Fatal methyl mercury poisoning; clinical and toxicological data on 29 cases. Ann Neurol 1980;7:348-355.

Matsumoto H, Suzuki A, Morita C. Fetal Minamata Disease: a neuropathological study of two cases of intrauterine intoxication by a methyl mercury compound. J Neuropathol Exp Neurol 1965;24:563-74.

Miller J, Chaffin D, Smith R. Subclinical psychomotor and neuromuscular changes in workers exposed to inorganic mercury. Am Ind Hyg Assoc J 1975;33:725-733.

Morton W, Starr G, Pohl D, Stoner J, Wagner S, Weswig P. Skin cancer and water arsenic in Lane County, Oregon. Cancer 1976;37: 2523-2532.

Ott MG, Holder BB, Gordon HL. Respiratory cancer and occupational exposure to arsenicals. Arch Environ Health 1984; 29:250-255.

Patterson JE, Weissberg DG, Dennison PJ. Mercury in human breath from dental amalgams. Bull Environ Contam Toxicol 1985;34:459-468.

Pershagen G. The Carcinogenicity of Arsenic. Environ Health Perspec 1981;40: 93-100.

Piikivi L, Hanninen H, Martelin T et al. Psychological performance and long term exposure to mercury vapors. Scand J Work Environ Health 1984;10:35-41.

Shaw BP, Sahu A, Panigrahy AK. Mercury in plants, soil and water from a caustic chlorine industry. Bull Environ Contam Toxicol 1986;

36:299-305.

Smith PJ, Longolf GD, Goldberg J. Effects of occupational exposure to elemental mercury on short term memory. Br J Ind Med 1983;40:413-419.

Smith RG, Varwald AJ, Patel LS et al. Effects of exposure to mercury in the manufacture of chlorine. Am Ind Hyg Assoc J 1970;3:687-700.

Southwick JW, Western AE, Beck MM et al. 1981. Community health associated with arsenic in drinking water in Millard County, Utah. Final Report. EPA 600/1-810064. Cincinnati, Ohio: U.S. EPA , Health Effects Research Lab. 74pp.

Tamashiro H, Agaki H, Arakaki M et al. Causes of death in Minamata Disease: Analysis of death certificates. Int Arch Occup Environ Health 1984;54:135-46.

Taylor JR. Neurotoxicity of certain environmental substances. Clin Lab Med. 1984;4:489-497.

Thorne, David S., et al. (1979) Biological Monitoring of Pesticides, Heavy Metals and Other Contaminants at Rocky Mountain Arsenal Phase I. Dept. of the Army, Rocky Mountain Arsenal, Commerce City, CO.

Trevisan A. Concentration adjustment of spot samples in analysis of urinary xenobiotic metabolites. Am J Indust Med. 1990;17:643.

Tseng W-P., Chu HM, How SW, Fong JM, Lin CS. Prevalence of skin cancer in an endemic area of chronic arsenicism in Taiwan. J Natl Cancer Inst 1968;40:453-463.

U.S. EPA. 1983. Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory, Office of Research and Development. Cincinnati, OH. 206.3, 245.2.

U.S. EPA. 1984. Health effects assessment for arsenic. Office of Emergency and Remedial Response, Washington DC. EPA/540/1-86-020. September, 1984.

Vahter M. 1988. Arsenic. In:Biological Monitoring of Toxic Metals. Clarkson TW, Friberg L, Nordberg GF and Sager PR, eds. Plenum Press, New York.

Verberk M, Salle H, Kemper C. Tremor in workers with low exposure to metallic mercury. Am Ind Hyg Assoc J 1986;47:559-562.

Voth-Beach LM, Shrader DE. Reduction of interferences in the determination of arsenic and selenium by hydride generation. Spectroscopy 1985;1:60.

Vroom FQ, Greer M. Mercury vapor intoxication. Brain 1972;95:305-318.

Williamson AM, Teo R, Sanderson J. Occupational mercury exposure and its consequences for behavior. Int Arch Occup Environ Health 1982; 50:273-286.

ACKNOWLEDGEMENTS

The authors of this report wish to thank the people whose help, guidance, patience and cooperation made this study possible.

We would especially like to thank Dr. P. Michael Wilson, Dr. Ellen Mangione, Lane Cook, Susan Miller, Claudia Carmody, Char Butler, Rosemary Novakovich, Yvonne Herman, Lee Koleski, Dr. Robert McCurdy, Lee Theilen and Thomas Haddon of the Colorado Department of Health;

Dr. Robert Amler, Dr. Michael Straight, Terry Maricle, Susan Baburich and Marcie Edwards at the Agency for Toxic Substances and Disease Registry;

Donna Winn and Denise May of the Department of Environmental Health at Colorado State University;

For the use of facilities at Rosemary Street Building we would like to thank the staff of Adams County School District #14 and Commerce City Community Health Services, especially Ronnie Rosenblum and Betty Peppin who made room for us and welcomed us through the winter of 1989-90;

To the people of Commerce City, Brighton, Lochbuie, Irondale and Henderson without whose participation and great patience we could not have done this study;

To the Mayor and City Manager of Commerce City, the Mayor and Town Council of Lochbuie, the Mayor and City Manager of Brighton, the Adams County Commissioners, the Weld County Commissioners, the Commerce City Police Department, and the Adams County Sheriff's Department for help in getting the field study started;

To Beth Gallegos for her help in arranging public meetings;

To Norm from the Commerce City Beacon and Susan of the Commerce City Sentinel for their continued interest in the study;

And finally, we would like to extend our great thanks and respect for the stalwart and cheerful members of our field staff, census takers, interviewers, and phlebotomists, who braved the weather, long hours and our stringent specifications to gather the data upon which we depended for this report.

Figure 1

General Area of the Rocky Mountain Arsenal

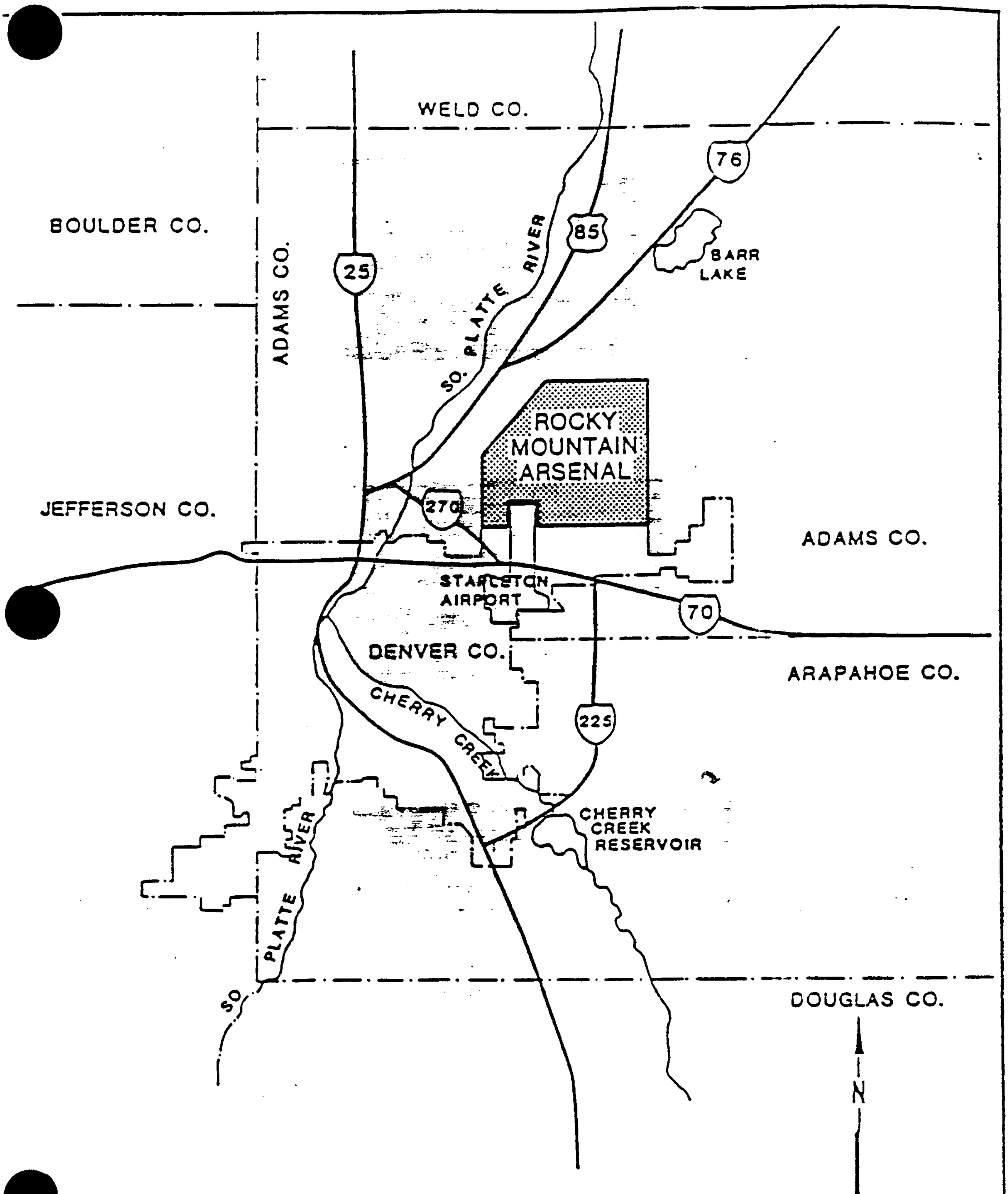


Figure 2

Land Use Patterns in the Vicinity of the Rocky Mountain Arsenal

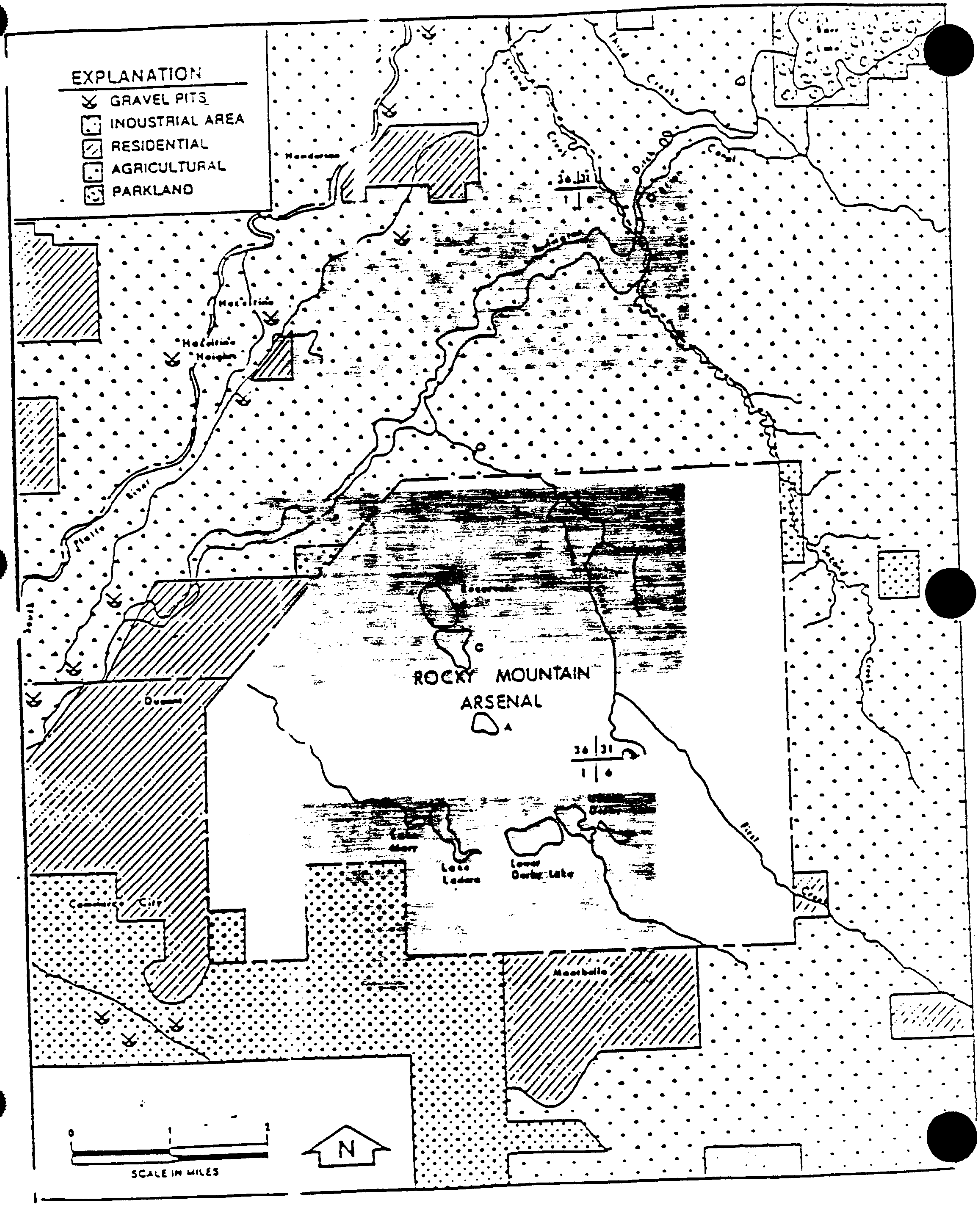
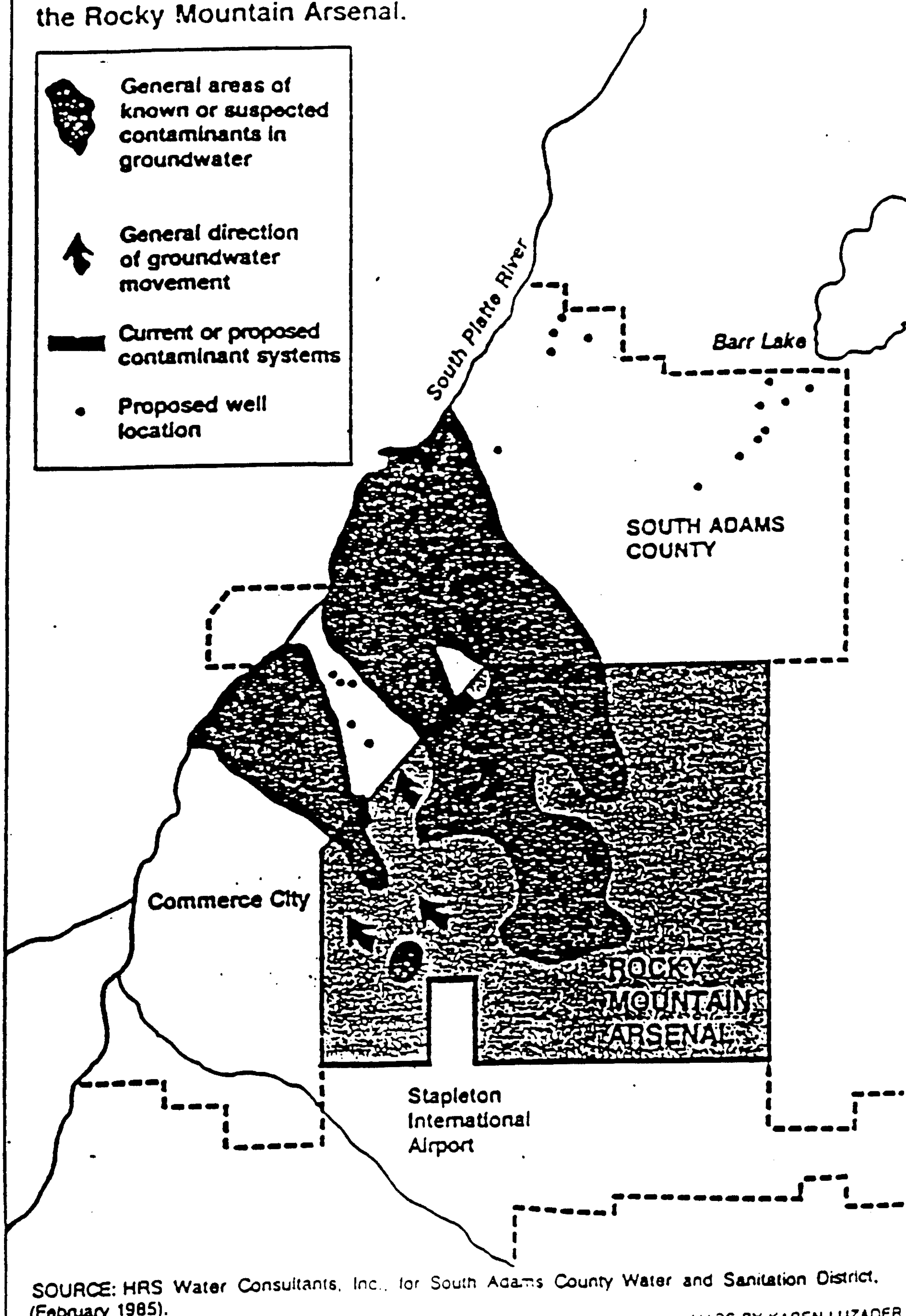


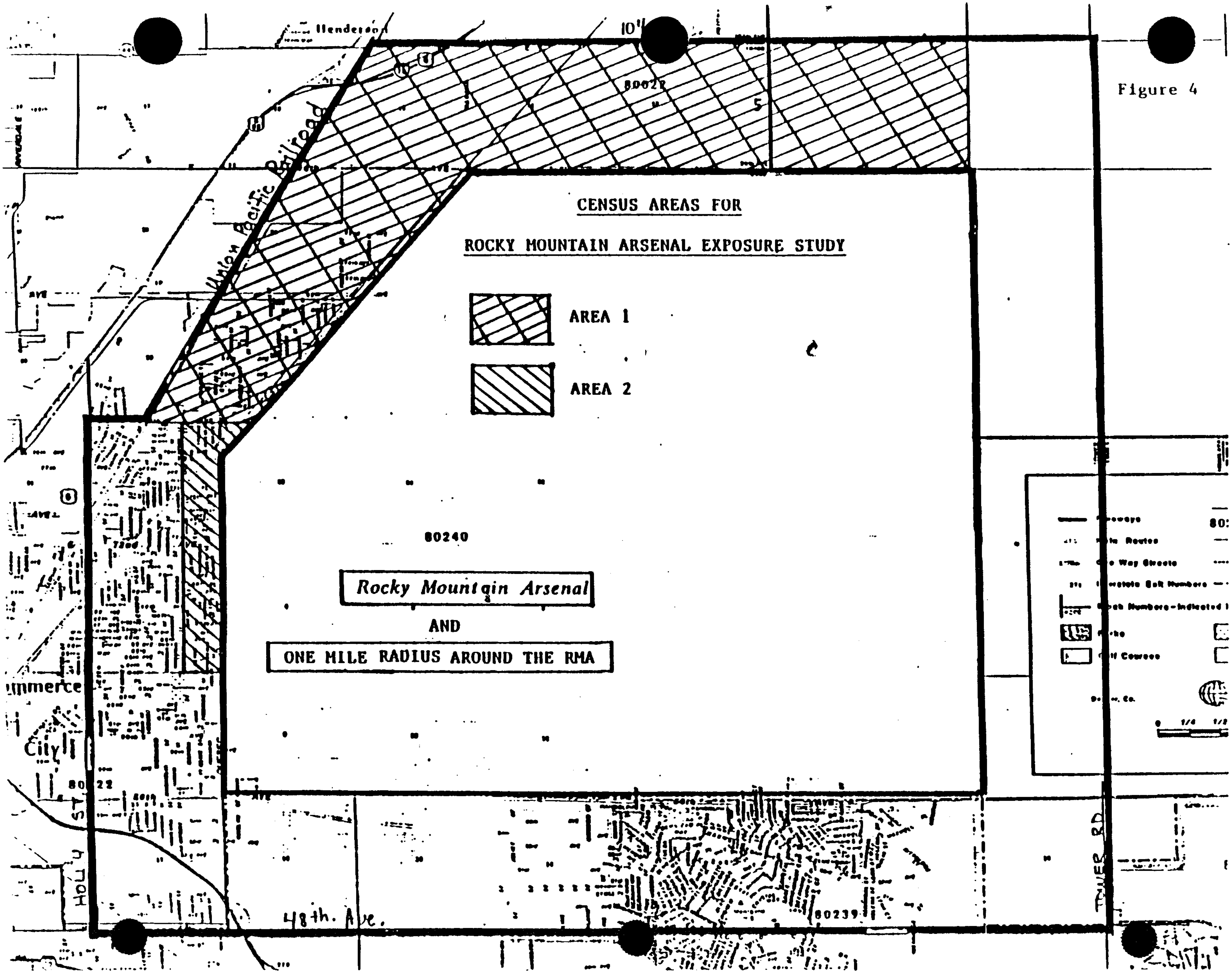
FIGURE 3 Contamination in South Adams County around the Rocky Mountain Arsenal.



SOURCE: HRS Water Consultants, Inc., for South Adams County Water and Sanitation District. (February 1985).

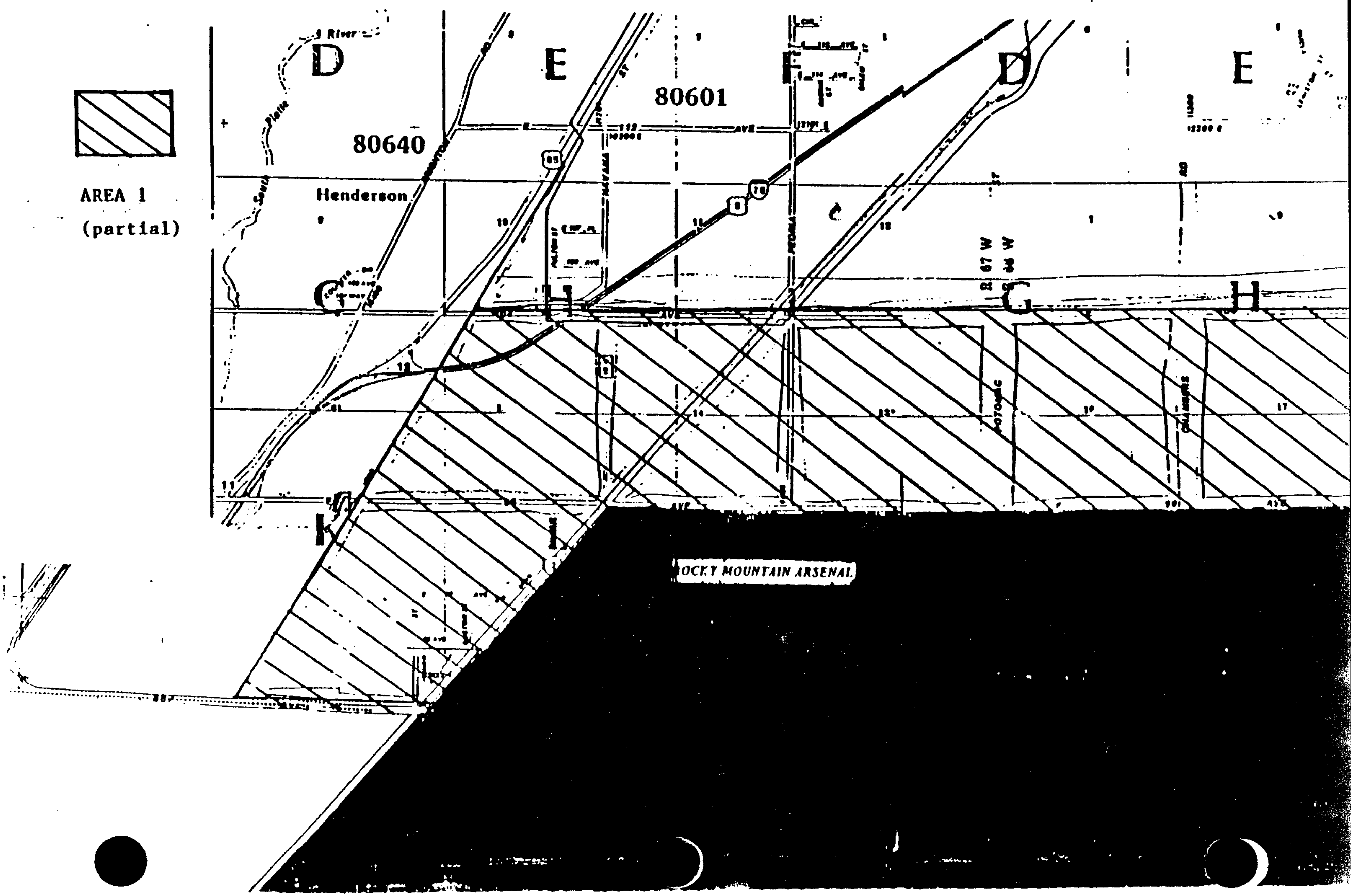
MAPS BY KAREN LUZADER

Figure 4


CENSUS AREAS FOR
ROCKY MOUNTAIN ARSENAL EXPOSURE STUDY
AREA 1
AREA 2
80240
Rocky Mountain Arsenal
AND
ONE MILE RADIUS AROUND THE RMA
80022
80239
Henderson
Union Pacific Railroad
48th. Ave.
Holly St
Tower Rd
Commerce City

PARTICIPANT STUDY AREA 1 (partial) FOR ROCKY MOUNTAIN ARSENAL EXPOSURE STUDY

Figure 5



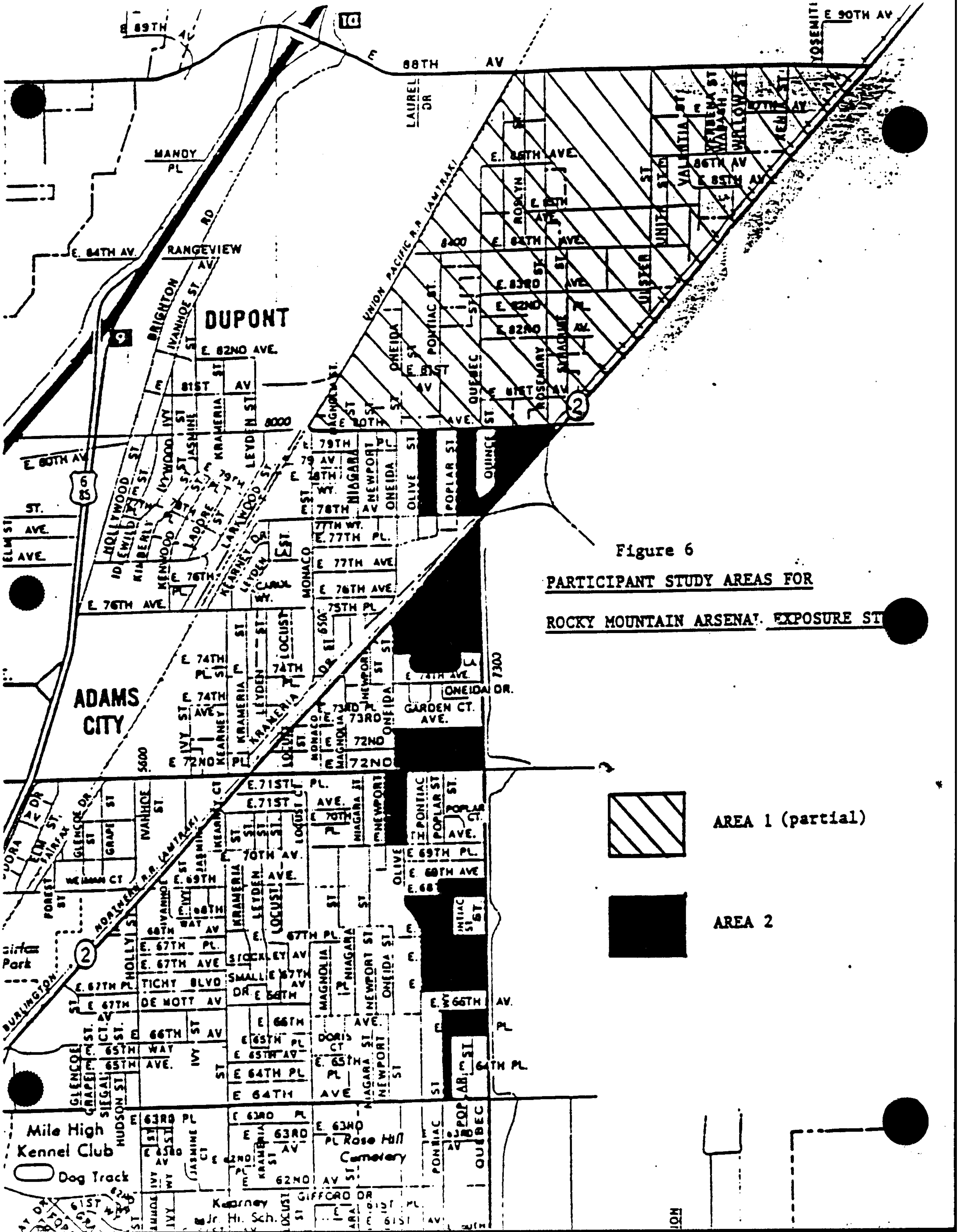


Figure 6

PARTICIPANT STUDY AREAS FOR

ROCKY MOUNTAIN ARSENAL EXPOSURE ST

TOWN OF LOCHBUIE - PART OF CENSUS AREA 3 FOR THE ROCKY MOUNTAIN

ARSENAL EXPOSURE STUDY

Figure 7a

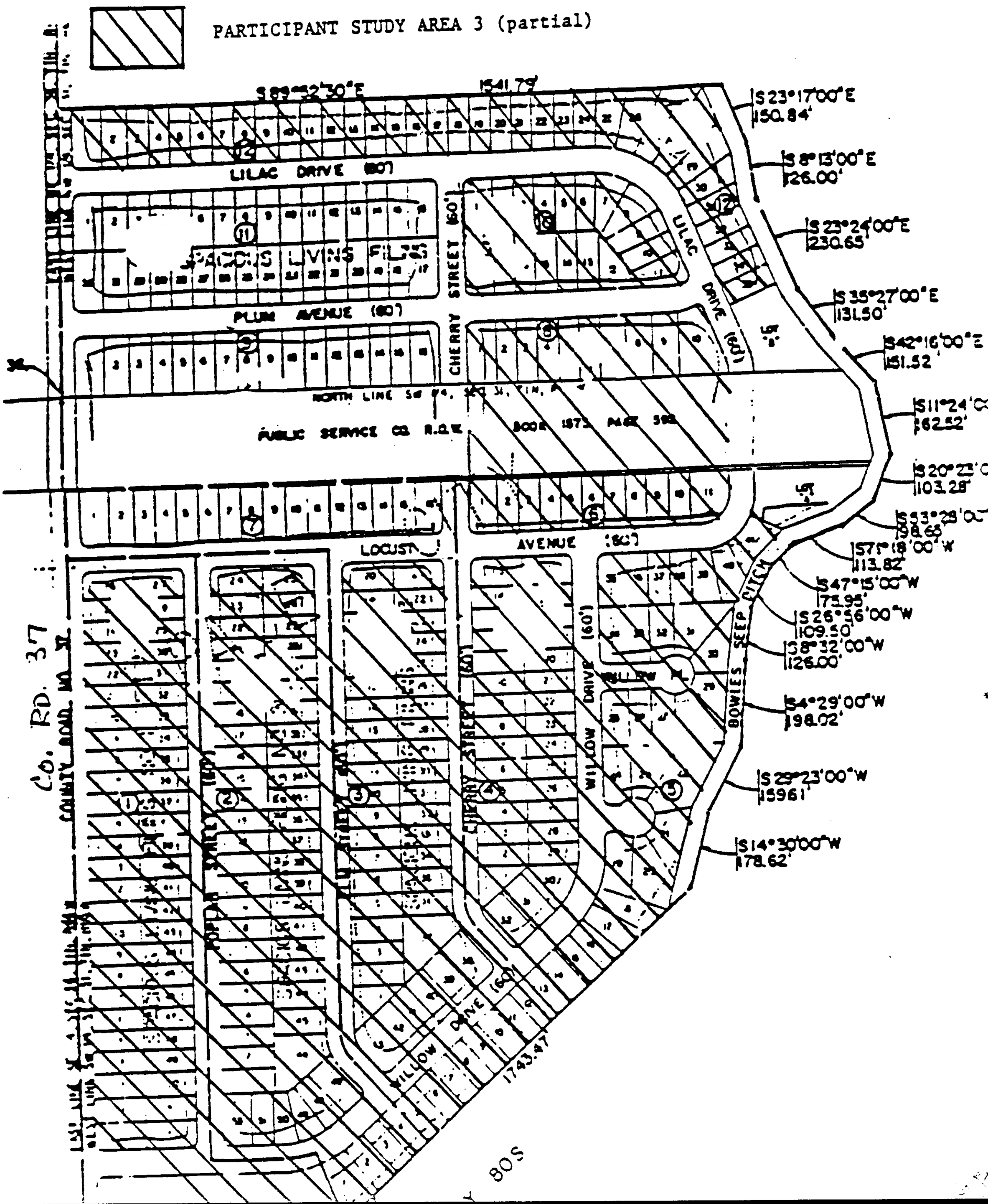
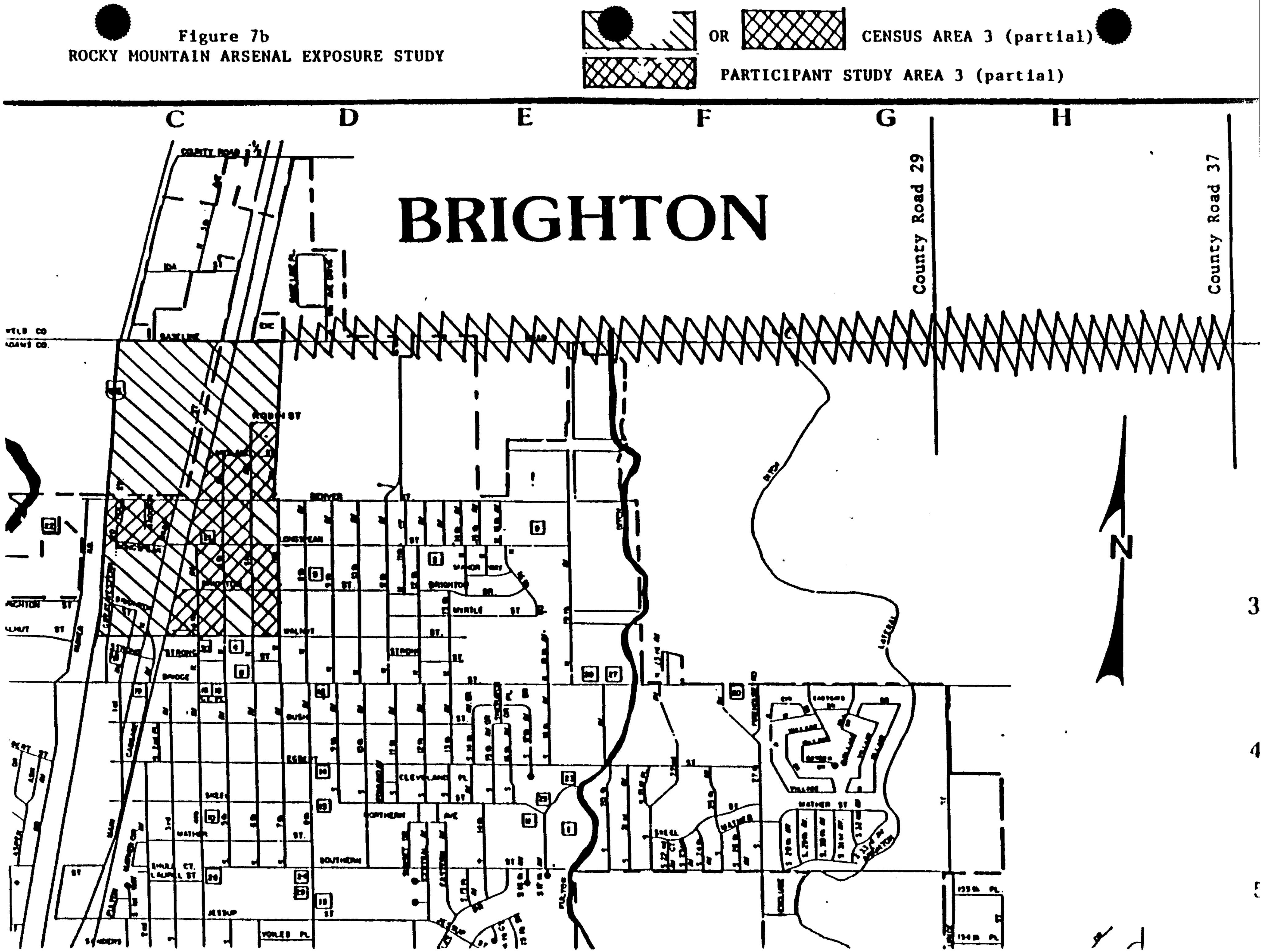


Figure 7b
ROCKY MOUNTAIN ARSENAL EXPOSURE STUDY



3

4

5

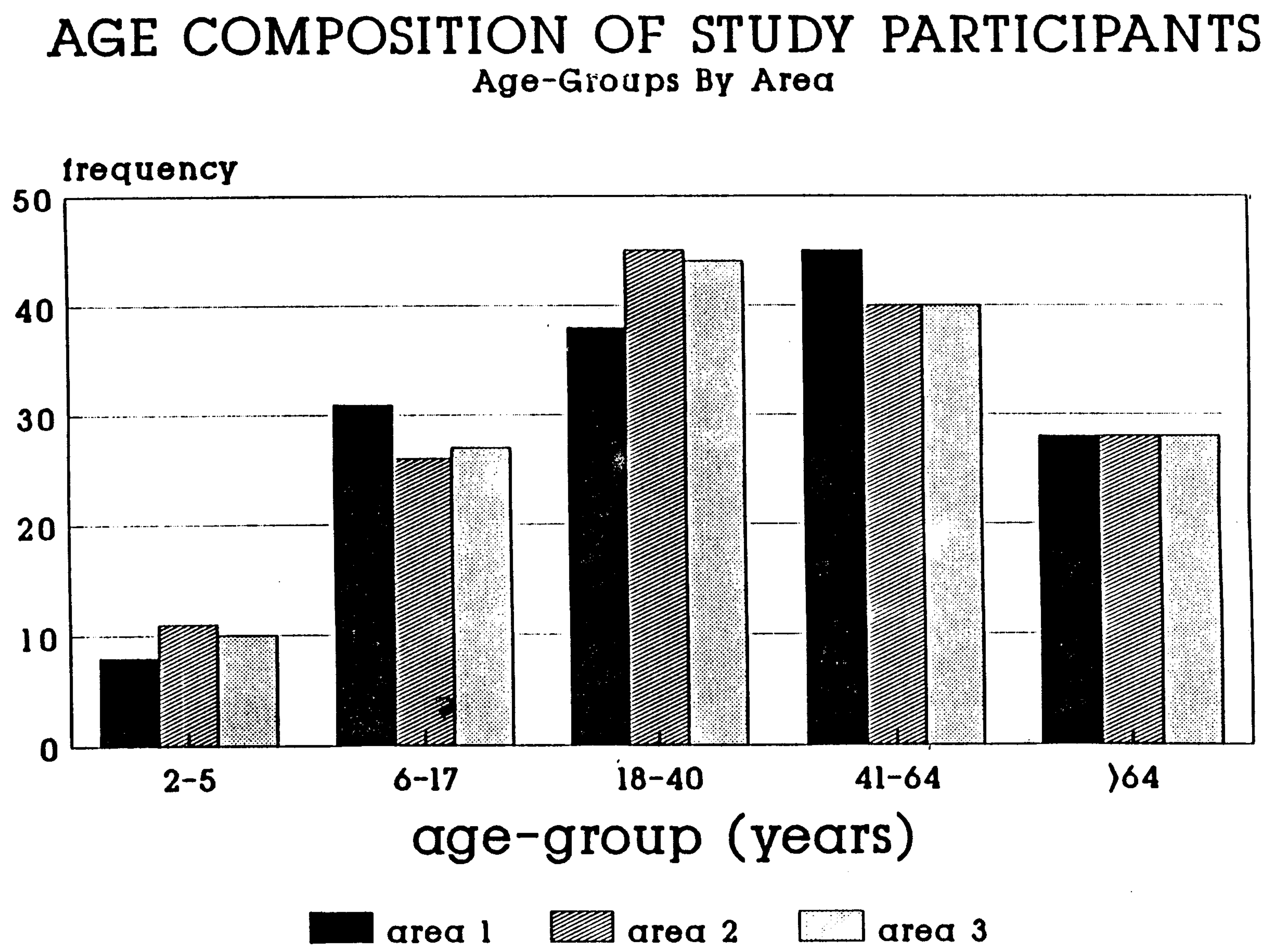


Figure 8. RMA Exposure Study

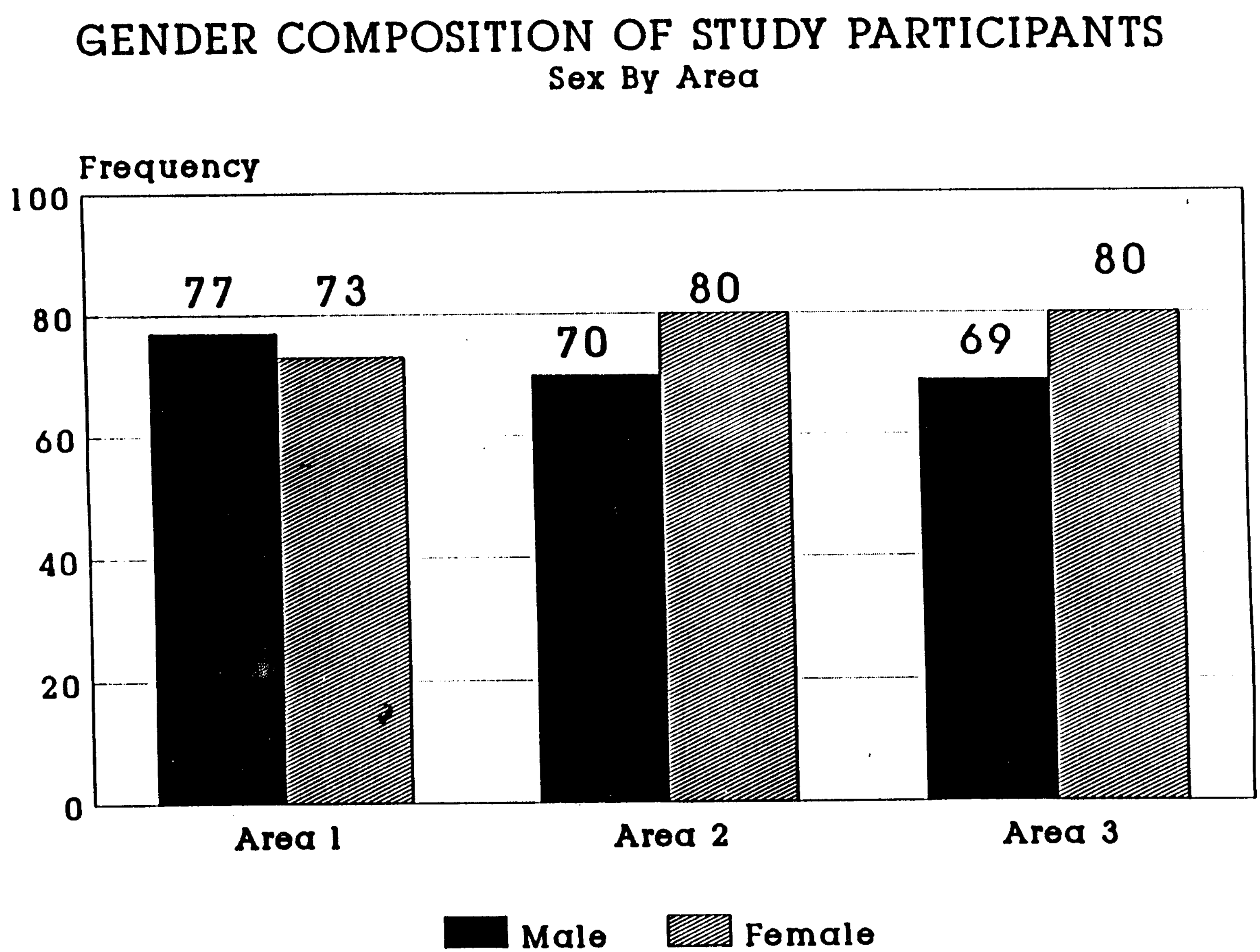


Figure 9. RMA Exposure Study

MEAN ARSENIC LEVELS BY AREA
(For levels 〉 D.L.=10ppb)

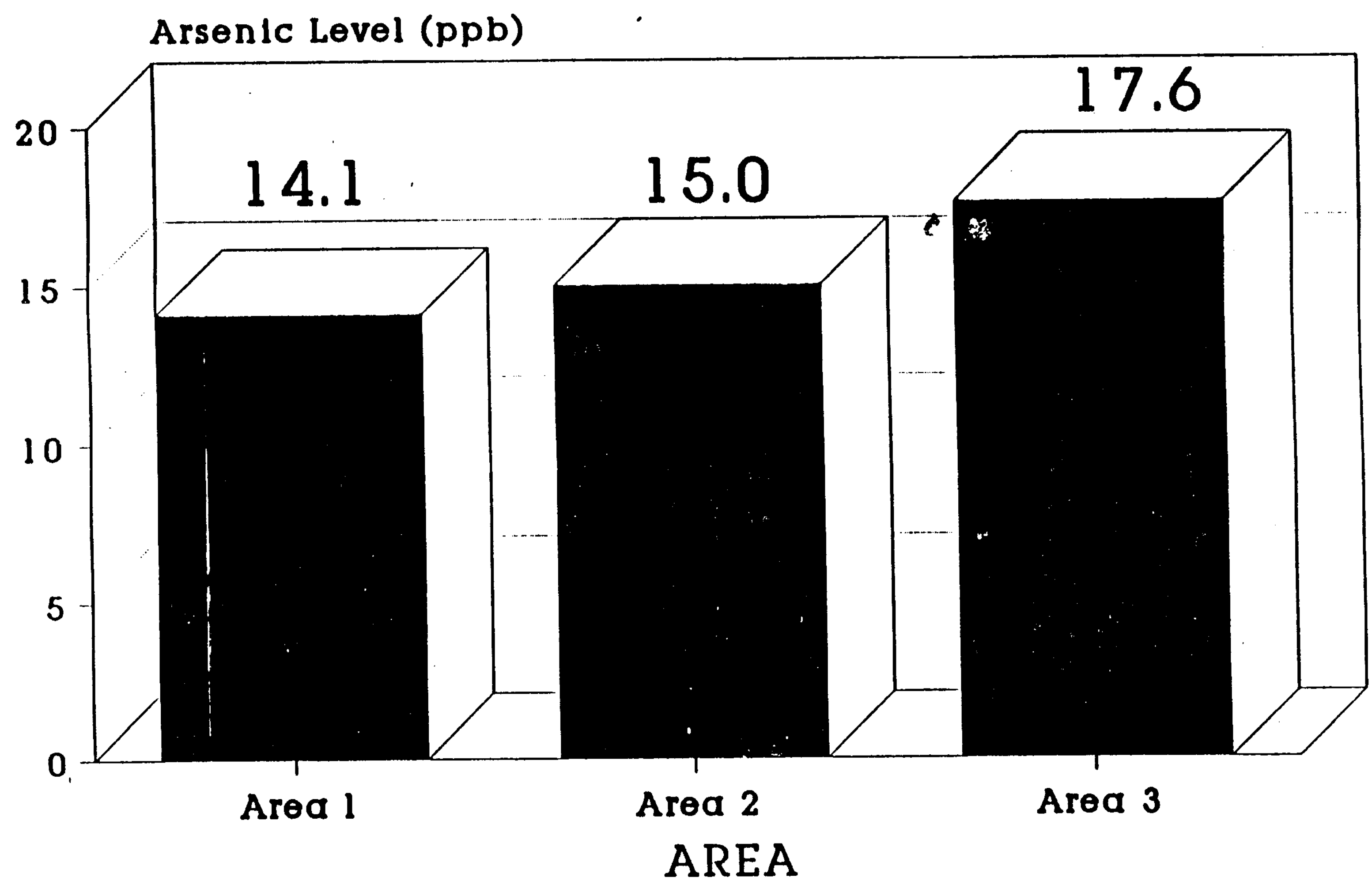


Figure 10. RMA Exposure Study

MEAN MERCURY LEVELS BY AREA

(For values 〉 D.L.= 5ppb)

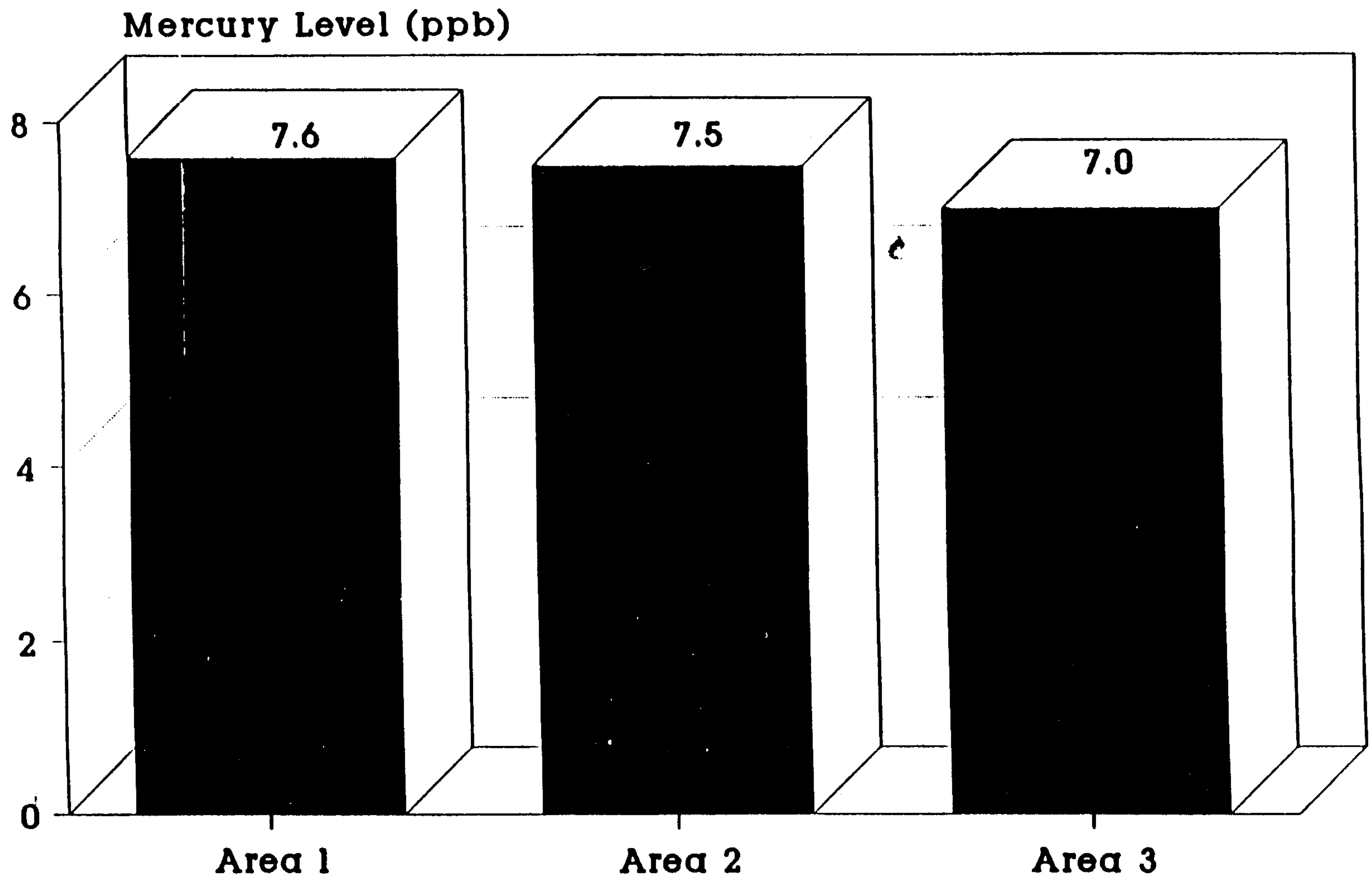
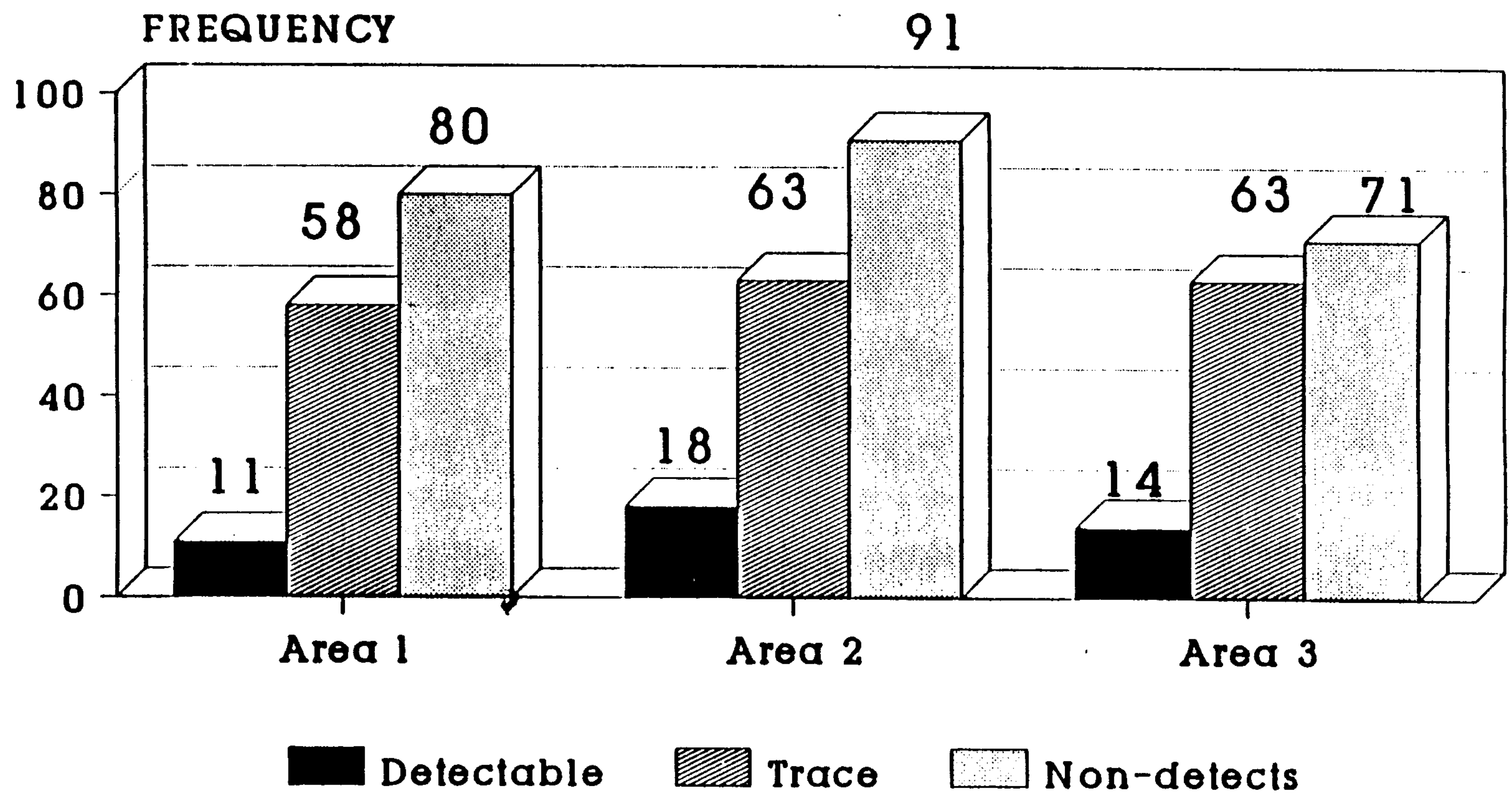


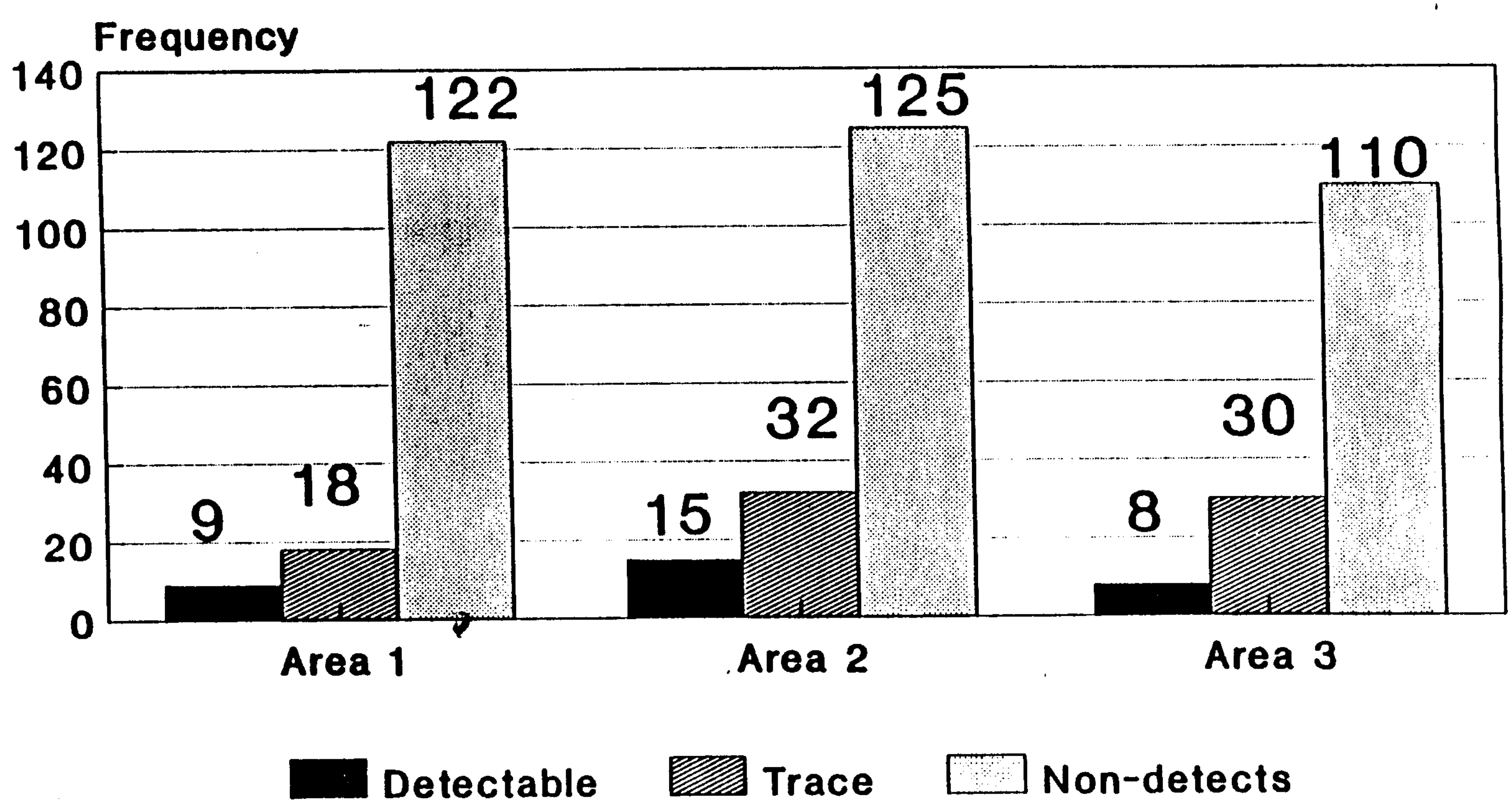
Figure 11. RMA Exposure Study

Frequency of Detectable Arsenic Levels
Rocky Mountain Arsenal Exposure Study
Figure 12



Area 1 N=149
Area 2 N=172
Area 3 N=148

Frequency of Detectable Mercury Levels
Rocky Mountain Arsenal Exposure Study
Figure 13



Area 1 N=149
Area 2 N=172
Area 3 N=148

Table 1. Census Population by Age Group, Gender and Area. Rocky Mountain Arsenal Exposure Study, 1989-1990.

(N = 2552)

Area 1 (n_1 = 598)

Age Group	Male		Female		Total
	No.	%	No.	%	%
2-9	47	7.9	42	7.0	14.9
10-19	42	7.0	27	4.5	11.5
20-29	39	6.5	36	6.0	12.5
30-39	48	8.0	32	5.4	13.4
40-49	42	7.0	38	6.4	13.4
50-59	44	7.4	36	6.0	13.4
60-69	29	4.9	37	6.2	11.0
≥70	23	3.8	36	6.0	9.9
	314	52.5%	284	47.5%	100.0%

Area 2 (n_2 = 795)

Age Group	Male		Female		Total
	No.	%	No.	%	%
2-9	50	6.3	36	4.5	10.8
10-19	61	7.7	62	7.8	15.5
20-29	43	5.4	45	5.7	11.1
30-39	61	7.7	77	9.7	17.4
40-49	66	8.3	59	7.4	15.7
50-59	40	5.0	43	5.4	10.4
60-69	48	6.0	49	6.2	12.2
≥70	27	3.4	28	3.5	6.9
	396	49.8%	399	50.2%	100.0%

Area 3 (n_3 = 1159)

Age Group	Male		Female		Total
	No.	%	No.	%	%
2-9	71	6.1	80	6.9	13.0
10-19	92	7.9	97	8.4	16.3
20-29	77	6.6	82	7.1	13.7
30-39	87	7.5	89	7.7	15.2
40-49	61	5.3	83	7.2	12.4
50-59	61	5.3	61	5.3	10.5
60-69	55	4.7	57	4.9	9.7
≥70	38	3.3	68	5.9	9.1
	542	46.8%	617	53.2%	100.0%

Table 2. Random Sample by Age Group, Gender and Area. Rocky Mountain Arsenal Exposure Study, 1989-1990. (N = 1457)

Area 1 (n_1 = 376)

Age Group	Male No.	Male %	Female No.	Female %	Total %
2-9	26	6.9	25	6.6	13.6
10-19	30	8.0	17	4.5	12.5
20-29	21	5.6	23	6.1	11.7
30-39	33	8.8	21	5.6	14.4
40-49	29	7.7	20	5.3	13.0
50-59	22	5.9	22	5.9	11.7
60-69	23	6.1	20	5.3	11.4
≥70	16	4.3	28	7.4	11.7
	200	53.2%	176	46.8%	100.0%

Area 2 (n_2 = 469)

Age Group	Male No.	Male %	Female No.	Female %	Total %
2-9	29	6.2	25	5.3	11.5
10-19	39	8.3	26	5.5	13.9
20-29	23	4.9	24	5.1	10.0
30-39	44	9.4	33	7.0	16.4
40-49	34	7.3	27	5.8	13.0
50-59	23	4.9	23	4.9	9.8
60-69	39	8.3	29	6.2	14.5
≥70	23	4.9	28	6.0	10.9
	254	54.2%	215	45.8%	100.0%

Area 3 (n_3 = 612)

Age Group	Male No.	Male %	Female No.	Female %	Total %
2-9	39	6.4	34	5.6	11.9
10-19	46	7.5	33	5.4	12.9
20-29	44	7.2	32	5.2	12.4
30-39	53	8.7	41	6.7	15.4
40-49	36	5.9	41	6.7	12.6
50-59	36	5.9	29	4.7	10.6
60-69	43	7.0	39	6.4	13.4
≥70	32	5.2	34	5.6	10.8
	329	53.8%	283	46.3%	100.0%

Table 3. Stages in Selection of Study Participants. Rocky Mountain Arsenal Exposure Study, 1989-1990.

Sampling Stage	Study Area 1	Study Area 2	Study Area 3
Residents enumerated through census	758	1004	1631
Residents meeting one year eligibility requirement	598	795	1159
Random sample from one year eligibles	376	469	612
Residents meeting two year eligibility requirement	330	437	544
Residents meeting 5 days per week and 9 months per year eligibility requirement	321	428	536
Area 3 residents not living within 1 mile of RMA in past 10 years			518
Number of Eligibles	321	428	518
No contacts	8	5	3
Screening Refusal	66	104	186
Preliminary Participation Rate (includes no contact)	76.9	74.5	63.5
Invited to Participate	188	204	193
Participated	158	178	152
Participation Rate	84.0	87.3	79.2

Table 4. Study Participants by Age Group, Gender and Area. Rocky Mountain Arsenal Exposure Study, 1989-1990.

(N = 472)

Area 1 (n_1 = 150)

Age Group	Male No.	Male %	Female No.	Female %	Total %
2-9	12	8.0	7	4.7	12.7
10-19	12	8.0	10	6.7	14.7
20-29	7	4.7	7	4.7	9.3
30-39	11	7.3	8	5.3	12.7
40-49	12	8.0	13	8.7	16.7
50-59	7	4.7	12	8.0	12.6
60-69	12	8.0	9	6.0	14.0
≥70	4	2.7	7	4.7	7.3
	77	51.3	73	48.7	100.0

Area 2 (n_2 = 173)

Age Group	Male No.	Male %	Female No.	Female %	Total %
2-9	7	4.0	14	8.1	12.1
10-19	14	8.1	8	4.6	12.7
20-29	6	3.5	13	7.5	11.0
30-39	12	6.9	14	8.1	15.0
40-49	15	8.7	14	8.1	16.8
50-59	7	4.0	7	4.0	8.1
60-69	15	8.7	10	5.8	14.5
≥70	8	4.6	9	5.2	9.8
	84	48.6	89	51.4	100.0

Area 3 (n_3 = 149)

Age Group	Male No.	Male %	Female No.	Female %	Total %
2-9	10	6.7	8	5.4	12.1
10-19	6	4.0	13	8.7	12.8
20-29	11	7.4	8	5.4	12.8
30-39	8	5.4	12	8.0	13.4
40-49	5	3.4	12	8.0	11.4
50-59	10	6.7	11	7.4	14.1
60-69	12	8.0	11	7.4	15.4
≥70	7	4.7	5	3.4	8.0
	69	46.3	80	53.7	100.0

Table 5. Census Population, Random Sample and Study Population by Race/Ethnicity, Gender and Area. Rocky Mountain Arsenal Exposure Study, 1989-1990.

CENSUS POPULATION
(N = 2252)

Area		% Caucasian	% Hispanic	% Other	Total
1	MALE	37.8	12.0	2.7	52.5
	FEMALE	35.8	10.2	1.5	47.5
2	MALE	34.7	14.2	0.9	49.8
	FEMALE	35.8	13.5	0.9	50.2
3	MALE	26.8	9.3	0.6	46.7
	FEMALE	32.0	20.3	1.0	53.3

RANDOM SAMPLE
(N = 1457)

Area		% Caucasian	% Hispanic	% Other	Total
1	MALE	39.1	12.8	1.3	53.2
	FEMALE	35.1	10.1	1.6	46.8
2	MALE	38.2	14.7	1.3	54.2
	FEMALE	34.1	10.4	1.3	45.8
3	MALE	34.8	18.5	0.5	53.8
	FEMALE	31.0	15.0	0.2	46.2

STUDY POPULATION
(N = 472)

Area		% Caucasian	% Hispanic	% Other	Total
1	MALE	36.7	14.0	0.6	51.3
	FEMALE	34.0	12.7	2.0	48.7
2	MALE	37.2	10.0	1.4	48.6
	FEMALE	36.0	14.0	1.4	51.4
3	MALE	36.2	9.4	0.7	46.3
	FEMALE	37.6	16.1	-	53.7

Table 6. Selected Demographic and Lifestyle Characteristics Rocky Mountain Arsenal Exposure Study 1989-1991

Variable	Area 1 (n=150)	Area 2 (n=173)	Area 3 (n=149)
Households Sampled	96	114	104
Persons/Household	1.56	1.52	1.43
Length of residence (mean years)	13.7	13.1	11.7
Education (% <12 years)	42.1	35.9	35.8
Cigarette smoker (%) (Current)	30.8	26.7	36.0
Alcohol consumption (%) (Current)	47.2	45.3	45.0
Occupation in pesticide manufacture (%)	5.7	4.9	8.3
Worked at RMA (%) (Ever)	14.6	13.4	11.7

Table 7. Frequency Distribution for Detection of Urine Arsenic[1] Rocky Mountain Arsenal Exposure Study, 1989-1990.

ARSENIC	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0.0	242	51.6	242	51.6
-10.0*	184	39.2	426	90.8
10.0	2	0.4	428	91.3
10.1	2	0.4	430	91.7
10.2	1	0.2	431	91.9
10.3	2	0.4	433	92.3
10.5	1	0.2	434	92.5
10.6	2	0.4	436	93.0
10.8	1	0.2	437	93.2
10.9	2	0.4	439	93.6
11.0	1	0.2	440	93.8
11.2	1	0.2	441	94.0
11.4	1	0.2	442	94.2
11.5	1	0.2	443	94.5
11.6	1	0.2	444	94.7
11.9	1	0.2	445	94.9
12.3	1	0.2	446	95.1
12.7	1	0.2	447	95.3
13.1	2	0.4	449	95.7
13.8	1	0.2	450	95.9
13.9	1	0.2	451	96.2
14.1	1	0.2	452	96.4
14.5	2	0.4	454	96.8
16.0	1	0.2	455	97.0
16.8	1	0.2	456	97.2
17.9	1	0.2	457	97.4
18.2	1	0.2	458	97.7
18.6	1	0.2	459	97.9
18.9	2	0.4	461	98.3
20.1	1	0.2	462	98.5
20.2	1	0.2	463	98.7
23.0	1	0.2	464	98.9
23.2	1	0.2	465	99.1
23.9	1	0.2	466	99.4
24.4	1	0.2	467	99.6
31.7	1	0.2	468	99.8
53.3	1	0.2	469	100.0

* Trace Values

[1] Values are unadjusted parts per billion (ppb).

Table 8. Frequency Distribution for Detection of Urine Mercury[1]. Rocky Mountain Arsenal Exposure Study, 1989-1990.

MERCURY	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0.0	357	76.1	357	76.1
-5.0*	80	17.1	437	93.2
5.0	3	0.6	440	93.8
5.1	2	0.4	442	94.2
5.3	1	0.2	443	94.5
5.5	3	0.6	446	95.1
5.9	1	0.2	447	95.3
6.0	4	0.9	451	96.2
6.1	3	0.6	454	96.8
6.2	1	0.2	455	97.0
6.8	1	0.2	456	97.2
7.0	2	0.4	458	97.7
7.1	1	0.2	459	97.9
7.5	2	0.4	461	98.3
7.9	1	0.2	462	98.5
8.0	1	0.2	463	98.7
9.0	1	0.2	464	98.9
9.5	1	0.2	465	99.1
10.0	2	0.4	467	99.6
16.1	1	0.2	468	99.8
21.3	1	0.2	469	100.0

* Trace Values

[1] Values are unadjusted parts per billion (ppb).

Table 9. Summary statistics for urine arsenic levels in Exposure Area 2, with and without 23 extra samples collected in blocks 429 and 435, and comparison with area 3. Rocky Mountain Arsenal Exposure Study, 1989-1990.

	AREA 2 Without 23 (N=149)	AREA 2 With 23 (N=172)
As Detection Frequency (%) (Quantifiable)	16 (10.7)	18 (10.5)
Comparison with Area 3:		
Chi Square	0.13	0.09
Probability (p)	0.71	0.76
Geometric Mean (gsd)		
All Data	1.58 (2.9)	1.55 (2.8)
Detects only	14.9 (1.4)	14.4 (1.3)
Comparison with Area 3		
t test - All Data[1]	0.66	0.72
p-value	0.51	0.47
t test - Detects Only[1]	0.17	0.38
p-value	0.87	0.71

[1] Student's t-test applied to the log transformed values

Table 10. Summary statistics for urine mercury levels in Exposure Area 2, with and without 23 extra samples collected in blocks 429 and 435, and comparison with area 3. Rocky Mountain Arsenal Exposure Study, 1989-1990.

	AREA 2 Without 23 (N=149)	AREA 2 With 23 (N=172)
Hg Detection Frequency (%) (Quantifiable)	13 (8.7)	15 (8.7)
Comaprison with Area 3		
Chi Square	1.25	1.31
Probability (p)	0.26	0.25
Geometric Mean (gsd)		
All Data	0.48 (2.0)	0.51 (2.0)
Detects only	7.08 (1.3)	7.10 (1.3)
Comparison with Area 3		
t test - All Data[1]	0.34	0.65
p-value	0.73	0.51
t test - Detects Only[1]	0.19	0.22
p-value	0.85	0.83

[1] Student's t-test applied to the log transformed values

Table 11. Descriptive statistics of laboratory results for urine arsenic, by area. Rocky Mountain Arsenal Exposure Study, 1989-1990.[1,2]

Area	N	Arithmetic Mean (SD)	Geometric Mean (GSD)	Median[3]	Range[4]
Area 1	149	2.96 (4.05)	1.43 (2.70)	13.8	ND - 20.1
Area 2	172	3.38 (4.86)	1.55 (2.83)	13.1	ND - 24.4
Area 3	148	3.76 (6.19)	1.77 (2.82)	13.1	ND - 53.3

1. Urine levels are reported in parts per billion (ppb).
2. To compute means, all trace values were entered as one half the detection limit, or as 5.0 ppb.
3. Median of detects only
4. ND = Non-detect.

Table 12. Descriptive statistics of laboratory results for urine mercury, by area. Rocky Mountain Arsenal Exposure Study, 1989-1990.[1,2]

Area	N	Arithmetic Mean (SD)	Geometric Mean (GSD)	Median[3]	Range[4]
Area 1	149	0.75 (2.26)	0.31 (1.85)	5.9	ND - 21.3
Area 2	172	1.11 (2.34)	0.51 (0.71)	6.1	ND - 16.1
Area 3	148	0.88 (1.80)	0.44 (1.91)	6.6	ND - 10.0

1. Urine levels are reported in parts per billion (ppb).
2. To compute means, all trace values were entered as one half the detection limit, or as 2.5 ppb.
3. Median of detects only.
4. ND = Non-detect.

Table 13. Geometric mean values by Method of Adjustment and Area for Quantifiable Levels of Arsenic in Urine. Rocky Mountain Arsenal Exposure Study, 1989-1990.

Area & Method	Mean	Std Dev
AREA 1 (N = 149)		
Uncorrected	14.06	3.7
Spec. grav.-corrected	15.98	8.0
Creatinine-corrected	10.62	6.6
Corrected for specific gravity & creatinine	13.32	12.3
AREA 2 (N = 172)		
Uncorrected	15.03	4.9
Spec. grav.-corrected	13.69	4.2
Creatinine-corrected	9.30	6.0
Corrected for specific gravity & creatinine	8.60	5.0
AREA 3 (N = 148)		
Uncorrected	17.56	12.1
Spec. grav.-corrected	19.95	16.1
Creatinine-corrected	10.88	5.3
Corrected for specific gravity & creatinine	13.39	10.7

1. All means were computed from detectable levels of the analytes in urine only.

Table 14. Geometric mean values by Method of Adjustment and Area for Quantifiable Levels of Mercury in Urine. Rocky Mountain Arsenal Exposure Study, 1989-1990.

Area & Method	Mean	Std Dev
AREA 1 (N = 149)		
Uncorrected	7.57	5.2
Spec. grav.-corrected	9.91	9.6
Creatinine-corrected	4.66	3.4
Corrected for specific gravity & creatinine	5.83	5.2
AREA 2 (N = 172)		
Uncorrected	7.46	2.9
Spec. grav.-corrected	7.45	2.8
Creatinine-corrected	4.62	3.1
Corrected for specific gravity & creatinine	4.98	3.7
AREA 3 (N = 148)		
Uncorrected	7.01	1.5
Spec. grav.-corrected	10.15	8.3
Creatinine-corrected	6.71	8.5
Corrected for specific gravity & creatinine	14.07	28.0

1. All means were computed from detectable levels of the analytes in urine only.

Table 15. Comparison of mean urine arsenic values between exposure areas (Area 1 and Area 2) and the comparison area (Area 3). Rocky Mountain Arsenal Exposure Study, 1989-1990.

	EXPOSURE AREAS Area 1	Area 2	COMPARISON AREA Area 3
Frequency of Quantifiable Urine Arsenic (%)	7.4	10.5	9.5
Comparison with Area 3			
p-value (Chi-square)	0.41	0.99	
Geometric Mean Urine Arsenic[1]			
All Data	1.43	1.55	1.77
Detects only	13.67	14.40	15.28
Comparison with Area 3			
p-value (t test)[2]			
All Data	0.27	0.48	
Detects only	0.49	0.70	

1. All means are geometric means of log-transformed values.

2. P-value is for Student's t-test applied to the log-transformed values, comparing each exposure area to the comparison area. Comparisons are based on uncorrected urine values only.

Table 16. Comparison of mean urine mercury values between exposure ar(Area 1 and Area 2) and the comparison area (Area 3). Ro Mountain Arsenal Exposure Study, 1989-1990.

	EXPOSURE AREAS		COMPARISON AREA
	Area 1	Area 2	Area 3
Frequency of Quantifiable Urine Mercury (%)	6.0	8.7	5.4
Comparison with Area 3			
p-value (Chi-square)	0.98	0.27	
Geometric Mean Urine Mercury[1]			
All Data	0.31	0.51	0.44
Detects only	6.77	7.10	6.90
Comparison with Area 3			
p-value (t test)[2]			
All Data	0.22	0.51	
Detects only	0.91	0.83	

1. All means are geometric means of log-transformed values.

2. P-value is for Student's t-test applied to the log-transformed values, comparing each exposure area to the comparison area. Comparisons are based on uncorrected urine values only.

Table 17. Odds ratios and 95% confidence intervals for the detection of arsenic in urine. Area 1 and Area 2 compared to Area 3. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
	<u>Quantifiable Arsenic >= 10 ppb</u>			
Area 1	11/91	14/85	0.70	0.30-1.63
Area 2	18/109	14/85	1.00	0.47-2.16
	<u>Trace Arsenic < 10 ppb</u>			
Area 1	58/138	63/134	0.82	0.51-1.32
Area 2	63/154	63/134	0.78	0.49-1.24

*Odds ratio
**Confidence interval

Table 18. Odds ratios and 95% confidence intervals for the detection of mercury in urine. Area 1 and Area 2 compared to Area 3. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
	Quantifiable Mercury >= 5 ppb			
Area 1	9/131	8/118	1.01	0.38-2.73
Area 2	15/140	8/118	1.65	0.70-4.02
	Trace Mercury < 5 ppb			
Area 1	18/140	30/140	0.54	0.29-1.02
Area 2	32/157	30/140	0.94	0.54-1.65

*Odds ratio
**Confidence interval

Table 19. Frequency and geometric mean of quantifiable urine arsenic levels, by area of residence, gender and age group[1]. Rocky Mountain Arsenal Exposure Study, 1989-1990.

	Area 1 (N=149)	Area 2 (N=172)	Area 3 (N=148)
GENDER			
Frequency			
Male	9/77 (11.7)	8/83 (9.6)	7/68 (10.3)
Female	2/72 (2.8)	10/89 (11.2)	7/80 (8.8)
Mean			
Male	13.8	16.3	19.1
Female	13.0	13.1	12.2
AGE GROUP			
Frequency			
2-5 yrs	1/8 (12.5)	1/11 (9.1)	1/9 (11.1)
6-14 yrs	1/21 (4.8)	3/20 (15.0)	2/19 (10.5)
15+ yrs	9/120 (7.5)	14/141 (9.9)	11/120 (9.2)
Mean			
2-5 yrs	10.9	13.1	18.9
6-14 yrs	18.9	17.4	14.1
15+ yrs	13.5	13.9	15.2

[1] Geometric means for each variable compared for area 1 vs area 3; area 2 vs. area 3. Significant differences indicated by *.

Table 20. Frequency and geometric mean of quantifiable urine mercury levels, by area of residence, gender and age group[1]. Rocky Mountain Arsenal Exposure Study, 1989-1990.

	Area 1 (N=149)	Area 2 (N=172)	Area 3 (N=148)
GENDER			
Frequency			
Male	3/77 (3.9)	6/83 (7.2)	1/68 (1.5)
Female	6/72 (8.3)	9/89 (10.1)	7/80 (8.8)
Mean			
Male	6.4	6.7	5.5
Female	7.0	7.4	7.1
AGE GROUP			
Frequency			
2-5 yrs	0/8	2/11 (18.2)	0/9
6-14 yrs	2/21 (9.5)	2/20 (10.0)	1/19 (5.3)
15+ yrs	7/120 (5.8)	11/141 (7.8)	7/120 (5.8)
Mean			
2-5 yrs	ND	9.2	ND
6-14 yrs	6.5	7.6	6.1
15+ yrs	6.9	7.0	7.0

[1] Geometric means for each variable compared for area 1 vs area 3; area 2 vs. area 3. Significant differences indicated by *.

ND = No data

Table 21. Arithmetic and geometric mean levels of urine arsenic and mercury with all values less than the detection limit defined as one half the detection limit. Rocky Mountain Arsenal Exposure Study, 1989-1990.

Analyte	Area 1	Area 2	Area 3	P[1]
Arsenic				
Arithmetic Mean	5.66	6.04	6.17	ns
Std. Deviation	2.56	3.44	5.13	ns
Geometric Mean	5.41	5.62	5.59	ns
Std. Deviation	1.27	1.35	1.39	ns
Mercury				
Arithmetic Mean	2.68	2.93	2.74	ns
Std. Deviation	0.77	1.63	1.07	ns
Geometric Mean	2.67	2.77	2.66	ns
Std. Deviation	1.24	1.29	1.21	ns

1 Probability that area 1 or area 2 differs from area 3.
ns = (not significant at p = 0.05)

Table 22. Frequency of detection of urine arsenic and mercury by week of sample collection. Rocky Mountain Arsenal Exposure Study 1989-1990.

Week		Arsenic		Mercury	
	# Sampled	# Detects	% Positive	# Detects	% Positives
12/03/89-12/09/89	26	2	7.7	6	23.1
12/10/89-12/16/89	60	7	11.7	2	3.3
12/17/89-12/23/89	34	10	29.4	3	8.8
12/24/89-12/30/89	0	0	0.0	0	0.0
12/31/89-01/06/90	11	1	9.1	1	9.1
01/07/90-01/13/90	18	2	11.1	1	5.5
01/14/90-01/20/90	22	2	9.1	0	0.0
01/21/90-01/27/90	61	4	6.5	3	4.9
01/28/90-02/03/90	62	4	6.4	6	9.7
02/04/90-02/10/90	64	2	3.1	3	4.7
02/11/90-02/17/90	40	1	2.5	3	7.5
02/18/90-02/24/90	13	0	0.0	1	7.7
02/25/90-03/03/90	6	0	0.0	0	0.0
03/04/90-03/10/90	28	4	14.3	2	7.1
03/11/90-03/17/90	17	3	17.6	1	5.9
03/18/90-03/24/90	5	1	20.0	0	0.0
03/25/90-03/31/90	1	0	0.0	0	0.0
04/01/90-04/07/90	1	0	0.0	0	0.0
	469	43		32	

Table 23. Selected weather variables by week of sample collection for urine arsenic and mercury. Rocky Mountain Arsenal Exposure Study 1989-1990.

Week	Average Temperature (F)	Average Snow/Ice on ground (")	Precipitation (Total ") Water Equivalent	Precipitation (Total ") Snow/Ice Pellets
12/03/89-12/09/89	42.0	0.0	Trace	Trace
12/10/89-12/16/89	20.4	3.1	0.55	7.2
12/17/89-12/23/89	10.7	3.3	0.18	2.4
12/24/89-12/30/89	34.6	1.0	0.08	1.2
12/31/89-01/06/90	32.0	3.0	Trace	Trace
01/07/90-01/13/90	45.0	0.0	0.00	0.0
01/14/90-01/20/90	33.6	1.1	0.72	8.3
01/21/90-01/27/90	35.3	3.6	0.02	0.2
01/28/90-02/03/90	31.7	0.7	0.17	1.6
02/04/90-02/10/90	38.4	0.1	0.00	0.0
02/11/90-02/17/90	26.1	1.0	0.16	3.5
02/18/90-02/24/90	35.7	0.1	0.14	1.4
02/25/90-03/03/90	39.4	0.0	0.08	0.5
03/04/90-03/10/90	40.4	2.6	1.96	11.8
03/11/90-03/17/90	39.1	0.7	0.36	6.1
03/18/90-03/24/90	40.1	0.1	0.16	1.2
03/25/90-03/31/90	38.7	0.1	0.67	3.9
04/01/90-04/07/90	46.4	0.3	0.28	2.0

Table 24. Odds ratios and 95% confidence intervals for arsenic in u[illegible]e ≥ 10 PPB[1] among children aged 2-14. Univariate Analyse[illegible] Personal Risk Factors. Rocky Mountain Arsenal Exposure S 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Age (≥ 6 yrs vs < 6)	6/24	3/10	0.78	0.15-4.09
Gender (male)	7/17	2/17	5.25	0.96-28.66
Race (hispanic or non-white)	5/16	4/18	1.59	0.34-7.50
Lived within one mile of RMA (5-10 yrs)	5/22	4/12	0.59	0.12-2.80
Lived on farm or ranch	0/3	9/31	-	-
Child was breast fed	6/22	3/12	1.13	0.22-5.76
Takes food outside	8/29	1/5	1.52	0.14-16.14
Chews nails	2/15	7/19	0.26	0.05-1.47
Sucks thumb	-	3/10	-	-
Uses pacifier	-	3/10	-	-
Eats dirt/grass	1/4	2/6	0.67	0.03-13.04
Smokes	-	6/24	-	-
Drinks alcohol	0/2	2/22	-	-

*Odds ratio
**Confidence interval
[1]traces deleted

Table 25. Odds ratios and 95% confidence intervals for arsenic ≥ 10.0 PPB[1] among children aged 2-14. Univariate Analyses of Dietary Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Drinks ≥ 3 glasses tap water/day	4/23	5/11	0.25	0.05-1.22
Ate fish in past week	4/13	5/21	1.42	0.30-6.82
Ate wild game (2 yrs)	5/17	4/17	1.35	0.29-6.39
Taking vitamins	2/15	7/19	0.26	0.05-1.47
Home grown fruits/veg (summer)	5/18	4/16	1.15	0.24-5.46
Home grown fruits/veg (winter)	2/10	7/24	0.61	0.10-3.67
Fruits/veg (one mile from RMA)	3/11	6/23	1.06	0.21-5.51
Fish/game (one mile from RMA)	0/1	9/33	-	-
Wild plants (one mile from RMA)	1/3	8/31	1.44	0.11-18.57

*Odds ratio
**Confidence interval
[1]traces deleted

Table 26. Odds ratios and 95% confidence intervals for arsenic ≥ 1 PPB[1] among children aged 2-14. Univariate Analyses Behavioral Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Spends >7 hrs/day outdoors summer weekday	6/17	3/17	2.55	0.52-12.53
Spends >2 hrs/day outdoors winter weekday	2/8	7/26	0.91	0.14-5.74
Spends >7 hrs/day outdoors summer weekend	7/22	2/22	2.33	0.40-13.58
Spends >2 hrs/day outdoors winter weekend	1/7	8/27	0.40	0.04-3.75
Spends >5 hrs/day on floor	2/6	1/4	1.50	0.08-29.34
Play Area (other than home)				
neighbor yard	4/17	2/7	0.77	0.10-5.80
school yard	1/7	5/17	0.40	0.04-4.23
park	0/3	6/21	-	-
sidewalks	1/5	5/19	0.70	0.06-8.20
Usual play area within one mile from RMA	4/14	2/10	1.60	0.22-11.45
Play area is dirt/ground	4/19	5/15	0.53	0.11-2.52

*Odds ratio
**Confidence interval
[1]traces deleted

Table 27. Odds ratios and 95% confidence intervals for arsenic ≥ 10.0 PPB[1] among children aged 2-14. Univariate Analyses of Hobbies and Activities. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Gardening/yard work	4/20	2/4	0.25	0.03-2.24
Glassmaking	-	6/24	-	-
Leatherwork	-	6/24	-	-
Electrical work	0/2	6/22	-	-
Silkscreen/dyes	-	6/24	-	-
Farm animals/ranch	2/11	4/13	0.50	0.07-3.54
Rides bicycle (one mile from RMA)	3/29	2/17	0.87	0.12-5.89
Fishes/hunts/hikes (one mile from RMA)	0/5	6/19	-	-

*Odds ratio
**Confidence interval
[1]traces deleted

Table 28. Odds ratios and 95% confidence intervals for arsenic urine $\geq$ 10.0 PPB[1] among adults aged 15 and over. Univari Analyses of Personal Risk Factors. Rocky Mountain Arse Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Age >64 (vs. < 40)	2/66	18/89	0.12	0.03-0.45
Age 40-64 (vs. < 40)	14/99	18/89	0.65	0.30-1.40
Gender (female)	17/136	17/118	0.85	0.41-1.75
Race (hispanic or non-white)	15/67	19/187	2.55	1.23-5.23
Education (<12 yrs)	10/97	24/156	0.63	0.29-1.38
Lived one mile from RMA (10 yrs)	23/177	11/77	0.90	0.41-1.95
Lived on farm or ranch (10 yrs)	4/34	30/220	0.84	0.28-2.57
Dental fillings (2 wks)	0/3	34/251	-	-
Smokes	13/89	21/165	1.17	0.56-2.47
Drinking alcohol	21/125	13/128	1.79	0.86-3.73

*Odds ratio
**Confidence interval
[1]traces deleted

Table 29. Odds ratios and 95% confidence intervals for arsenic in urine $\geq$ 10.0 PPB[1] among adults aged 15 and over. Univariate Analyses of Dietary Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Uses bottled water	15/127	19/126	0.75	0.37-1.56
Drinks tap water	29/214	5/40	1.10	0.40-3.04
Glasses (water/day)				
1-5 vs. 0	20/107	5/40	1.61	0.56-4.61
>5 vs. 0	9/107	5/40	0.64	0.20-2.04
Ate fish (past week)	18/110	16/143	1.55	0.75-3.20
Ate wild game (past 2 yrs)	10/89	24/163	0.73	0.33-1.61
Takes vitamins	9/99	25/155	0.52	0.23-1.16
Ate game/fish at RMA (self caught)	0/2	0/3	-	-
Ate game/fish at RMA (others caught)	0/4	34/248	-	-
Ate wild plants/fruits (one mile from RMA)	1/17	33/235	C.38	0.05-2.78
Drinks some red wine	6/35	16/91	0.97	0.34-2.73
Drinks some white wine	4/29	18/97	0.70	0.22-2.27
Red wine (previous week)	2/9	32/244	1.89	0.39-9.31

*Odds ratio
**Confidence interval
[1]traces deleted

Table 30. Odds ratios and 95% confidence intervals for arsenic [in] urine ≥ 10.0 PPB[1] among adults aged 15 and over. Univar[iate] Analyses of Behavioral Risk Factors. Rocky Mountain Arse[nal] Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
<u>Hobbies</u>				
Gardening/yard work	19/147	15/106	0.90	0.43-1.87
Woodwork	5/36	29/217	1.05	0.38-2.91
Silkscreening/dyes	0/2	34/251	-	-
Glassmaking	0/1	34/252	-	-
Photography	0/1	34/252	-	-
Welding	6/29	28/224	1.83	0.69-4.83
Auto restoration/ bodywork	4/13	30/240	3.11	0.95-10.18
Ceramics	0/5	34/248	-	-
Leatherwork	0/5	34/248	-	-
Electrical work	7/27	27/226	2.58	1.02-6.50
<u>Activities</u>				
Fish/hunt (1 mile RMA)	0/4	34/249	-	-
Walk/hike (1 mile RMA)	12/85	22/168	-	-
Ride bike (1 mile RNA)	4/24	30/229	1.33	0.43-4.14
Spends >4 hours/day outdoors summer weekday	14/133	20/121	0.59	0.29-1.23
Spends >2 hours/day outdoors winter weekday	14/117	20/137	0.80	0.38-1.66
Spends >6 hours/day outdoors summer weekend	13/123	21/131	0.62	0.30-1.29
Spends >3 hours/day outdoors winter weekend	15/117	19/137	0.91	0.44-1.89

*Odds ratio
**Confidence interval
[1]traces deleted

Table 31. Odds ratios and 95% confidence intervals for arsenic in urine ≥ 10.0 PPB[1] among adults aged 15 and over. Univariate Analyses of Occupational Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Working outside of home (vs. at home or none)	22/139	11/114	1.76	0.82-3.78
Worked at RMA (ever vs. never)	6/35	28/219	1.41	0.54-3.70
<u>Agriculture</u>				
Farm/ranch	3/34	31/220	0.59	0.17-2.03
Vegetable farm/greenhouse	1/16	33/238	0.41	0.06-3.06
Grain crops	2/23	32/231	0.59	0.13-2.62
Orchard	0/2	34/252	-	-
Sprayed crops	2/11	32/243	1.47	0.31-7.05
Sugar beets	0/1	34/253	-	-
Fertilizer	0/1	34/253	-	-
Sheep ranch	1/3	33/251	3.30	0.33-32.9
Feed mill	2/5	32/249	4.52	0.84-24.22
Pesticide use	2/25	32/229	0.54	0.12-2.34
<u>Other Occupations</u>				
Pesticide manufacture	1/12	33/242	0.58	0.07-4.51
Mining/smelting	1/9	33/245	0.80	0.10-6.63
Chemical Production	2/2	32/252	-	-
Glass manufacturing	0/2	34/252	-	-
Wood preservative/trtmt	1/8	33/246	0.92	0.11-7.77
Welding/battery/ electroplate	2/20	32/234	0.70	0.16-3.15
Automobile painting/ bodywork	2/10	32/244	1.66	0.34-8.85
Lawn/tree service	1/17	33/237	0.39	0.05-2.81
Exterminator	0/3	34/251	-	-
Woolen textiles	1/3	33/251	3.30	0.33-32.9
Inks/dyes	3/6	31/248	7.00	1.67-29.36
Tanning	-	34/254	-	-
Carpentry	3/22	31/232	1.02	0.29-3.67

*Odds ratio
**Confidence interval
[1]traces deleted

Table 32. Odds ratios and 95% confidence intervals for arsenic urine ≥ 10.0 PPB[1]. Univariate Analyses of Household F Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
General Household Characteristics				
Treated for termites	0/5	33/247	-	-
Noticed chemical odors	18/135	14/109	1.04	0.49-2.21
Still notice odors	10/67	8/71	1.38	0.51-3.75
Dogs/cats	21/145	12/108	1.36	0.64-2.89
Area around home dirt	14/141	29/147	0.45	0.23-0.88
Street dirt	4/52	39/236	0.96	0.48-1.89
Trailer (vs. other)	7/64	36/224	0.64	0.27-1.51
Storm windows	19/164	24/124	0.55	0.29-1.04
Central air cond. (Y/N)	1/14	42/274	0.43	0.06-3.15
Swamp cooler	18/146	25/142	0.66	0.34-1.27
Windows open ≥ 50%	24/158	19/130	1.05	0.54-2.01
Household income <$25,000	23/172	17/100	0.75	0.38-1.49
Dietary Factors				
Consumed locally produced:				
beef	6/20	23/205	3.39	1.24-9.24
poultry	4/34	25/191	0.89	0.29-2.73
milk	2/4	27/221	7.19	1.27-40.66
other meat	0/1	29/224	-	-
Fruit/veg grown within one mile of RMA	11/72	22/179	1.29	0.59-2.81
Consumed fish ≥4 times/month vs. <4/month	14/82	29/206	1.26	0.63-2.52
Water Supply				
City water	28/215	5/38	0.99	0.36-2.75
Well water	8/50	25/203	1.36	0.57-3.22
Filter used	3/38	30/212	0.52	0.15-1.77
Softener used	8/41	25/206	1.76	0.73-4.20
Water garden (well vs. city)	11/79	5/52	1.52	0.50-4.66

Table 32. (Continued)

Gardening Activities

Vegetable garden	15/128	18/125	0.79	0.38-1.65
Summer veg/fruit >1/wk vs ≤ 1/wk	11/95	4/34	0.98	0.29-3.34
Winter veg/fruit >1/wk vs ≤ 1/wk	7/44	7/64	1.54	0.50-4.75
Leaf vegetables (lettuce)	7/63	8/67	0.92	0.31-2.72
Root crops (carrots)	13/103	2/26	1.73	0.37-8.12
Squash/zucchini	12/104	3/25	0.96	0.25-3.70
Broccoli/cabbage	7/45	8/84	1.75	0.59-5.16
Fruit (trees)	3/41	12/88	0.50	0.14-1.85
Fruit (plants)	12/77	3/52	3.02	0.84-10.77
Green beans	9/75	6/54	1.09	0.36-3.28
Tomatoes	15/124	9/8	-	-

*Odds ratio
**Confidence interval
[1]traces deleted

Table 33. Odds ratios and 95% confidence intervals for arsenic in urine ≥ 10.0 PPB[1]. Univariate Analyses of Household Risk Factors - Selected Variables for Areas 1 and 2. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Water Supply:				
City Water				
Area 1 and 2	19/149	4/30	0.95	0.30-3.03
Well Water				
Area 1 and 2	5/40	18/139	0.96	0.33-2.78
Area 1	4/36	5/46	1.03	0.25-4.17
Area 2	1/4	13/93	2.05	0.21-20.56
Water Garden From Well				
Area 1 and 2	5/45	6/43	0.77	0.22-2.75
Area 1	4/36	1/9	1.00	----
Area 2	1/9	5/34	0.73	0.07-7.26
Filter used	3/28	20/148	0.77	0.21-2.78
Filter used on well	3/11	2/29	5.06	0.80-32.21
Softener used	6/29	17/148	2.01	0.73-5.57
Softener used on well water	1/3	4/35	3.88	0.32-47.10
Consumption of Locally Produced:				
Beef	3/13	6/60	2.70	0.60-12.19
Poultry	3/21	6/52	1.28	0.29-5.71
Milk	2/4	7/69	8.86	1.43-55.01

*Odds ratio
**Confidence interval
[1]traces deleted

Table 34. Odds ratios and 95% confidence intervals for mercury in urine ≥ 5.0 PPB[1] among children aged 2-14. Univariate Analyses of Personal Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Age (≥ 6 yrs vs < 6)	5/47	2/27	1.49	0.27-8.28
Gender (female)	5/38	2/36	2.60	0.48-13.71
Race (hispanic or non-white)	3/36	4/38	0.77	0.16-3.75
Lived with one mile of RMA (5-10 yrs)	6/51	1/23	2.93	0.36-24.07
Lived on farm or ranch (within 5-10 yrs)	1/14	6/60	0.69	0.08-6.29
Child was breast fed	5/48	2/26	1.40	0.25-7.79
Takes food outside	6/59	1/14	1.47	0.16-13.36
Chews nails	2/28	5/45	0.62	0.11-3.41
Sucks thumb	0/1	2/26	-	-
Used pacifier	-	2/27	-	-
Eats dirt/grass	2/11	0/16	-	-
Dental fillings (2 wks)	0/1	7/72	-	-
Smokes	0/1	5/45	-	-
Drinks alcohol	1/6	4/40	1.80	0.17-19.47

*Odds ratio
**Confidence interval
[1]traces deleted

Table 35. Odds ratios and 95% confidence intervals for mercury ≥ PPB[1] among children aged 2-14. Univariate Analyses Dietary Risk Factors. Rocky Mountain Arsenal Exposure Stu 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Drinks ≥ 3 glasses tap water/day	6/54	1/20	2.38	0.28-20.18
Ate fish in past week	2/25	5/49	0.77	0.14-4.29
Ate wild game (2 yrs)	3/26	4/48	1.44	0.29-6.99
Taking vitamins	2/33	5/41	0.47	0.09-2.51
Home grown fruits/veg (summer)	5/46	1/2	0.12	0.01-1.55
Home grown fruits/veg (winter)	3/35	3/13	0.31	0.06-1.72
Fruits/veg (one mile of RMA)	0/29	7/43	-	-
Fish/game (one mile of RMA)	0/2	7/71	-	-
Wild plants (one mile of RMA)	0/6	7/60	-	-

*Odds ratio
**Confidence interval [1]traces deleted

Table 36. Odds ratios and 95% confidence intervals for mercury $\geq$ 5.0 PPB[1] among children aged 2-14. Univariate Analyses of Behavioral Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Spends >7 hrs/day outdoors summer weekday	6/39	1/35	6.18	0.88-43.68
Spends >2 hrs/day outdoors winter weekday	5/40	2/34	2.29	0.43-12.30
Spends >7 hrs/day outdoors summer weekend	5/39	2/35	2.43	0.45-12.99
Spends >2 hrs/day outdoors winter weekend	5/44	2/30	1.80	0.33-9.85
Spends >5 hrs/day on floor	1/10	1/17	1.78	0.10-38.70
Play Area (other than home)				
neighbor yard	3/30	2/16	0.78	0.11-5.30
school yard	2/12	3/34	2.07	0.30-14.05
park	0/7	5/39	-	-
sidewalks	0/8	5/38	-	-
Usual play area within one mile of RMA	3/29	2/18	0.92	0.14-6.26
Play area is dirt/ground	6/43	1/31	4.86	0.65-36.19

*Odds ratio
**Confidence interval
[1]traces deleted

Table 37. Odds ratios and 95% confidence intervals for mercury ≥ PPB[1] among children aged 2-14. Univariate Analyses Hobbies and Activities. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Gardening/yard work	3/35	2/11	0.42	0.06-2.86
Glassmaking	-	5/46	-	-
Leatherwork	0/1	5/46	-	-
Electrical work	0/3	5/43	-	-
Silkscreen/dyes	0/1	5/45	-	-
Farm animals/ranch	4/15	1/31	10.91	1.5-78.82
Rides bicycle (one mile of RMA)	3/29	2/17	0.87	0.12-5.89
Fishes/hunts/hikes (one mile of RMA)	1/8	4/34	1.21	0.12-12.86

*Odds ratio
**Confidence interval
[1]traces deleted

Table 38. Odds ratios and 95% confidence intervals for mercury in urine ≥ 5.0 PPB[1] among adults aged 15 and over. Univariate Analyses of Personal Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Age >64 (vs <40)	3/80	14/111	0.27	0.08-0.91
Age 40-64 (vs <40)	8/127	14/111	0.47	0.19-1.14
Gender (female)	17/154	8/164	2.42	1.03-5.66
Race (hispanic or non-white)	9/75	16/242	1.93	0.82-4.51
Education (<12 yrs)	5/122	20/196	0.38	0.14-1.00
Lived one mile from RMA (10 yrs)	18/222	7/96	1.12	0.45-2.78
Lived on farm on ranch (10 yrs)	3/45	22/273	0.82	0.23-2.84
Dental fillings (2 wks)	1/5	24/313	3.01	0.36-25.29
Smokes	8/118	17/200	0.78	0.33-1.87
Drinks alcohol	10/116	15/151	0.58	0.25-1.33

*Odds ratio
**Confidence interval
[1]traces deleted

Table 39. Odds ratios and 95% confidence intervals for mercury urine ≥ 5.0 PPB[1] among adults aged 15 and over. Univar: Analyses of Dietary Risk Factors. Rocky Mountain Arse... Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Uses bottled water	11/158	14/159	0.78	0.34-1.76
Drinks tap water	23/269	2/49	2.20	0.52-9.32
Glasses (water/day)				
1-5 vs. 0	12/135	2/49	2.29	0.51-10.28
>5 vs. 0	11/134	2/49	2.10	0.46-9.58
Ate fish (past week)	11/150	14/167	0.87	0.38-1.97
Ate wild game (past 2 yrs)	7/115	8/203	0.67	0.27-1.64
Takes vitamins	12/128	13/190	1.41	0.62-3.19
Ate game/fish at RMA (self-caught)	0/3	0/5	-	-
Ate game/fish at RMA (others caught)	0/7	25/307	-	-
Ate wild plants/fruits (one mile from RMA)	1/23	24/292	0.51	0.07-3.80
Drinks some red wine	5/53	6/115	1.89	0.56-6.42
Drinks some white wine	4/48	7/120	1.47	0.41-5.25

*Odds ratio
**Confidence interval
[1]traces deleted

Table 40. Odds ratios and 95% confidence intervals for mercury in urine ≥ 5.0 PPB[1] among adults aged 15 and over. Univariate Analyses of Behavioral Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
<u>Hobbies</u>				
Gardening/yard work	16/192	9/125	1.17	0.50-2.74
Woodwork	5/48	20/269	1.45	0.52-4.05
Silkscreening/dyes	0/3	25/314	-	-
Glassmaking	0/2	25/315	-	-
Photography	1/4	24/313	4.01	0.48-33.94
Welding	2/39	23/278	0.60	0.13-2.61
Auto restoration/ bodywork	3/19	22/298	2.35	0.66-8.41
Ceramics	0/5	25/312	-	-
Leatherwork	0/4	25/313	-	-
Electrical work	2/37	23/280	0.64	0.15-2.80
<u>Activities</u>				
Fish/hunt (1 mile RMA)	0/5	25/312	-	-
Walk/hike (1 mile RMA)	11/102	14/215	1.74	0.76-3.94
Ride bike (1 mile RMA)	5/36	20/281	2.11	0.75-5.89
Spends >4 hours/day outdoors summer weekday	10/166	15/151	0.58	0.25-1.33
Spends >2 hours/day outdoors winter weekday	10/152	15/163	0.70	0.30-1.59
Spends >6 hours/day outdoors summer weekend	12/152	13/165	1.00	0.44-2.27
Spends >3 hours/day outdoors winter weekend	12/150	13/165	1.02	0.45-2.31

*Odds ratio
**Confidence interval
[1]traces deleted

Table 41. Odds ratios and 95% confidence intervals for mercury urine ≥ 5.0 PPB[1] among adults aged 15 and over. Univaria Analyses of Occupational Risk Factors. Rocky Mounta Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Working outside of home (vs. at home or none)	18/178	7/138	2.11	0.87-5.12
Worked at RMA (ever vs. never)	4/39	21/279	1.40	0.46-4.32
Agriculture				
Farm/ranch	2/40	23/277	0.58	0.13-2.53
Grain crops	2/32	23/285	0.76	0.17-3.37
Orchard	1/5	24/312	3.00	0.36-25.22
Sprayed crops	1/12	24/305	1.06	0.13-8.62
Sugar beets	0/1	25/316	-	-
Fertilizer	1/2	24/315	12.13	1.3-110.5
Sheep ranch	0/3	25/314	-	-
Feed mill	0/6	25/311	-	-
Pesticide use	4/33	21/285	1.73	0.56-5.34
Other Occupations				
Pesticide manufacture	2/19	23/299	1.41	0.31-6.46
Mining/smelting	2/12	23/306	2.46	0.53-11.37
Chemical Production	1/5	24/33	3.01	0.36-25.29
Glass manufacturing	1/4	24/314	4.03	0.48-34.03
Wood preservative/trtmt	0/11	25/307	-	-
Welding/battery/ electroplate	4/34	21/284	1.67	0.54-5.14
Automobile painting/ bodywork	2/16	23/302	1.73	0.38-7.97
Lawn/tree service	2/18	23/300	1.50	0.33-6.90
Exterminator	1/4	24/314	4.03	0.48-34.03
Woolen textiles	0/6	25/312	-	-
Inks/dyes	0/9	25/309	-	-
Tanning	-	25/318	-	-
Carpentry	1/29	24/289	0.40	0.02-2.91

*Odds ratio
**Confidence interval
[1]traces deleted

Table 42. Odds ratios and 95% confidence intervals for mercury in urine ≥ 5.0 PPB[1]. Univariate Analyses of Household Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
<u>General Household Characteristics</u>				
Treated for termites	0/7	25/308	-	-
Noticed chemical odors	12/166	13/143	0.78	0.34-1.77
Still notice odors	9/87	3/80	2.96	0.82-10.81
Dogs/cats	13/81	12/136	0.80	0.35-1.81
Area around home dirt	16/168	9/143	1.57	0.67-3.65
Street is dirt	6/63	19/251	1.29	0.49-3.36
Alley is dirt	4/38	21/279	1.45	0.47-4.45
Trailer (vs. other)	3/60	22/253	0.55	0.16-1.88
Storm windows	15/206	10/111	0.79	0.34-1.83
Central air conditioner	3/17	22/300	2.71	0.76-9.68
Swamp cooler	11/177	14/140	0.60	0.26-1.35
Forced air heating	20/242	5/75	1.26	0.46-3.48
Windows open ≥501	19/277	6/40	0.42	0.16-1.09
Household income <$25,000	9/169	14/127	0.45	0.19-1.07
<u>Dietary Factors</u>				
Consumed Locally Produced:				
Beef	2/23	23/262	0.99	0.22-4.50
Poultry	6/45	19/241	1.80	0.68-4.74
Milk	2/7	23/278	4.44	0.93-21.10
Fruit/veg crown within one mile of RMA	8/88	17/227	1.24	0.51-2.98
Consumed fish ≥4 times/month vs. <4/month	7/100	25/292	0.80	0.34-1.92
<u>Water Supply</u>				
City water	17/263	8/54	0.40	0.17-0.95
Well water	8/67	17/250	1.86	0.77-4.47
Filter used	5/51	20/264	1.33	0.47-3.71
Softener used	5/54	19/259	1.29	0.46-3.62
Bottle water used	5/95	20/215	0.54	0.20-1.47
Water garden (well vs. city)	7/69	4/98	2.65	0.77-9.11

Table 43. Odds ratios and 95% confidence intervals for mercury in urine $\geq$ 5.0 PPB. Univariate Analyses of Household Risk Factors - Selected Variables for Areas 1 and 2. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Water Supply:				
City Water				
Areas 1 and 2	12/180	6/42	0.43	0.15-1.19
Well Water				
Areas 1 and 2	6/53	12/169	1.67	0.60-4.66
Area 1	4/49	3/57	1.60	0.34-7.49
Area 2	2/4	9/112	11.44	2.08-62.93
Water Garden From Well				
Areas 1 and 2	7/58	1/50	6.73	1.02-44.24
Area 1	3/49	0/9	-	-
Area 2	4/9	1/41	32.00	5.27-194.4
Filter used	4/39	14/182	1.37	0.43-4.41
Filter used on well	1/13	5/40	0.58	0.06-5.50
Softener used	3/34	14/186	1.19	0.32-4.39
Softener used on well	0/3	5/48	-	-
Consumption of Locally Produced:				
Beef	1/15	17/186	0.71	0.08-5.71
Poultry	2/31	16/171	0.67	0.15-3.05
Milk	1/4	17/197	3.53	0.40-31.31

*Odds ratio
**Confidence interval
[1]traces deleted

Table 44. Multivariate analysis of risk factors for exposure to arsenic among children aged 2-14. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Odds Ratio	95% CI
Age >5	0.94	0.07-12.49
Male	6.05	0.71-51.63
Hispanic or non-white	2.65	0.26-27.16
Area around home is dirt/soil	1.41	0.08-23.16
Drinks ≥3 glasses of water/day	0.20	0.02-2.12
Spends >7 hours/day outdoors	5.12	0.63-41.84
Residence in Area 1	0.45	0.29-43.59
Residence in Area 2	2.10	0.16-27.54

Table 45. Multivariate analysis of risk factors for exposure to mercury among children aged 2-14. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Odds Ratio	95% CI
Age >5	3.08	0.21-45.97
Female	2.84	0.42-22.77
Hispanic or non-white	2.36	0.29-19.20
Area around home is dirt/soil	9.98	0.67-148.0
Drinks ≥3 glasses of water/day	1.31	0.11-18.26
Spends >7 hours/day outdoors	4.38	0.42-46.03
Residence in Area 1	3.97	0.23-69.46
Residence in Area 2	7.42	0.50-110.8

Table 46. Multivariate analysis of risk factors for exposure to arsenic among adults aged 15 and over. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Odds Ratio	95% CI
<u>Demographic Variables</u>		
Age <40	8.05	1.66-39.16
Age 40-64	4.74	0.99-22.81
Female	1.07	0.45-2.55
Hispanic or non-white	3.61	1.52-8.58
Education <12 yrs	0.48	0.20-1.15
Residence in Area 1	0.77	0.28-2.11
Residence in Area 2	0.77	0.29-2.02
<u>Occupational Variables</u>		
Ever worked at RMA	1.90	0.60-6.05
Worked on farm/ranch	0.23	0.04-1.24
Sprayed crops	7.54	0.86-66.17
Electrical work	2.81	0.88-8.99

Variables not selected for model: alcohol consumption, red wine, woodworking, carpentry, pesticide use.

Table 47. Multivariate analysis of risk factors for exposure to mercury among adults aged 15 and over. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Odds Ratio	95% CI
Demographic Variables		
Age <40	3.77	0.89-15.96
Age 40-64	1.16	0.27-5.02
Female	10.39	2.50-43.18
Hispanic or non-white	3.22	1.18-8.77
Education <12 yrs	0.27	0.09-0.83
Residence in Area 1	1.12	0.34-3.72
Residence in Area 2	1.92	0.63-5.85
Occupational Variables		
Ever worked at RMA	2.36	0.56-9.99
Orchard work	4.05	0.35-47.02
Electroplating/welding	5.34	1.03-27.68
Mining/smelting	4.20	0.55-32.05
Autorestoration/bodywork	3.28	0.59-18.15
Other		
Drank tap water	2.42	0.92-6.41
Used pesticides	2.45	0.64-9.33

Variables not selected for model: ate fish in past week, dental fillings past 2 weeks, rode bike near RMA, pesticide manufacture, lawncare.

Table 48. Odds ratios and 95% confidence intervals for arsenic in uri
among children aged 2-14 . Univariate Analyses of Person
Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Age (≥ 6 yrs vs < 6)	42/60	21/28	0.78	0.28-2.16
Gender (male)	34/44	29/44	1.76	0.69-4.51
Race (hispanic or non-white)	29/40	34/48	1.09	0.43-2.77
Farm residence	11/14	52/74	1.56	0.39-6.11
Mile Radius	42/59	21/29	0.94	0.35-2.55
Takes food outside	52/73	11/15	0.90	0.26-3.17
Chews fingernails	22/35	41/53	0.50	0.19-1.27
Eats dirt/grass	8/11	13/17	0.82	0.14-4.8
Drinks ≥ 3 glasses tap water/day	42/61	21/27	0.63	0.22-1.82
Ate fish in past week	20/29	43/59	0.83	0.31-2.20
Ate wild game (2 yrs)	22/34	41/54	0.58	0.23-1.49
Vitamins	23/36	40/52	0.53	0.21-1.35
Home grown fruits/veg (≥ 1/week summer)	27/39	8/11	0.84	0.19-3.80
Home grown fruits/veg (≥ 1/week winter)	15/17	20/33	4.86	1.03-23.04
Wild plants (one mile from RNA)	5/7	58/81	0.79	0.18-5.53
Spends >7 hrs/day outdoors summer weekday	40/53	23/35	1.61	0.63-4.11
Spends >7 hrs/day outdoors winter weekday	6/12	57/76	0.33	0.10-1.12
Play area is dirt/ground	35/50	28/38	0.83	0.32-2.15
Usual play area within one mile from RMA	26/36	16/24	1.30	0.42-4.01
Spends ≥ 5 hrs/day on floor (toddler)	8/12	13/16	0.46	0.08-2.66
~~Hazardous hobby~~	28/45	35/43	0.38	0.14-0.99

*Odds ratio
**Confidence interval
[1]trace values included

Table 49. Odds ratios and 95% confidence intervals for Arsenic in urine[1] among adults aged 15 and over. Univariate Analyses of Personal and Household Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Personal Risk Factors				
Age >64 (vs. < 40)	23/87	82/153	0.31	0.17-0.55
Age 40-64 (vs. < 40)	59/144	82/153	0.60	0.38-0.95
Gender (male)	90/191	74/193	1.43	0.96-2.15
(female)	74/193	90/191	0.70	0.47-1.05
Race (hispanic or non-white)	46/98	118/286	1.26	0.79-2.00
Education (<12 yrs)	57/144	107/240	0.81	0.54-1.24
Income				
<15,000	32/102	37/81	0.54	0.30-0.99
15,000-35,000 (vs. ≥ 35,000)	86/179	37/81	1.10	0.65-1.86
Lived one mile from RMA (past 10 yrs)	109/263	55/121	0.85	0.55-1.31
Lived on farm or ranch (past 10 yrs)	21/51	143/333	0.93	0.51-1.69
Smokes	60/136	104/248	1.09	0.72-1.67
Dietary Risk Factors				
Drinks alcohol	92/196	72/188	1.43	0.95-2.10
Red wine in previous week	13/20	151/363	2.61	1.05-6.5
Uses bottled water	80/192	84/192	0.92	0.61-1.38
Drinks tap water Glasses (water/day)				
1-5 vs. 0	73/160	25/60	1.18	0.64-2.14
>5 vs. 0	66/164	25/60	0.94	0.52-1.72
Ate fish past week	83/176	81/208	1.40	0.93-2.10
once a week	63/126	81/208	1.57	1.00-2.45
≥ twice a week	20/50	81/208	1.05	0.56-1.97

Table 49. (Continued)

Activities				
Walk/hike (1 mile RMA)	54/127	110/257	0.99	0.64-1.52
Ride bike (1 mile RMA)	23/43	141/341	1.63	0.87-3.07
Spends >4 hrs/day outdoors summer weekday	44/107	119/274	0.91	0.58-1.43
Spends >4 hrs/day outdoors winter weekend	55/128	108/253	1.01	0.65-1.55
Hobbies				
Any Hazardous Hobby	117/264	47/120	1.24	0.80-1.92
Gardening/yard work	101/229	63/155	1.15	0.76-1.74
Woodwork	32/63	132/321	1.48	0.86-2.54
Photography	3/4	161/380	4.08	0.50-33.42
Welding	25/48	139/336	1.54	0.84-2.82
Auto restoration/ bodywork	14/23	150/361	2.19	0.94-5.10
Electrical work	23/43	141/341	1.63	0.87-3.07
Occupation				
Any Hazardous Occupation	61/113	103/271	1.91	1.23-2.98
Worked at RMA (ever vs. never)	22/51	142/333	1.02	0.56-1.87
Agriculture	50/128	114/256	0.80	0.52-1.23
Sprayed crops	4/13	160/371	0.59	0.18-1.92
Fertilizer	2/3	162/381	2.70	0.27-27.45
Feed mill	9/20	155/364	1.10	0.45-2.73
Pesticide use	16/39	148/345	0.93	0.47-1.82
Other Occupations				
Pesticide manufacture	13/24	151/360	1.64	0.72-3.73
Mining/smelting	6/14	158/370	1.06	0.34-2.96
Chemical Production	8/8	156/376	23.95	1.37-418.0[2]
Wood preservative	8/15	156/369	1.56	0.56-4.37
Welding/battery	21/39	143/345	1.65	0.85-3.19
Auto painting bodywork	10/18	154/366	1.72	0.67-4.42
Woolen textiles	4/6	160/378	2.73	0.53-14.12
Inks/dyes	9/12	155/372	4.20	1.23-14.31
Carpentry	18/37	146/347	1.30	0.66-2.57

Table 49. (Continued)

General Household Characteristics				
Treated for termites	5/10	150/370	1.37	0.39-4.81
Noticed chemical odors	81/198	77/172	0.85	0.56-1.29
Still notice odors	44/101	37/100	1.31	0.75-2.32
Dogs/cats	97/221	65/261	1.16	0.76-1.75
Area around home dirt	80/203	77/170	0.79	0.52-1.19
Trailer (vs. other)	27/72	135/310	0.78	0.46-1.32
Central air cond. (Y/N)	9/22	153/360	0.94	0.39-2.25
Windows open ≥ 50%	206/416	21/36	1.64	0.93-2.89
Gardening Activities				
Vegetable garden	78/191	83/190	0.89	0.59-1.34
Water garden	47/82	68/116	0.95	0.53-1.68
Winter vegetables	45/104	57/151	1.26	0.76-2.09
Summer vegetables	51/129	51/126	0.96	0.58-1.59
Root crops vs no garden	40/106	50/124	0.90	0.53-1.53

*Odds ratio
**Confidence interval
[1]trace values included
[2]logit estimate

Table 50. Odds ratios and 95% confidence intervals for arsenic in urine[1]. Univariate Analyses of Selected Variables for Area 1 and 2. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Water Supply:				
City Water	121/196	32/59	1.36	0.76-2.45
Well Water	37/69	116/186	0.70	0.40-1.22
Area 1	24/56	25/66	1.23	0.59-2.55
Area 2	2/5	56/136	0.95	0.15-5.92
Water Garden				
From Well (1&2)	27/67	25/62	1.00	0.49-2.03
Area 2	4/9	32/78	1.15	0.28-4.65
Filter used on well (Areas 1 and 2)	6/14	20/47	1.01	0.30-3.42
Consumption of Locally Produced:				
Beef	12/32	83/214	1.89	0.79-4.54
Milk	4/6	91/230	3.05	0.54-15.77

*Odds ratio
**Confidence interval
[1]trace values included

Table 51. Odds ratios and 95% confidence intervals for mercury in urine[1] among children aged 2-14. Univariate Analyses of Personal Risk Factors. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Age (≥ 6 yrs vs < 6)	18/60	3/28	3.57	1.00-12.71
Gender (female)	11/44	10/44	1.13	0.42-3.04
Race (hispanic or non-white)	7/40	14/48	0.52	0.19-1.43
Farm residence	1/14	20/74	0.21	0.03-1.44
Mile Radius	14/59	7/29	0.98	0.34-2.79
Eats dirt/grass	2/11	1/17	3.56	0.30-41.77
Chews fingernails	8/35	13/53	0.91	0.33-2.51
Take food outside	20/73	1/15	5.28	0.78-35.77
Drinks ≥ 3 glasses tap water/day	13/61	8/27	0.64	0.23-1.80
Ate fish in past week	6/29	15/59	0.77	0.26-2.25
Ate wild game (one mile of RMA)	3/13	18/75	0.95	0.23-3.86
Vitamins	5/36	16/52	0.36	0.12-1.08
Home grown fruits/veg (≥ 1/week summer)	6/39	6/11	0.15	0.04-0.61
Home grown fruits/veg (≥ 1/week winter)	4/17	8/33	0.96	0.24-3.86
Ate wild plants (one mile of RMA)	0/6	21/82		
Spends >7 hrs/day outdoors summer weekday	18/53	3/35	5.49	1.61-18.71
Spends >7 hrs/day outdoors winter weekday	3/12	18/76	1.07	0.26-4.43
Spends >5 hrs/day on floor (toddler)	2/12	1/16	3.00	0.25-36.05
Usual play area within one mile of RMA	10/36	8/24	0.77	0.25-2.38
Play area is dirt/ground	13/50	8/38	1.32	0.48-3.61
Hazardous Hobby	13/45	8/43	1.78	0.65-4.84
Farm animals/ranch	8/19	13/69	3.13	1.08-9.12

*Odds ratio
**Confidence interval

[1]trace values included

Table 52. Odds ratios and 95% confidence intervals for Mercury in urine[1] among adults aged 15 and over. Univariate Analyses Personal and Household Risk Factors.
Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
__Personal Risk Factors__				
Age				
>64 vs. <40	10/87	56/153	0.23	0.11-0.45
40-64 vs. 40	25/144	56/153	0.36	0.21-0.62
Gender (female)	56/193	35/191	1.82	1.13-2.94
Race (hispanic or non-white)	31/98	60/286	1.74	1.05-2.90
Education (<12 yrs)	27/144	64/240	0.64	0.38-1.0
Income				
<15,000	19/102	22/81	0.61	0.31-1.23
15,000-35,000	47/179	22/81	0.96	0.53-1.7
(vs. ≥ 35,000)			1.0	----
Lived one mile from RMA (10 yrs)	59/263	32/121	0.80	0.49-1.32
Lived on farm or ranch (10 yrs)	9/51	82/333	0.66	0.31-1.40
Fillings (2 wks)	2/6	89/378	1.62	0.30-8.89
Smokes	26/110	65/248	0.67	0.40-1.11
__Dietary Risk Factors__				
Drinks alcohol	40/196	31/188	0.69	0.43-1.11
Red wine in previous week	5/20	86/363	1.07	0.38-3.04
Ate fish past week	36/176	55/208	0.72	0.44-1.15
Uses bottled water	45/192	46/192	0.97	0.61-1.56
Drinks tap water				
Glasses (water/day)				
1-5 vs. 0	37/160	13/160	1.09	0.53-2.23
>5 vs. 0	41/164	13/60	1.21	0.59-2.45

Table 52. (Continued)

Activities				
Walk/hike (1 mile RMA)	36/127	35/257	1.45	0.89-2.36
Ride bike (1 mile RMA)	12/43	79/341	1.28	0.63-2.62
Spends >4 hrs/day outdoors winter weekday	25/107	66/274	0.57	1.63
Spends >4 hrs/day outdoors winter weekend	31/128	60/253	1.03	0.62-1.6
Hobbies				
Any Hazardous Hobby	58/264	33/120	0.74	0.45-1.22
Gardening/yard work	53/229	38/155	0.93	0.58-1.50
Woodwork	20/63	71/321	1.64	0.91-2.95
Photography	1/4	90/380	1.07	0.11-10.48
Welding	11/48	80/336	0.95	0.46-1.95
Auto restoration/ bodywork	7/23	84/361	1.44	0.58-3.61
Electrical work	8/43	83/341	0.71	0.32-1.59
Occupation				
Any Hazardous Occupation	27/113	64/271	1.02	0.61-1.70
Worked at RMA (ever vs. never)	16/51	75/333	1.57	0.83-2.99
Agriculture	27/128	64/256	0.80	0.48-1.34
Sprayed crops	2/13	89/371	0.58	0.13-2.61
Fertilizer	2/3	89/381	6.56	0.80-53.6
Pesticide use	10/39	81/345	1.12	0.33-2.41
Orchard	1/5	90/379	0.80	0.09-7.26
Other Occupations				
Pesticide manufacture	7/24	84/360	1.35	0.54-3.37
Mining/smelting	4/14	87/370	1.30	0.40-4.25
Chemical Production	4/8	87/376	3.32	0.88-12.59
Glass manufacture	1/4	90/380	1.07	0.11-10.48
Welding/battery/ electroplate	9/39	82/345	0.96	0.44-2.11
Automobile painting/ bodywork	4/18	87/366	0.92	0.29-2.86
Lawn and tree care	6/22	83/362	1.22	0.46-3.22
Exterminator	2/3	89/379	2.17	0.37-12.68

Table 52. (Continued)

General Household Characteristics				
Dogs/cats	53/221	37/161	1.06	0.65-1.71
Area around home dirt	51/203	36/170	1.25	0.77-2.03
Trailer (vs. other)	12/72	78/310	0.60	0.31-1.16
Central air cond. (Y/N)	8/22	82/360	1.94	0.80-4.72
Windows open ≥ 50%	90/326	22/56	0.43	0.24-0.76
Gardening Activities				
Vegetable garden	39/191	51/190	0.70	0.44-1.13
Water Garden from well (vs from city water)	19/82	23/116	1.22	0.61-2.43
Root crops (vs no garden)	33/153	49/186	0.77	0.46-1.27
Winter vegetables	23/104	35/151	0.94	0.52-1.71
Summer vegetables	28/129	30/126	0.89	0.49-1.60

*Odds ratio
**Confidence interval
[1]trace values included

Table 53. Odds ratios and 95% confidence intervals for Mercury in urine[1]. Univariate Analyses of Selected Variables for Areas 1 and 2. Rocky Mountain Arsenal Exposure Study 1989-1990.

Risk Factor	Detects/ Exposed	Detects/ Unexposed	OR*	95% CI**
Water Supply:				
City Water	155/196	42/59	1.53	0.79-2.96
Well Water	51/69	146/186	0.78	0.41-1.47
Area 1	11/45	12/66	1.10	0.44-2.74
Area 2	2/5	33/136	4.68	0.87-2.53
Water Garden				
From Well (1&2)	15/67	14/62	0.99	0.43-2.25
Area 2	6/9	18/78	6.67	1.73-2.5
Filter used on well (Area 1 and 2)	2/14	12/47	0.49	0.10-2.46
Consumption of Locally Produced:				
Beef	8/22	45/214	2.15	0.86-5.35
Milk	3/6	50/230	3.60	0.78-16.73

*Odds ratio
**Confidence interval
[1]trace values included

Table 54. Multivariate analysis of risk factors for exposure arsenic among adults aged 15 and over. Rocky Mountai Arsenal Exposure Study 1989-1990.[1,2]

Risk Factor	Odds Ratio	95% CI
<u>Demographic Variables</u>		
Age <40	3.42	1.87-6.24
Age 40-64	1.71	0.94-3.12
Male	1.29	0.81-2.06
Hispanic or non-white	1.28	0.78-2.09
Residence in Area 1	0.77	0.45-1.32
Residence in Area 2	0.69	0.40-1.18
Fishmeal in Past Week	1.70	1.09-2.64
Red Wine in Past Week	2.36	0.90-6.19
Any Hazardous Occupation	1.72	1.03-2.86
Agricultural Occupation	0.61	0.37-1.00

1 Trace values included
2 Variables not selected for model: education < 12 years, any hazardous hobby.

[redacted]

Table 1.3-2: Target Analytes Detected at the Offpost Operable Unit

Analyte	Analyte
Aldrin	1,4-Dithiane
Arsenic, Total	Endrin
Benzene	Ethylbenzene
Cadmium, Total	Fluoride
Calcium	HCCPD
Carbon tetrachloride	Lead, Total
Chlorobenzene	Magnesium
Chloroform	Mercury, Total
CPMS	Methylene Chloride
CPMSO	Nitrogen, NO_2 + NO_3
CPMSO2	1,4-Oxathiane
Chromium, Total	Potassium
Copper, Total	Sodium
DBCP	Sulfate
DDE	Tetrachloroethylene
DDT	1,1,1-TCE
1,1-DCE	1,1,2-TCE
1,2-DCLE	Trichloroethylene
1,2-DCE	Toluene
DCPD	Xylene (-m)
Dieldrin	Xylene (-o, -p)
DIMP	Zinc, Total
DMMP	

Source: ESE, 1988a.

Table 1
Army RMA Air Monitoring Data
VOC analytes 1 mile north of Basin F, RMA, July-August 1988

Compound	Highest 24-hour Value in Air ug/m3
acetone	19.19
benzene	1.20
bicycloheptadiene	00.21
carbon disulfide	-----
carbon tetrachloride	-----
chlorobenzene	-----
chloroform	00.08
dimethylsulfide	-----
ethyl benzene	01.29
methylene chloride	81.25
methyl ethyl ketone	01.75
tetrachloroethylene	03.06
1,1,1-trichloroethane	29.11
1,1,2-trichloroethane	-----
toluene	23.36
trichloroethylene	00.31
xylene (o,m,p)	10.17

SVOC Analytes 1 mile north of Basin F, RMA, July-August 1988

Compound	Highest 24-hour Value in Air ug/m3
aldrin	00.02
dieldrin	00.05
endrin	00.02

Inorganic Chemical Analytes 1 mile north of Basin F, RMA, July-August 1988

Compound	Highest 24-hour Value ug/m3
arsenic	-----
lead	-----
cadmium	-----
chromium	00.02
copper	00.07
mercury	00.43
zinc	00.13
ammonia	-----

Source: Office of the Program Manager, RMA, 1988

APPENDIX C

11?34 East Colfax Avenue
Englewood Colorado 80111
(303) 790 2777 (800) 282 1835
FAX # (303) 790 2756

|AGER
3ORATORIES, INC.

REPORT ON SERVICE NUMBER 38744EN
December 12, 1988

Customer Project Code:

Mr. John Martyny
Tri-County Health Department
7000 E. Belleview, Suite 301
Englewood, CO 80111-1628

lysis: The following samples were submitted for analysis:
Two PUF plug samples for TO10.

hod: The plugs were extracted using soxhlets for 18 hours. The extracts were then concentrated to 10 mLs and analyzed by gas chromatography with an electron capture detector. The results were compared to a calibration curve. All positive results were confirmed using a different column, 3% OV-1.

: The results are found on Tables 1, 2, and 3.

on: Hager Laboratories, Inc., has been AIHA accredited since 1977.

Laboratory data are filed and available upon request.

If you have any questions, please call customer service.

nitted by: Michael Aaronson, Ph.D.
Environmental Chemistry Manager

:n

Source: Tri-County Health Department, 1988

38744EN
mber 12, 1988

TABLE 1

le Number	Hager Reference No.	Analysis	Concentration (ug/M^3)
#1	AA-43443	aldrin	0.011
		dieldrin	0.800
		endrin	0.008
#2	AA-43444	aldrin	0.036
		dieldrin	1.434
		endrin	0.018

Source: Tri-County Health Department, 1988

APPENDIX D

STATE OF COLORADO

COLORADO DEPARTMENT OF HEALTH

4210 East 11th Avenue
Denver, Colorado 80220
Phone (303) 320-8333

Roy Romer
Governor

Thomas M. Vernon, M.D.
Executive Director

December 29, 1988

To Whom It May Concern:

Enclosed are the preliminary test results from the samples obtained from the Irondale Trailer Park area during December, 1988. The water samples were taken from two drinking water taps within the trailer park. The seven superficial soil samples were taken by the Colorado Department of Health (CDH) from various points throughout the trailer park indicated on the map attached. All CDH air samples were taken between December 21, and December 28, 1988 at locations to the north and northwest of Rocky Mountain Arsenal as indicated in the summary of these results.

The Colorado Department of Health has done a preliminary review of these data and does not believe the levels present in surface soils, water or air pose an immediate health hazard. For some substances, drinking water standards have been established by the Environmental Protection Agency. These standards or maximum contaminant level (MCL) are listed to the right of the level observed. With the exception of nitrate, levels of substances in tap water are below these recommended levels. Air sampling will continue until the Basin F interim action is complete. All of the enclosed data will be evaluated in more detail during the coming week.

The Colorado Department of Health will be happy to discuss any questions you may have. Please contact either Dr. Ellen Mangione at 331-8330 or Mr. Jeff Edson at 331-4830.

Sincerely,

S. E. Mangione for

Thomas M. Vernon, M.D.
Director
Colorado Department of Health

Enclosures

APPENDIX D

COLORADO DEPARTMENT OF HEALTH

The following is a summary of results of soil samples which were obtained from the Irondale Trailer Court area on December 21, 1988. On preliminary review, these results appear consistent with background levels as indicated below. Most samples were below detection limits (BDL).

Soils Analysis--Irondale Trailer Court--December 21, 1988
Pesticide Analysis (ppm by weight)

Sample	1	2	3	4	5	6	7
Aldrin	0.0005	0.0023	0.0021	0.00002	BDL	BDL	0.00021
Dieldrin	0.0004	0.0033	0.0026	0.0001	0.0110	0031	0.004.6
Endrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Isodrin	BDL	BDL	BDL	BDL	BDL	BDL	BDL
DDE	BDL	BDL	0.0073	BDL	BDL	BDL	0.022

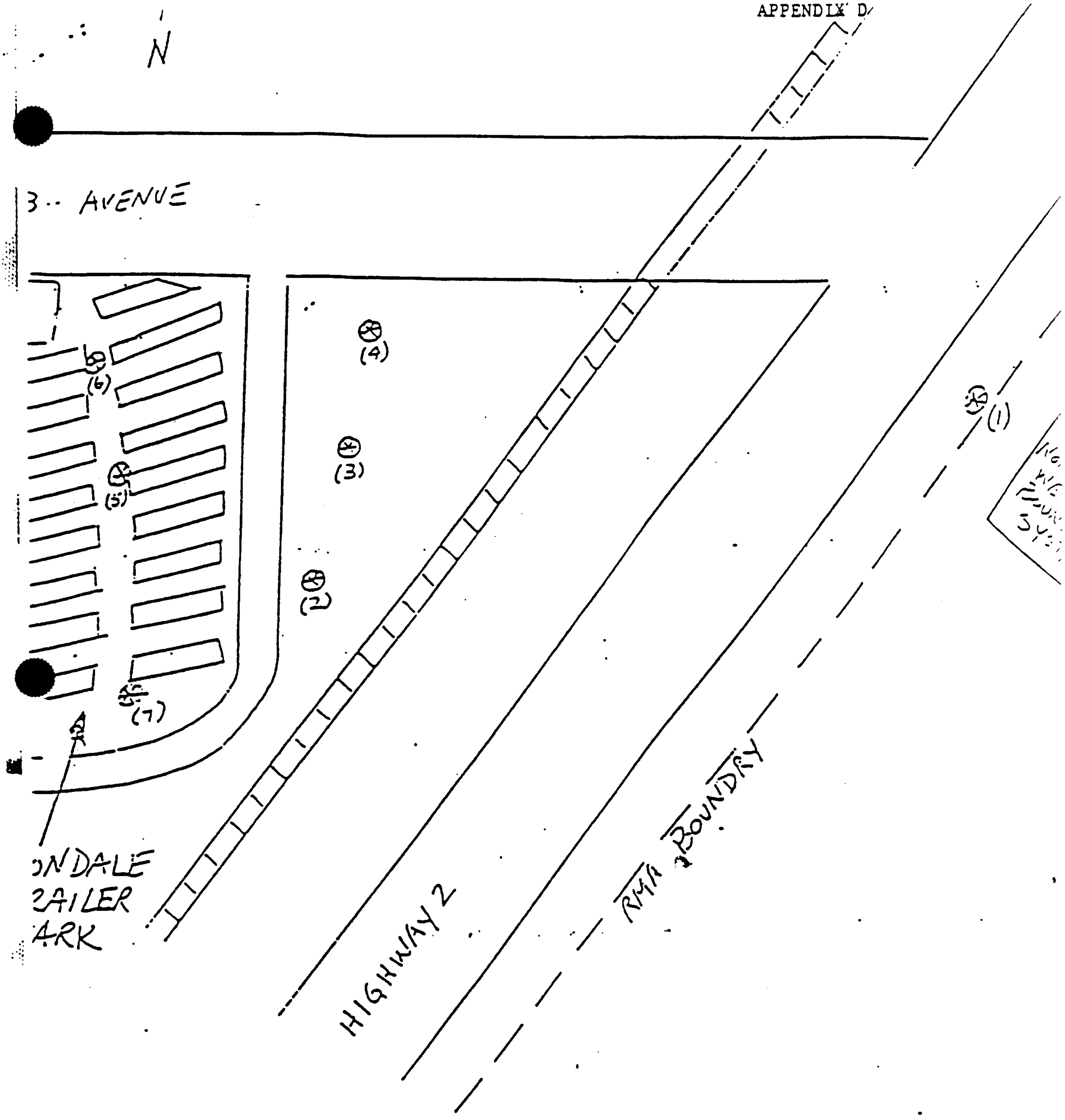
ppm = parts per million
Detection limit - .02 ppb
BDL = Below Detection Limit
Methodology = EPA 8080 (SW846)

Soil Summary--Irondale Trailer Court--December 21, 1988
Inorganic Analysis (ppm by weight)

Sample	1	2	3	4	5	6	7
Arsenic	NYA	NYA	NYA	NYA	NYA	NYA	NYA
Barium	130	72	93	110	79	88	76
Cadmium	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Chromium	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Copper	10	8	10	6	12	9	11
Lead	36	42	BDL	BDL	42	26	24
Mercury	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Selenium	NYA	NYA	NYA	NYA	NYA	NYA	NYA
Silver	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zinc	49	41	38	30	120	52	130

BDL = Below Reportable Detection Limit
ppm = parts per million
NYA = Not Yet Available

The following additional contaminants are currently being analyzed for the seven (7) soil samples, and the results will be available as soon as possible:



⊗: SURFICIAL SOIL SAMPLING LOCATIONS

( ) SAMPLE NUMBER

COLORADO DEPARTMENT OF HEALTH

Air Analysis Summary - North and Northwest of Rocky Mountain Arsenal
December 21 through 28, 1988

Analyses were conducted on all air samples for the following contaminants:

Lindane	Dieldrin	DDD
Heptachlor	Endosulfan I	DDT
Aldrin	DDE	Methoxychlor
Heptachlor Epoxide	Endrin	

Methodology - EPA 8080
ug/m^3 - 10^{-6} grams per cubic meter of air
Instrument Detection Limit - 0.00002 ug/m^3 assuming a 60-minute sample taken at the rate of 1 liter per minute.

All samples were below detectable limits except for those samples as noted below. All detectable concentrations are well below those which would present a threat to public health.

Date, Time, Location, Wind Speed and Direction, Analytical Results

12/23/88, 12:17 to 13:19, north of RMA on 96th Avenue approximately 1/2 mile east of Hwy 2, winds north to west at 1 mph.

Results: No listed contaminants were detected except:
Aldrin detected at 0.0005 ug/m^3
DDT detected at 0.068 ug/m^3

12/24/88, 9:05 to 10:00, north of RMA on 96th Avenue approximately 1/2 mile east of Hwy 2, winds south southwest to southwest at 2-4 mph gusts.

Results: No listed contaminants were detected except:
DDT detected at 0.20 ug/m^3

12/26/88, 19:10 to 20:10, west of RMA on Hwy 2 approximately 1 mile south of 88th Avenue, winds south at 0-7 mph.

Results: No listed contaminants were detected except:
Aldrin detected at 0.001 ug/m^3
DDT detected at 0.29 ug/m^3

12/27/88, 10:52 to 11:52, north of RMA on 96th Avenue approximastely 1 1/2 miles east of Hwy 2, winds south southwest at 5-10 mph.

Results: No listed contaminants were detected except:
Aldrin detected at 0.001 ug/m^3
DDT detected at 0.058 ug/m^3

ate, Time, Location, Wind Speed and Direction, Analytical Results

12/28/88, 8:18 to 9:18, north or RMA on 96th Avenue approximately 200 yards east of Hwy 2, winds south to south southeast at 0-1 mph.

Results: No listed contaminants were detected except:
DDT detected at 0.059 ug/m^3

*12/28/88, 17:02 to 18:00, west of RMA at intersection of 88th Avenue and Hwy 2, winds southeast to southwest at 1-2 mph.

Results: No listed contaminants were detected except:
Aldrin detected at 0.002 ug/m^3
DDE detected at 0.002 ug/m^3
Endrin detected at 0.013 ug/m^3

*12/28/88, 18:00 to 20:34, north of RMA on 96th Avenue approximately 1/2 miles east of Hwy 2, winds south to southwest at 3-6 mph.

Results: No listed contaminants were detected except:
Aldrin detected at 0.02 ug/m^3
Endrin detected at 0.02 ug/m^3

2/28/88, 18:24 to 20:24, north of RMA on 96th Avenue approximately 3/4 mile st of Hwy 2, winds southeast to west southwest at 1-6 mph.

Results: No listed contaminants were detected except:
Aldrin detected at 0.005 ug/m^3
DDE detected at 0.00014 ug/m^3
Endrin detected at 0.0028 ug/m^3

*12/28/88 Temporary inversion was present.

WATER ANALYTICAL SUMMARY—IRONDALE TRAILER COURT—DECEMBER 21, 1988

SAMPLE #1

	LEVEL	MAXIMUM CONTAMINANT LEVEL (MCL)
1,1 dichloroethylene	0.92 ppb	7 ppb
chloroform	2.10 ppb	*
1,1,1 trichloroethane	0.5 ppb	200 ppb
Trichloroethylene	2.46 ppb	5 ppb
Tetrachloroethylene	1.21 ppb	none
Dibromochloroethane	1.35 ppb	*
Chlorobenzene	0.7 ppb	none
Bromoform	18.96 ppb	*
DBCP	less than 0.025 ppb (detection limit)	none
DCPD	less than 5 ppb (detection limit)	none
DIMP	less than 5 ppb (detection limit)	none
Aldrin	less than ~~0.5~~ 0.05 ppb (detection limit)	none
Dieldrin	less than ~~0.5~~ 0.05 ppb (detection limit)	none
Endrin	less than ~~0.5~~ 0.05 ppb (detection limit)	0.2 ppb
Isodrin	less than ~~0.5~~ 0.05 ppb (detection limit)	none
Arsenic	less than 10 ppb (detection limit)	50 ppb
Barium	less than 0.5 ppb (detection limit)	1000 ppb
Cadmium	less than 25 ppb (detection limit)	10 ppb
Chromium	less than 500 ppb (detection limit)	50 ppb
Copper	less than 25 ppb (detection limit)	none
Cyanide Direct	less than 0.01 ppm (detection limit)	none
Flouride	0.42 ppm	4 ppm
Lead	less than 5 ppb (detection limit)	50 ppb
Mercury	less than 0.2 ppb (detection limit)	2 ppb
Nitrate/Nitrite	13 ppm	10 ppm
Selenium	3.7 ppb	10 ppb
Silver	25 ppb	50 ppb
Sodium	80 ppm	none
Zinc	less than 10 ppb (detection limit)	none

ppb = parts per billion
ppm = parts per million
* MCL for these substances is 100 ppb total concentration

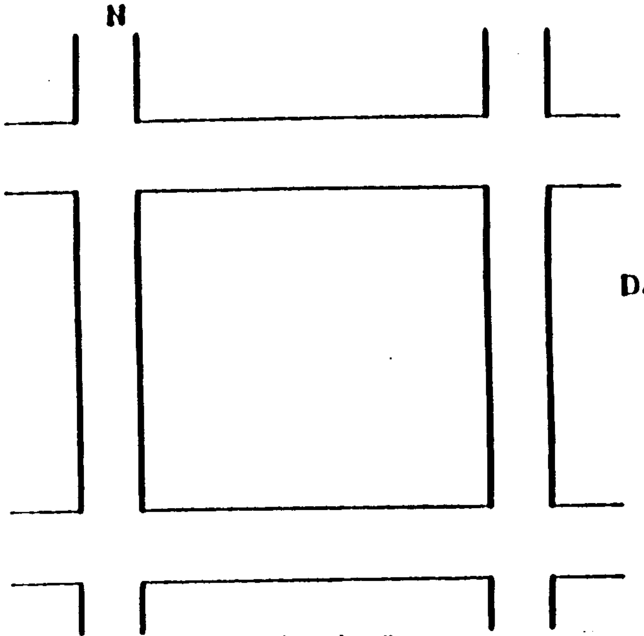
APPENDIX D

WATER ANALYTICAL SUMMARY—IRONDALE TRAILER COURT—DECEMBER 21, 1988

SAMPLE #2

	LEVEL	MAXIMUM CONTAMINANT LEVEL (MCL)
1,1 dichloroethylene	0.82 ppb	7 ppb
chloroform	2.27 ppb	*
1,1,1 trichloroethane	0.5 ppb	200 ppb
Trichloroethylene	2.12 ppb	5 ppb
Tetrachloroethylene	0.97 ppb	none
Dibromochloroethane	1.33 ppb	*
Chlorobenzene	0.7 ppb	none
Bromoform	19.92 ppb	*
DBCP	less than 0.025 ppb (detection limit)	none
DCPD	less than 5 ppb (detection limit)	none
DIMP	less than 5 ppb (detection limit)	none
Aldrin	less than ~~0.5~~ 0.05 ppb (detection limit)	none
Dieldrin	less than ~~0.5~~ 0.05 ppb (detection limit)	none
Endrin	less than ~~0.5~~ 0.05 ppb (detection limit)	0.2 ppb
Isodrin	less than ~~0.5~~ 0.05 ppb (detection limit)	none
Arsenic	less than 10 ppb (detection limit)	50 ppb
Barium	less than 0.5 ppb (detection limit)	1000 ppb
Cadmium	less than 25 ppb (detection limit)	10 ppb
Chromium	less than 500 ppb (detection limit)	50 ppb
Copper	less than 25 ppb (detection limit)	none
Cyanide Direct	less than 0.01 ppm (detection limit)	none
Flouride	0.43 ppm	4 ppm
Lead	less than 5 ppb (detection limit)	50 ppb
Mercury	less than 0.2 ppb (detection limit)	2 ppb
Nitrate/Nitrite	13 ppm	10 ppm
Selenium	4.3 ppb	10 ppb
Silver	25 ppb	50 ppb
Sodium	80 ppm	none
Zinc	less than 10 ppb (detection limit)	none

ppb = parts per billion
ppm = parts per million
* MCL for these substances is 100 ppb total concentration



CDII - CSU RMA
EXPOSURE STUDY
OCTOBER, 1989

BLOCK SURVEY FORM

Date _ _/_ _/89 Interviewer: ______________________

Block # _ _ _ _

Building#	Premises Address	Residential/ Single Family	Residential/ Multiple Family	Vacation/ Weekend	Business	Vacant	Eligible	Not Eligible	Completed	Refused	Comments

COLORADO DEPARTMENT OF HEALTH -- COLORADO STATE UNIVERSITY

RMA HAZARDOUS CHEMICAL EXPOSURE STUDY - 1989

CENSUS FORM

___ BLOCK __ BLDG.

Interviewer Initials __ __ Date __ __/__ __/__ __ Time __ :__ am/pm Adult at home? 1=yes 2=no Is this a year round residence? 1=yes 2=no

Contact name ____________ (Last) ____________ (First) Best time to recontact __ __ : __ __ am/pm

Address ________ (Number) ______________ (Street)

Best day to recontact
__Sun
__Mon
__Tue
__Wed
__Thu
__Fri
__Sat

Telephone Home __ __ __ - __ __ __ __
Work __ __ __ - __ __ __ __

Total number of persons in home ____

Contact #1 ____
#2 ____
#3 ____
#4 ____

Completion Status
1=Refused
2=Participate
3=No contact
4=Invalid address
5=Other

NAME	Sex 1-M 2-F	Relationship 1-self 2-spouse 3-parent 4-child 5-other family 6-other	Birthdate mo-day-yr	Lived [illegible]ouse 12 months? 1-yes 2-no	Lived in neighborhood 12 months? 1-yes 2-no		
1. F____ MI__ L____	__	__	__/__/__	__	__	__	__
2. F____ MI__ L____	__	__	__/__/__	__	__	__	__
3. F____ MI__ L____	__	__	__/__/__	__	__	__	__
4. F____ MI__ L____	__	__	__/__/__	__	__	__	__
5. F____ MI__ L____	__	__	__/__/__	__	__	__	__

APPENDIX F

STATE OF COLORADO

COLORADO DEPARTMENT OF HEALTH

4210 East 11th Avenue
Denver, Colorado 80220
Phone (303) 320-8333

Roy Romer
Governor

Thomas M. Vernon, M.D.
Executive Director

CONSENT FORM

COLORADO DEPARTMENT OF HEALTH - COLORADO STATE UNIVERSITY
ROCKY MOUNTAIN ARSENAL CHEMICAL EXPOSURE STUDY - 1989/1990

You are being asked to participate in a study of your (or your child's/ward's) exposure to several pesticides, arsenic, mercury, and diisopropylmethylphosphonate.

If you agree to participate in this study, a sample of blood will be obtained by venipuncture which involves placing a needle in your arm and withdrawing about 30 cc (about two tablespoons) of blood. You can expect to experience a slight pain at the moment the needle goes into your arm. In about 10% of cases, there may be a small bruise which will disappear by itself. The blood sample will be collected by trained health specialists. We will also ask you to collect a sample of urine in a container which we will provide.

The blood sample will be analyzed to measure the amount of the pesticides aldrin, dieldrin, endrin, and isodrin. Blood samples from persons age 13 and over will also be analyzed for blood lipids including cholesterol. The urine sample will be analyzed to measure the amount of arsenic, mercury, and diisopropylmethylphosphonate and its metabolite isopropylmethylphosphonic acid (IMPA). The urine will also be analyzed for creatinine and specific gravity to standardize for volume.

The health specialists will also ask you to answer questions about your length of residence, the length of time you spend at home, water supply, dietary habits, hobbies, and the type of work that you do, in order to help interpret the results. These questions and the collection of blood and urine samples should take about one hour.

Your participation is strictly voluntary and refusal to participate will result in no penalty to you (or to your child/ward). You may withdraw from the study at any time without penalty or prejudice.

Test results will be reviewed and interpreted by a panel of experts and you will receive a letter with your individual results and their interpretation. The investigators are not obligated to treat or further evaluate any problems that may be found.

The primary benefit from this study will be the determination of the levels of these chemicals in your (your child's/ward's) blood and urine, and for persons 13 and older, cholesterol. An additional benefit to the public health that can result from this study is the identification of persons exposed to hazardous chemicals.

Initials_____

All information collected in this study will be kept confidential. Your name (or that of your child/ward) will NOT be used in any published report of this study.

If you have any questions about this study, you may contact Dr. Theodora Tsongas at the Division of Disease Control and Environmental Epidemiology, State Health Department, 4210 East 11th Avenue, Denver, CO 80220, telephone 331-8330.

AUTHORIZATION: I have read the above and understand the discomforts, inconveniences, and risks of this study. I agree to the participation of:

____

Participant's Name

I also give my permission to be contacted in the future should further testing be indicated. I understand that I (he/she) can refuse to participate or withdraw at any time. (Initial first page of the consent form.)

SIGNED: ______________________________ ______________

Adult Participant or Parent/Guardian DATE

WITNESS: ______________________________________

Investigator/Witness

TO THE MINOR PARTICIPANT:
We are going to take about a tablespoon full of blood by inserting a very small needle into your arm. If you are fifteen to seventeen, we will take about two tablespoons. There will be a small pain. It may leave a bruise or mark, but that will go away soon. We would also like you to take a small cup into the bathroom and urinate into it. This is to see if you have some chemicals in your body.

The above has been read by or explained to a participant who is a minor 8 years through 17 years of age.

Verbal assent has been given by the participant who is a minor 8 years through 17 years of age.

SIGNED: ______________________________ ______________

Adult or Parent/Guardian DATE

WITNESS: ______________________________________

Investigator/Witness

Investigator check here (   ) : copy provided to participant.

CHEMICAL EXPOSURE STUDY QUESTIONNAIRE

Household ID __ Block - / __ Bldg. __

Household Address ______________________________

Phone ____________________

Interviewer Initials _ _ _

Date of Interview _ _ - _ _ - _ _

Household prefers Spanish translation?
1= Yes 2=No

ADULTS AND CHILDREN AGE 15 AND OLDER - LIST BY AGE, OLDEST FIRST

	NAME	AGE	LAB LABEL
1.	____________	______	____________
2.	____________	______	____________
3.	____________	______	____________
4.	____________	______	____________

CHILDREN AGE 6 THROUGH 14 YEARS OLD - LIST BY AGE, OLDEST FIRST

	NAME	AGE	LAB LABEL
5.	______________________	______	____________
6.	______________________	______	____________
7.	______________________	______	____________
8.	______________________	______	____________

CHILDREN AGE 2 THROUGH 5 YEARS OLD - LIST BY AGE, OLDEST FIRST

	NAME	AGE	LAB LABEL
9.	______________________	______	____________
10.	______________________	______	____________
11.	______________________	______	____________
12.	______________________	______	____________

HOUSEHOLD CHARACTERISTICS

THE FOLLOWING QUESTIONS SHOULD BE ANSWERED BY ANY HOUSEHOLD MEMBER AGE 18 AND OVER

NAME OF RESPONDENT ______________________________

13. PLEASE GIVE ME THE NAME OF THE SCHOOL THAT EACH CHILD SELECTED TO PARTICIPATE ATTENDS.

CHILD'S NAME	SCHOOL NAME
1. ____________	______________________________
2. ____________	______________________________
3. ____________	______________________________
4. ____________	______________________________

NOW I'D LIKE TO ASK YOU SOME QUESTIONS ABOUT YOUR FAMILY'S DIET.

14. Did you or your family have a vegetable garden during the last 2 years?

1=Yes 2=No 9=Don't know

IF YES ASK Q15, OTHERWISE GO ON TO Q19.

15. Which of the following foods have you or your family grown within the past two years in this garden?
(CIRCLE ALL THAT APPLY).

1=Leafy vegetables like spinach, lettuce
2=Tomatoes, chilies, peppers
3=Root crops like carrots, radishes, onions, beets, potatoes
4=Squash, zucchini, cucumbers
5=Broccoli or cabbage
6=Corn
7=Fruit trees (apples, pears, peaches, cherries)
8=Fruit (strawberries, grapes, watermelon, cantaloup)
9=Green beans
11=Okra
12=Herbs, such as chives, basil, oregano, etc.
10=Other (Specify) ____________________

16. In the past two years, how often, on an average, did you or your family eat fruits or vegetables grown in your garden?
(INCLUDE FOOD THAT WAS CANNED OR FROZEN)

A. SUMMER CONSUMPTION

1=Less than once per week
2=Once per week
3=More than once per week
8=Never
9=Don't know

B. REMAINDER OF THE YEAR

1=Less than once per week
2=Once per week
3=More than once per week
8=Never
9=Don't know

17. In the past two years, have you or your family eaten any of the following meat, egg or milk products from livestock raised within one mile of your house?
(CIRCLE ALL THAT APPLY)

1= Beef, pork, lamb or goat meat
2= Poultry products (MEAT OR EGGS)
3= Milk from cows or goats
4= None of the above
9=Don't know
10=Other (Specify)

18. What water supply have you used to water your garden within the past two years?

1=public/city water supply
2=private well
3=Farm Pond
4=Irrigation ditch
9=Don't know
10=Other (Specify ________________)

19. In the past two years, have you or your family eaten fruits or vegetables grown from someone else's garden or a farm market, that was located within one mile of the Rocky Mountain Arsenal?
(SHOW PARTICIPANT THE MAP)

1=Yes 2=No

(IF NO, GO TO Q21. IF YES, ANSWER Q20)

20. If yes to Q19, how often, on an average, have you eaten these fruits or vegetables? (INCLUDE FOODS THAT WERE CANNED OR FROZEN)

A. SUMMER CONSUMPTION

1=Less than once per week
2=Once per week
3=More than once per week
8=Never
9=Don't know

B. REMAINDER OF THE YEAR

1=Less than once per week
2=Once per week
3=More than once per week
8=Never
9=Don't know

21. How many times, <u>per week or month</u>, do you or your family eat fish, including tuna, shrimp, crab, clams, or other seafood? (INCLUDE EATING OUT)

______ (MEALS PER WEEK/ MEALS PER MONTH)

(CIRCLE ONE OF THE ABOVE)

NOW I'D LIKE TO ASK YOU SOME QUESTIONS ABOUT THE WATER SUPPLY IN YOUR HOME

22. What is the source of water for this house?
    1=public/city water supply
    2=private well
    3=Cistern
    4=Haul water in (INDICATE SOURCE, IF HAULED IN ____________)
    9=Don't know
    10=Other (Specify) ______________________________

23. If on public or city water system, to whom do you pay your monthly water bill?

    1=Name of company ______________________________
    2=Don't pay water bill for this residence
    9=Don't know

24. If on well water, what is the depth of the well?

    ____________ feet   9= Don't know

25. Has your water source changed since you've lived at this address?

    1=Yes   2=No   9=Don't know

26. If your water supply has changed, indicate type of change and date change occured. (CIRCLE ALL THAT APPLY)

TYPE OF CHANGE	DATE OF CHANGE TO NAMED SYSTEM (month and year)
1=Public/City water to private well water	
2=Private well water to public/city water	
3=Public/City water to bottled water	
4=Private well water to bottled water	
10=Other (Specify) ____________	

27. Do you use bottled water at home for:
(CIRCLE ALL THAT APPLY)

1=Drinking water
2=Cooking
3=Bathing
4=Don't use bottled water
9=Don't know
10=Other (Specify) ____________________

28. Do you have a filter system on your home tap water?

1=YES, for kitchen tap only
2=YES, for entire house
3=NO filter system in this home
9=Don't know
10=Other (Specify____________________)

29. If you do have a filter system, what type is it?

____

30. Do you have a water softener in your home?

1=YES, for kitchen tap only
2=YES, for entire house
3=NO softener in this home
9=Don't know
10=Other (Specify____________________)

NOW I'D LIKE TO ASK YOU SOME QUESTIONS ABOUT CHEMICALS USED IN AND AROUND YOUR HOME

31. Within the past five years, has an exterminator treated this property or house for termites?

1=Yes   2=No   9=Don't know

(IF NO, GO TO Q34)

32. If yes, list product and brand name(s) for any chemicals that you know were used in the following locations:

Inside the House	Outside the House
________________	________________
________________	________________
________________	________________

33. May I have tne exterminator's name, so that we can check to see what product they used?

________________ (NAME/PHONE OF EXTERMINATOR)

________________ (NAME/PHONE OF LANDLORD, IF RENTING)

2=No, refused to provide name
9=Don't know

34. Within the past 5 years, were any of the following chemical products used at this house or on this property, that you know of? (CIRCLE ALL THAT APPLY)

1=Compound 118
2=Aldrite
3=Octalene
4=Aldrosol
5=Aldron
6=Algran
7=Soildrin
11=Aldrec
12=Aldrex
13=Algran
14=HHDN
15=Altox
16=Bangald
17=SD-3418
18=Drinox
19=Octalene
20=Seedrin liquid
21=Entoma 15949
22=HEOD
23=Panoram D-31
24=Dieldrex
25=Octalox
26=Dieldrite
27=Endrex
28=Nendrin
29=Hexadrin
30=Mendrin
31=Experimental insecticide 269

8=None of the above
9=Don't know

35. Have you or your family noticed unusual or unpleasant chemical odors around your house in the past two years?

1=Yes   2=No   9=Don't Know

36. If you have noticed odors, when did they begin?

__________ (MONTH)   __________ (YEAR)

37. Do you still notice the odors?

1=Yes   2=No   3=Sometimes   9=Don't know

38. Do you have any dogs or cats that go in and out of the house?

1=Yes   2=No

39. Is the area around your home mostly:

1=dirt/uncovered soil
2=grass
3=gravel/stones
4=asphalt or concrete
5=equal mix of grass and dirt
9=Don't know
10=Other (Specify ______)

40. Is there a dirt or gravel alley behind your house?

1=YES, dirt
2=YES, gravel
3=NO, neither
4=Don't know

41. Is the street in front of your house:

1=paved   2=dirt   3=gravel

10=Other (Specify ________________________)

VENTILATION AND HEATING

42. Is your current residence a:

1=Trailer or mobile home
2=Single family house
3=Multiple family dwelling or apartment
10=Other (Specify)

43. How old is this dwelling?

1= ________ (YEARS)
9=Don't know

44. Have you used storm windows on your home in the past two years?

1=Yes
2=No
9=Don't know

45. In the past two years, have you used any of the following in your home? (CIRCLE ALL THAT APPLY)

1=Single room air conditioner
2=Central or whole house air conditioning
3=Swamp cooler or evaporative condenser
4=Humidifier or vaporizer
5=Forced air heating system
6=Air purifying device (Specify brand or type________________)
7=None of the above
9=Don't know

46. How often do you leave your windows open in the summer or when the weather is nice?

1=All of the time
2=About half of the time
3=Occasionally
4=Never
9= Don't know
10=Other (Specify___________)

47. Which income level in the following list comes closest to the total household income for this family before taxes in 1988?

1=Under $5,000
2=$5,000 or more but less than $15,000
3=$15,000 or more but less than $25,000
4=$25,000 or more but less than $35,000
5=$35,000 or more but less than $50,000
6=$50,000 or more
9=Don't know
11=Refused to respond to this question

THE FOLLOWING QUESTIONS APPLY TO THE ADULT MEMBERS OF THE HOUSEHOLD (ALL THOSE 15 YEARS OLD AND OLDER). PLEASE COMPLETE THIS SECTION FOR EACH ADULT PARTICIPANT LIVING IN THE HOUSEHOLD.

Interviwer Initials _ _ _

Name of Participant ______________________________

Lab Label for Participant:

200. What is your age and date of birth?

BIRTH DATE __ __ - __ __ - __ __ (MO-DA-YR)

AGE ____________

201. (PARTICIPANT'S SEX IS:)

1=Male
2=Female

202. What is your race or ethnic group?

1=White, non-Hispanic
2=Hispanic
3=Black, non-Hispanic
4=Asian or Pacific Islander
5=American Indian/Alaska native
6=Refused
9=Don't know
10=Other (Specify) ____________

203. What is the highest grade or year of school that you have completed? (CIRCLE ANSWER)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 19+

204. How many years have you lived at this residence?

______ (YEARS)

205. Within the past 10 years, have you lived within one mile of the Rocky Mountain Arsenal? (SHOW RESPONDENT THE MAP)

1=Yes 2=No

206. Within the past 10 years, have you lived on a farm or ranch where crops were grown?

1=Yes (IF YES, FOR HOW MANY YEARS ________)
2=No
9=Don't know

207. Between January, 1980 and December, 1987, did you live in any of the following areas:

*Denver Metro Area
*Denver County
*Adams County
*Weld County
*Jefferson County
*Boulder County
*Douglas County
*Arapahoe County

1=Yes 2=No

(IF NO, GO TO Q209. IF YES, ANSWER Q208)

208. Please give me the address and length of residence for all homes, from the above areas, in which you lived:

(LIST MOST RECENT ADDRESS FIRST)

Previous address	How long?
1. ________________________________	________
________________________________	
2. ________________________________	________
________________________________	
3. ________________________________	________
________________________________	
4. ________________________________	________
________________________________	

IF PARTICIPANT IS AN ADULT FEMALE BETWEEN THE AGES OF 15 TO 50 YEARS OLD, ASK Q209 - Q212. IF NOT AN ADULT FEMALE IN THIS AGE RANGE, PROCEED TO Q213.

209. Have you had any children in the past 5 years?

1=Yes 2=No

(IF NO, GO TO Q213. IF YES, GO TO Q210)

210. If yes, did you breast feed any of your children?

1=YES (IF YES, INDICATE TOTAL MONTHS, FOR ALL CHILDREN WHO WERE BREAST FED ________)

2=NO

211. Are you currently breast feeding any of your children?

1=Yes 2=No

212. If yes, for how many consecutive months have you been breast feeding?

________ (MONTHS)

213. Do you currently smoke cigarettes? (IF NO GO TO 216)

1=Yes 2=No

214. If yes, how many years have you smoked cigarettes?

________ (YEARS)

215. How many cigarettes per day do you smoke on an average?

________ (CIGARETTES) (20 PER PACK)

216. If you do not smoke currently, did you smoke previously? (IF NO, GO TO 218)

1=Yes 2=No

217. If yes, when did you stop smoking (year) ? ________

218. Do you drink alcohol? (IF NO GO TO 220)
1=Yes 2=No

219. If yes, what type of alcohol do you drink and how many glasses per day or per week. (CHECK EITHER PER DAY, PER WEEK, OR LESS)

	Check if Yes	No. of glasses/drinks	PER DAY	PER WEEK	LESS THAN WEEKLY
Beer	____	____	____	____	____
Red Wine	____	____	____	____	____
White Wine	____	____	____	____	____
Hard Liquor	____	____	____	____	____

220. In the past week, how many glasses of red wine have you consumed?

______ (GLASSES) 9=Don't know

221. In the past week, during how many meals did you eat fish, including tuna, shrimp, crab, clams or other seafood? (INCLUDE EATING OUT)

______ (MEALS) 9=Don't know

222. Within the past two years, how often did you eat wild game or wild fowl?

1=Less than once a month
2=About once a month
3=More than once a month
8=Never
9=Don't know

223. Are you currently taking any vitamin or mineral supplements, such as calcium, iron, a daily vitamin/mineral tablet, etc.?

1=Yes 2=No

If yes, specify ______________________________

224. Have you had any dental fillings within the last two weeks?

1=Yes 2=No

225. Do you currently participate in any of the following hobbies or activities?
(CIRCLE ALL THAT APPLY)

1=Gardening or yard work
2=Woodworking
3=Silkscreening or tie-dying
4=Glassmaking
5=Photography developing
6=Welding
7=Automobile restoration, painting, or bodywork (EXCLUDE MECHANICAL WORK)
8=Ceramics
9=Work with leathercrafts
10=Ride bikes within one mile of the Arsenal or on the Arsenal (SHOW MAP)
11=Walk or hike within one mile of the Arsenal or on the Arsenal
12=Work with electrical components

226. Within the past two years, did you fish or hunt within one mile of the Rocky Mountain Arsenal area or on the Arsenal itself? (IF NO, GO TO 228). (SHOW MAP FOR QUESTIONS 226-229)

1=Yes 2=No 9=Don't know

227. If yes, did you eat what you caught or shot?

1=Yes 2=No

228. In the past two years, did you eat fish or game that others caught on the Rocky Mountain Arsenal or within one mile of the Arsenal area?

1=Yes 2=No 9=Don't know

229. In the past two years, did you gather or eat any wild plants growing within one mile of the Rocky Mountain Arsenal area, such as asparagus, mushrooms, or berries?

1=Yes 2=No

If yes, specify____

230. In the past two years, have you used bottled water?

1=YES, at home
2=YES, at work
3=YES, at home and at work
4=NO, I don't use bottled water
9=Don't know

231. About how many glasses of home tap water do you drink each day, on an average ?

(INCLUDE ALL BEVERAGES CONSUMED THAT ARE MADE FROM HOME TAP WATER, SUCH AS COFFEE, TEA, JUICE, SOUP, ICE TEA, KOOLAID, ETC.)

_______________ (8 OZ. GLASSES)

NOW I'D LIKE TO ASK YOU SOME QUESTIONS ABOUT HOW MUCH TIME YOU SPEND INSIDE AND OUTSIDE YOUR HOME, DURING WEEKDAYS, AND ON YOUR DAYS OFF.

232. How many hours per day (IN A 24 HOUR DAY) do you spend inside your home, on weekdays?

A. SUMMER

_______ (HOURS)

B. REMAINDER OF YEAR

_______ (HOURS)

233. How many hours per day (IN A 24 HOUR DAY) do you spend inside your home, on weekends (ie, DAYS OFF)?

A. SUMMER

_______ (HOURS)

B.REMAINDER OF YEAR

_______ (HOURS)

234. How many hours per day are you outdoors, within one mile of your house, on weekdays ?

A. SUMMER

_______ (HOURS)

B. REMAINDER OF YEAR

_______ (HOURS)

235. How many hours per day are you outdoors, within one mile of your house, on weekends (ie, DAYS OFF)?

A. SUMMER

_______ (HOURS)

B. REMAINDER OF YEAR

_______ (HOURS)

WORK HISTORY

NOW I'D LIKE TO ASK YOU SOME QUESTIONS ABOUT YOUR WORK

300. Are you currently:

1=Working outside of the home
2=Working at home
3=Unemployed
4=Retired

(IF NOT CURRENTLY WORKING OUTSIDE OF HOME, SKIP TO 308)

301. If working outside of your home, where do you currently work (give company name and address, if applicable) ?

____

____

302. What is your current occupation?

____

303. What type of work do you do?

____

304. How long have you worked there? __________ (MONTHS)/ (YEARS) (CIRCLE ONE)

305. Do you change out of your work clothes and leave them at work?
1=Yes 2=No

306. Do you wash your work clothes at home?

1=Yes 2=No

307. Do you shower at work before coming home?

1=Yes 2=No

308. List your principal occupation(s) in the past 10 years:

OCCUPATION	YEARS

309. Have you ever worked at the Rocky Mountain Arsenal?

1=Yes 2=No

310. If yes, when? ______________________ (YEARS)

311. What type of work did you do at the Rocky Mountain Arsenal?

____

____

312. In the last 10 years, have you done any of the following agricultural work?
(CIRCLE ALL THAT APPLY)

1=Worked on a farm or ranch
2=Worked at a vegetable farm or greenhouse
3=Worked with either corn, alfalfa, clover or grain crops (SUCH AS WHEAT, BARLEY, OATS OR MILO)
4=Worked in an orchard
5=Sprayed Crops
6=Worked in a sugarbeet factory
7=Worked for a fertilizer company
11=Worked for a sheep ranch or sheep feedlot
10=Worked at a grain elevator or feed mill

8=None of the above

313. Were any of your occupations related to: (CIRCLE ALL THAT APPLY)

1=Pesticide manufacturing or pesticide products
2=Mining, smelting, or refining company
3=Chemical production
4=Glass manufacturing
5=Wood preservative or treatment
6=Electroplating, welding or battery manufacturing
7=Automobile painting, restoration, or bodywork
(EXCLUDE MECHANICAL WORK)
11=Lawn care service or tree pruning
12=Pest Extermination
13=Woolen textiles
14=Work with inks or dyes
15=Leather tanning
16=Carpentry

8=None of the above
9=Don't know

IF YOU HAVE EVER WORKED WITH PESTICIDE PRODUCTS, PLEASE ANSWER 314-316; IF NOT, GO TO QUESTION 400.

314. What pesticide products, such as weed killers, seed treatment, fungicides or insecticides, have you worked with and how long did you work with each of these?

Product or Trade Name	Years
1.________________	________
2.________________	________
3.________________	________

315. What application equipment was used, if any?

1= ________________ (SPECIFY TYPE)
8=None
9=Don't know

316. Did you use any protective clothing?
1=Yes If yes, specify ________________
2=No

PAST MEDICAL HISTORY

400. Have you ever been diagnosed by a doctor as having any of the following conditions? (CIRCLE ALL THAT APPLY)

1=hepatitis or other liver disease
2=cancer
3=diabetes
4=heart disease
5=kidney disease (EXCLUDE INFECTIONS)
8=None of the above

IF THERE ARE NO CHILDREN SELECTED TO PARTICIPATE BETWEEN THE AGES OF 2 THROUGH 14 YEARS OLD IN THE HOUSEHOLD, THE QUESTIONNAIRE IS COMPLETE.

IF THERE ARE CHILDREN BETWEEN THE AGES OF 2 THROUGH 5 YEARS OLD, PROCEED TO Q500. (PINK SECTION)

IF THERE ARE CHILDREN BETWEEN THE AGES OF 6 THROUGH 14 YEARS OLD, PROCEED TO Q600. (GREEN SECTION)

CHILDREN

THIS SECTION IS TO BE ANSWERED BY AN ADULT HEAD OF THE HOUSEHOLD FOR ALL CHILDREN BETWEEN THE AGES OF 2 THROUGH 5 YEARS OLD.

IF THERE ARE NO CHILDREN WITHIN THIS AGE RANGE, BUT THERE ARE CHILDREN BETWEEN THE AGES OF 6 THROUGH 14, PROCEED TO Q600. (GREEN SECTION)

Interviewer Initials _ _ _

Child's Name ______________________________

Lab Label for Participant

Respondent's Name ______________________________

Respondent's relationship to participant ________________

500. What is (CHILD'S NAME) age and date of birth?

BIRTH DATE — AGE

_ _ - _ _ - _ _ (MO-DA-YR) ________

501. (CHILD'S SEX IS):

1=Male
2=Female

502. What race or ethnic group does your child belong to?

1=White, non-Hispanic
2=Hispanic
3=Black, non-Hispanic
4=Asian or Pacific Islander
5=American Indian/Alaska native
6=Refused
9=Don't know
10=Other (Specify__________)

503. How many years has this child lived at this residence?

________ (YEARS)

504. Within the past 5 years, has (CHILD'S NAME) lived within one mile of the Rocky Mountain Arsenal? (SHOW RESPONDENT THE MAP)

1=Yes 2=No 9=Don't know

505. Within the past 5 years, has (CHILD'S NAME) lived on a farm or ranch where crops were grown?

1=Yes (IF YES, FOR HOW MANY YEARS ______)

2=No
9=Don't know

506. Between January, 1983 and December, 1987, did (CHILD'S NAME) live in any of the following areas:

*Denver Metro Area
*Denver County
*Adams County
*Weld County
*Jefferson County
*Boulder County
*Douglas County
*Arapahoe County

1=Yes 2=No

(IF NO, GO TO Q508. IF YES, ANSWER Q507)

507. Please give me the address and length of residence for all homes, from the above areas, in which this child lived.

(LIST MOST RECENT ADDRESSS FIRST)

Previous address	How long?
1. ______	______
______	
2. ______	______
______	
3. ______	______
______	

508. Has (CHILD'S NAME) ever been diagnosed by a doctor as having any of the following conditions? (CIRCLE ALL THAT APPLY)

1=hepatitis or other liver disease
2=cancer
3=diabetes
4=congestive heart failure or other heart disease
5=kidney disease (EXCLUDE INFECTIONS)
8=None of the above

509. Has (CHILD'S NAME) ever been breast fed?

1=Yes 2=No 9=Don't know

510. If yes, for how many months was he/she breast fed?

________________ (MONTHS)

NOW I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT WHERE YOUR CHILD SPENDS MOST OF THEIR TIME, ON WEEKDAYS AND WEEKENDS.

511. Where does your child spend most of his/her daytime hours?

1=At home
2=At babysitter
3=At a day care center
4=At a relative's home
5=At school
10=Other location
(Specify) ________________

512. Is this location, where (CHILD'S NAME) spends most of his/her time during the day, within one mile of the Rocky Mountain Arsenal?

1=Yes 2=No 9=Don't know

513. How many hours per day (IN A 24 HOUR DAY) does (CHILD'S NAME) spend <u>inside</u> your home, on <u>weekdays</u>?

A. SUMMMER

________ (HOURS)

9=Don't know

B. REMAINDER OF YEAR

________ (HOURS)

9=Don't know

514. How many hours per day (IN A 24 HOUR DAY) does (CHILD'S NAME) spend inside your home, on weekends?

A. SUMMER

_______ (HOURS)

9=Don't know

B. REMAINDER OF YEAR

_______ (HOURS)

9=Don't know

515. How many hours per day does (CHILD'S NAME) spend playing outdoors, within one mile of your home, on weekdays?

A. SUMMER

_______ (HOURS)

9=Don't know

B. REMAINDER OF THE YEAR

_______ (HOURS)

9=Don't know

516. How many hours per day does (CHILD'S NAME) spend playing outdoors, within one mile of your home, on weekends?

A. SUMMER

_______ (HOURS)

9=Don't know

B. REMAINDER OF THE YEAR

_______ (HOURS)

9=Don't know

517. Is the ground where (CHILD'S NAME) plays mostly :

1=Grassy
2=Concrete/asphalt
3=Dirt/uncovered soil
4=Equal mix of grass and dirt
5=Sandbox
6=Gravel/stones
9=Don't know
10=Other (Specify)

518. How often does (CHILD'S NAME) take food or a bottle outside with them when they play?

1=Daily 2=Less than daily 8=Never 9=Don't know

519. Has (CHILD'S NAME) used a pacifier in the last 6 months?
1=Yes 2=No 9=Don't know

520. Does he/she suck their thumb?
1=Yes 2=No 9=Don't know

521. Does he/she chew on their fingernails?
1=Yes 2=No 9=Don't know

522. Does he/she eat dirt, grass, or chew on objects outside?
1=Daily 2=Less than daily 3=Never 9=Don't know

523. How many hours during the day do you think he/she spends playing on the floor when indoors in this home?

_____ (HOURS) 9=Don't know

524. On an average, how many glasses of home tap water does (CHILD'S NAME) drink each day?

(INCLUDE ALL BEVERAGES CONSUMED THAT ARE MADE FROM HOME TAP WATER, SUCH AS JUICE, SOUP, ICE TEA, KOOLAID, ETC.)

______________ (8 OZ.GLASSES)

525. Has (CHILD'S NAME) had any dental fillings within the last two weeks?

1=YES 2=NO 9=Don't know

526. In the past week, during how many meals has (CHILD'S NAME) eaten fish, including tuna, shrimp, crab, clams or other seafood? (INCLUDE EATING OUT)

____ ____ (MEALS)

527. In the past two years, how often has (CHILD'S NAME) eaten wild game or wild fowl?

1=Less than once a month
2=About once a month
3=More than once a month
8=Never
9=Don't know

528. Is (CHILD'S NAME) currently taking a vitamin or mineral supplement, such as calcium, iron, a daily vitamin or mineral tablet, etc.?

1=Yes 2=No 9=Don't know

If yes, specify ____

529. If you have a garden, how often, in the past two years, has (CHILD'S NAME) eaten fruits or vegetables grown in your garden?

(INCLUDE FOOD THAT WAS CANNED OR FROZEN)

A. SUMMER CONSUMPTION

1=Less than once per week
2=Once per week
3=More than once per week
4=Don't have a garden
8=Never
9=Don't know

B. REMAINDER OF YEAR

1=Less than once per week
2=Once per week
3=More than once per week
4=Don't have a garden
8=Never
9=Don't know

530. In the past two years, has (CHILD'S NAME) eaten fruits or vegetables grown from someone else's garden or farm market, that was locateed within one mile of the Rocky Mountain Arsenal?
(SHOW RESPONDENT THE MAP)

1=Yes 2=No 9=Don't know

(IF NO, GO TO Q532. IF YES, ANSWER Q531)

531. If yes to Q530, how often, on an average, has (CHILD'S NAME) eaten these fruits or vegetables?
(INCLUDE FOODS THAT WERE CANNED OR FROZEN)

A. SUMMER CONSUMPTION

1=Less than once a week
2=Once a week
3=More than once a week
8=Never
9=Don't know

B. REMAINDER OF THE YEAR

1=Less than once a week
2=Once a week
3=More than once a week
8=Never
9=Don't know

532. In the past two years, has (CHILD'S NAME) eaten fish or game that was caught within one mile of the Rocky Mountain Arsenal area?

1=Yes 2=No 9=Don't know

ARSENAL STUDY 1989 CSU
BIORAD LYPOCHEK URINE METAL CONTROL
LOW SPIKE ARSENIC QA/QC
DL = 10 PPB BIORAD RANGE 42.9-64.4 MEAN = 53.7 PPB

REPLICATE NUMBER	CSU'S (PPB)	MEAN	UCL	UWL	LWL	LCL
1	50.4	53.4	62.07	59.18	47.62	44.73
2	54.8	53.4	62.07	59.18	47.62	44.73
3	56.4	53.4	62.07	59.18	47.62	44.73
4	52.6	53.4	62.07	59.18	47.62	44.73
5	52.1	53.4	62.07	59.18	47.62	44.73
6	48.2	53.4	62.07	59.18	47.62	44.73
7	56.2	53.4	62.07	59.18	47.62	44.73
8	56.5	53.4	62.07	59.18	47.62	44.73

8 AVG = 53.4
S = 2.889204

UWL = 59.17841 UCL = 62.06761

533. In the past two years, has (CHILD'S NAME) eaten wild plants, such as asparagus, mushrooms or berries that have been gathered from within one mile of the Rocky Mountain Arsenal area?

1=Yes 2=No 9=Don't know

If yes, specify ______________________________

IF THERE ARE NO CHILDREN SELECTED TO PARTICIPATE BETWEEN THE AGES OF 6 THROUGH 14 IN THE HOUSEHOLD, THE QUESTIONNAIRE IS NOW COMPLETE.

IF THERE ARE CHILDREN BETWEEN THE AGES OF 6 THROUGH 14, PROCEED TO Q600. (GREEN SECTION)

THIS SECTION IS TO BE ANSWERED BY AN ADULT MEMBER OF THE HOUSEHOLD FOR ALL CHILDREN BETWEEN THE AGES OF 6 THROUGH 14 YEARS OLD.

Interviwer Initials _ _ _

Child's Name ______________________________

Lab Label for Participant

Respondent's Name ______________________________

Respondent's Relationship to Participant ________________

600. What is (CHILD'S NAME) age and date of birth?

BIRTH DATE AGE

_ _ - _ _ - _ _ (MO-DA-YR) ____________

601. (CHILD'S SEX IS):

1=Male
2=Female

602. What race or ethnic group does your child belong to?

1=White, non-Hispanic
2=Hispanic
3=Black, non-Hispanic
4=Asian or Pacific Islander
5=American Indian/Alaska native
6=Refused
9=Don't know
10=Other (Specify __________)

603. How long has this child lived at this residence?

__________ (YEARS)

604. Within the past 10 years, has (CHILD'S NAME) lived within one mile of the Rocky Mountain Arsenal? (SHOW RESPONDENT THE MAP)

1=Yes 2=No 9=Don't know

605. Within the past 10 years, has (CHILD'S NAME) lived on a farm or ranch where crops were grown?

1=Yes (IF YES, FOR HOW MANY YEARS ______)

2=No
9=Don't know

606. Between January, 1980 and December, 1987, did (CHILD'S NAME) live in any of the following areas:

*Denver Metro Area
*Denver County
*Adams County
*Weld County
*Jefferson County
*Boulder County
*Douglas County
*Arapahoe County

1=Yes 2=No 9=Don't know

(IF NO, GO TO Q608. IF YES, ANSWER Q607)

607. Please give me the address and length of residence for all homes, from the above areas, in which this child has lived:

(LIST THE MOST RECENT ADDRESS FIRST)

Previous address	How long?
1. ______________________________	________
______________________________	
2. ______________________________	________
______________________________	
3. ______________________________	________
______________________________	

608. Has (CHILD'S NAME) ever been diagnosed by a doctor as having any of the following conditions? (CIRCLE ALL THAT APPLY)

1=hepatitis or other liver disease
2=cancer
3=diabetes
4=congestive heart failure or other heart disease
5=kidney disease (EXCLUDE INFECTIONS)
8=None of the above

609. Has (CHILD'S NAME) ever been breast fed?

1=Yes 2=No 9=Don't know

610. If yes, for how many months was he/she breast fed?

__________ (MONTHS)

NOW I WOULD LIKE TO ASK YOU SOME QUESTIONS ABOUT WHERE YOUR CHILD SPENDS MOST OF THEIR TIME, ON WEEKDAYS AND WEEKENDS.

611. How many hours per day (IN A 24 HOUR DAY) does (CHILD'S NAME) spend <u>inside</u> your home, on <u>weekdays</u>?

A. SUMMER

_____ (HOURS)

9=Don't know

B. REMAINDER OF YEAR

_____ (HOURS)

9=Don't know

612. How many hours per day (IN A 24 HOUR DAY) does (CHILD'S NAME) spend <u>inside</u> your home, on <u>weekends</u>?

A. SUMMER

_____ (HOURS)

9=Don't know

B. REMAINDER OF YEAR

_____ (HOURS)

9=Don't know

613. How many hours per day does (CHILD'S NAME) spend playing outdoors, within one mile of your home, on weekdays?

A. SUMMER

_______ (HOURS)

9=Don't know

B. REMAINDER OF THE YEAR

_______ (HOURS)

9=Don't know

614. How many hours per day does (CHILD'S NAME) spend playing outdoors, within one mile of your home, on weekends?

A. SUMMER

_______ (HOURS)

9=Don't know

B. REMAINDER OF THE YEAR

_______ (HOURS)

9=Don't know

615. Where has (CHILD'S NAME) usually played within the past two years when he/she wasn't in your yard?

1=Neighbor's yard
2=School playground
3=In a park
4=On sidewalks or streets
9=Don't know
10=Other (Specify) ______________________________

616. Is this location, where (CHILD'S NAME) plays, within one mile of the Rocky Mountain Arsenal?

1=Yes   2=No   9=Don't know

617. Is the ground where he/she plays mainly:

1=Grassy
2=Concrete/asphalt
3=Dirt/uncovered soil
4=Equal mix of grass and dirt
5=Sandbox
6=Gravel/stones
9=Don't know
10=Other (Specify_______)

618. How often does (CHILD'S NAME) take food outside with them when they play?

1=Daily   2=Less than daily   8=Never   9=Don't know

619. Does he/she chew on their fingernails?

1=Yes 2=No 9=Don't know

620. Does (CHILD'S NAME) participate in any of the following hobbies or activities?

1=Gardening or yard work
2=Glasssmaking
3=Work with leathercrafts
4=Ride bikes within one mile of the Arsenal or on the Arsenal
5=Fish, hunt, or hike within one mile of the Arsenal or on the Arsenal
6=Work with electrical components
7=Do silkscreening or tie-dying
11=Help with farm animals or ranch work

8=None of the above
10=Other (Specify) ____________________

621. How many glasses of home tap water does your child drink each day on an average?

(INCLUDE ALL BEVERAGES CONSUMED THAT ARE MADE FROM HOME TAP WATER, SUCH AS JUICE, SOUP, ICE TEA, COFFEE, KOOLAID, ETC.)

__________ (8 OZ.GLASSES)

622. Has (CHILD'S NAME) had any dental fillings within the past two weeks?

1=YES 2=NO 9=Don't know

623. In the past week, how often has (CHILD'S NAME) eaten fish, including tuna, shrimp, crab, clams, or other seafood? (INCLUDE EATING OUT)

___ ___ (MEALS) 9=Don't know

624. In the past two years, how often has (CHILD'S NAME) eaten wild game or wild fowl?

1=Less than once a month
2=About once a monthy
3=More than once a month
8=Never
9=Don't know

625. Is (CHILD'S NAME) currently taking a vitamin or mineral supplement, such as calcium, iron, a daily vitamin or mineral tablet, etc?

1=Yes 2=No 9=Don't know

If yes, specify ______________________________

626. If you have a garden, how often, in the past two years, has (CHILD'S NAME) eaten fruits or vegetables grown in your garden?

(INCLUDE FOOD THAT WAS CANNED OR FROZEN)

A. SUMMER CONSUMPTION

1=Less than once per week
2=Once per week
3=More than once per week
4=Don't have a garden
8=Never
9=Don't know

B. REMAINDER OF YEAR

1=Less than once per week
2=Once per week
3=More than once per week
4=Don't have a garden
8=Never
9=Don't know

627. In the past two years, has (CHILD'S NAME) eaten fruits or vegetables grown from someone else's garden or farm market, that was located within one mile of the Rocky Mountain Arsenal? (SHOW RESPONDENT THE MAP)

1=Yes 2=No 9=Don't know

628. If yes to Q627, how often, on an average, has (CHILD'S NAME) eaten these fruits or vegetables?

A. SUMMER CONSUMPTION

1=Less than once a week
2=Once a week
3=More than once a week
8=Never
9=Don't know

B. REMAINDER OF THE YEAR

1=Less than once a week
2=Once a week
3=More than once a week
8=Never
9=Don't know

629. In the past two years, has (CHILD'S NAME) eaten fish or game that was caught on the Rocky Mountain Arsenal or within one mile of the Arsenal?

1 = Yes 2 = No 9 = Don't know

630. Within the past two years, has (CHILD'S NAME) eaten wild plants, such as asparagus, mushrooms or berries, that have been gathered from within one mile of the Rocky Mountain Arsenal area?

1 = Yes 2 = No 9 = Don't know

If yes, specify ______________________________

631. Does (CHILD'S NAME) currently smoke cigarettes? (IF NO, GO TO Q634)

1 = Yes 2 = No 9 = Don't know

632. If yes, how many years has (CHILD'S NAME) smoked cigarettes?

________ (YEARS)

633. How many cigarettes per day does (CHILD'S NAME) smoke on an average?

________ (CIGARETTES) (20 PER PACK)

634. If (CHILD'S NAME) does not smoke currently, did (CHILD'S NAME) smoke previously? (IF NO, GO TO Q636)

1 = Yes 2 = No 9 = Don't know

635. If yes, when did (CHILD'S NAME) stop smoking (YEAR)? ______

636. Does (CHILD'S NAME) drink alcohol? (IF NO, GO TO Q638)

1 = Yes 2 = No 9 = Don't know

637. If yes, what type of alcohol does (CHILD'S NAME) drink and how many glasses per day or per week. (CHECK EITHER PER DAY, PER WEEK OR LESS)

	Check if Yes	No. of glasses/drinks	PER DAY	PER WEEK	LESS THAN WEEKLY
Beer	____	________	____	____	____
Red Wine	____	________	____	____	____
White Wine	____	________	____	____	____
Hard Liquor	____	________	____	____	____

638. In the past week, how many glasses of red wine has (CHILD'S NAME) consumed?

________(GLASSES) 9 = Don't know RDWINE

YOU HAVE NOW COMPLETED THE QUESTIONNAIRE. THANK YOU VERY MUCH FOR HELPING US WITH THIS STUDY.

APPENDIX J

QA/QC LABORATORY ANALYSES

------------Mercury Duplication of Urine Samples------------

ANALYSIS TIME
(PPB)

SAMPLE NO.	FIRST	SECOND
924	9.0	10.7
929	5.5	5.5
937	8.0	8.3
939	6.0	6.1
979	6.0	4.9
974	5.1	5.4
973	16.1	14.9
972	5.1	6.4
65	6.0	7.1
124	7.0	6.3
132	7.5	6.5
179	6.0	6.7
190	5.5	5.3
198	5.9	6.2
238	9.5	10.4
265	6.1	6.7
274	5.0	3.8
277	5.5	5.5
282	5.3	4.5
298	6.2	9.2
344	7.5	10.2
353	5.0	6.6
367	6.1	7.1
418	6.1	6.0
456	7.9	7.0
463	10.0	10.4
512	7.1	6.4
524	5.0	4.7
955	4.5	4.4
975	4.5	3.9

BIO
HI 30.5 = MEAN
SPIKE
1 34.7
2 35.7

COLO
LO 11.2 = MEAN
SPIKE
1 9.4
2 9.9

-----------Arsenic Duplication of Urine Samples -----------
ANALYSIS TIME
(PPB)

SAMPLE N .	FIRST	SECOND
935	10.9	8.0
940	11.5	10.7
983	24.4	22.7
03	31.7	26.3
13	13.9	14.8
21	20.2	19.2
22	11.2	10.5
49	13.7	13.0
58	16.8	15.4
60	14.1	12.7
62	11.4	11.5
71	18.2	16.6
96	12.7	12.3
109	11.6	12.0
111	11.0	13.1
127	16.0	8.7
[illegible]4	23.0	16.7
	18.9	16.8
	23.9	25.3
1[illegible]	13.8	12.4
18	23.2	12.5
1[illegible]	13.1	13.6
2[illegible]	12.2	11.4
3[illegible]	11.4	9.7
	21.7	7.0
43[illegible]	14.5	15.9
	53.3	47.8
	20.1	20.1
49	18.0	12.4
50	18.6	18.6

HIGH SPIKE — 63.9 = MEAN

1	63.2
2	63.7
3	59.3

BIO SPIKE — 53.7 = MEAN

1	59.0
2	63.9
3	49.3

CHAIN OF CUSTODY FORM
SAMPLE TRANSFER SHEET

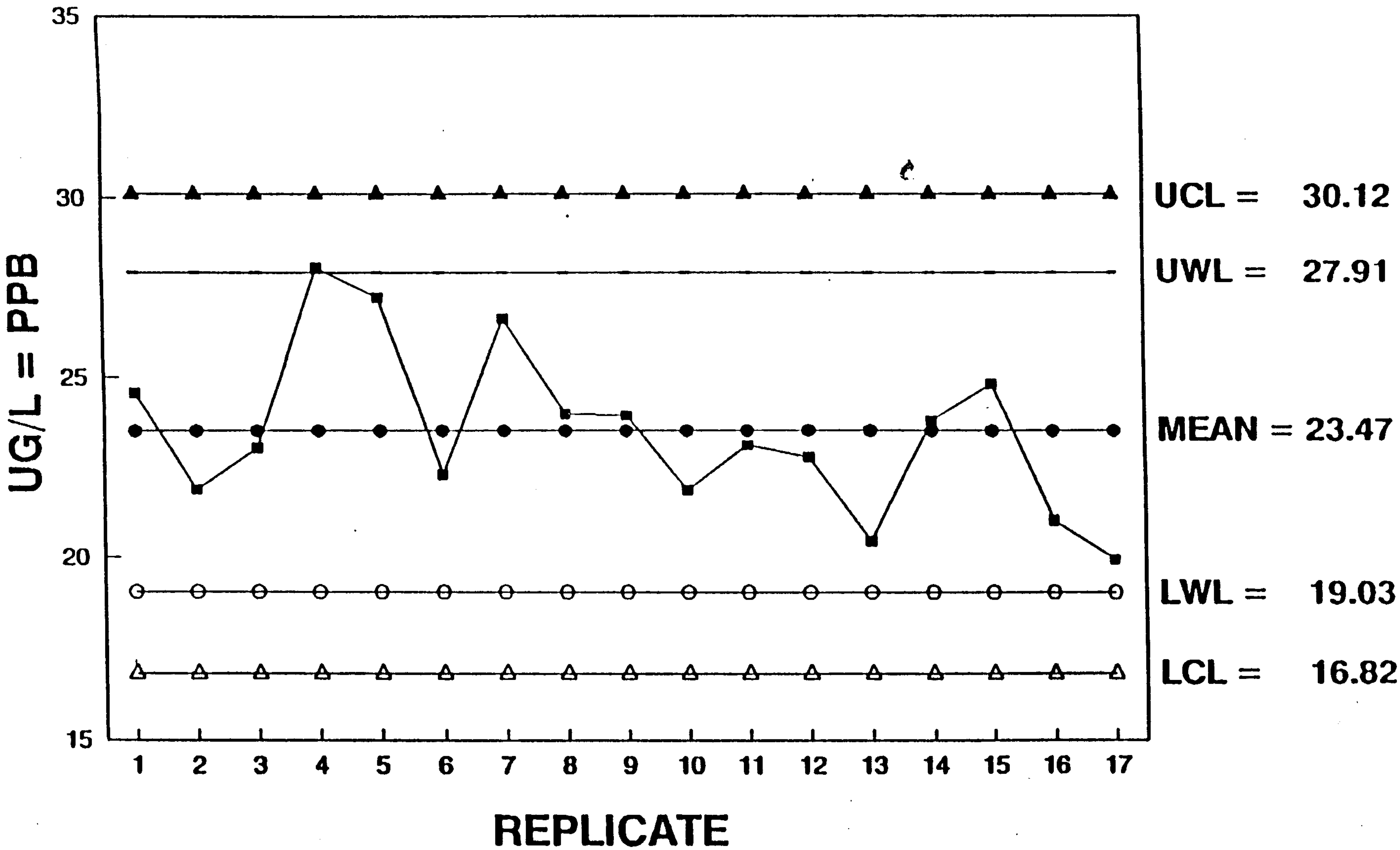
PROJECT NAME:
ROCKY MOUNTAIN ARSENAL
CHEMICAL EXPOSURE STUDY

MATRIX
B: BLOOD U: URINE

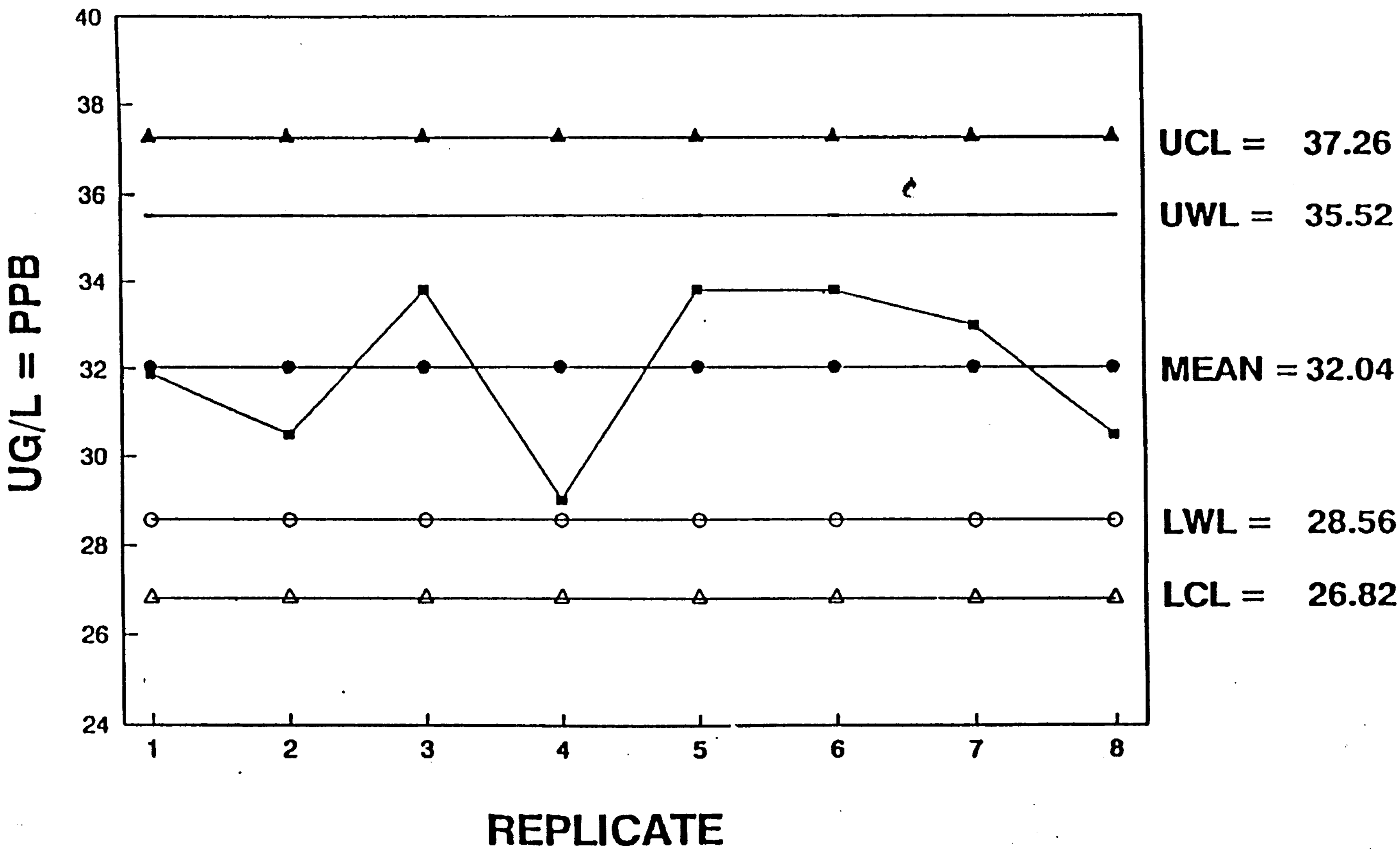
SAMPLE NO.	DATE COLLECTED	TIME COLLECTED	SAMPLER'S SIGNATURE	NO. TUBES	NO. MLs IN SAMPLE	REMARKS

(SIGNATURE) ELINQUISHED BY:	DATE	TIME	ORG	COMMENTS*	(SIGNATURE) RECEIVED BY:	DATE	TIME	ORG	COMMENTS*
ELINQUISHED BY:					RECEIVED BY:				
ELINQUISHED BY:					RECEIVED BY:				
ELINQUISHED BY:					RECEIVED BY:				
ELINQUISHED BY:					RECEIVED BY:				
ELINQUISHED BY:					RECEIVED BY:				
SHED BY:					RECEIVED BY:				

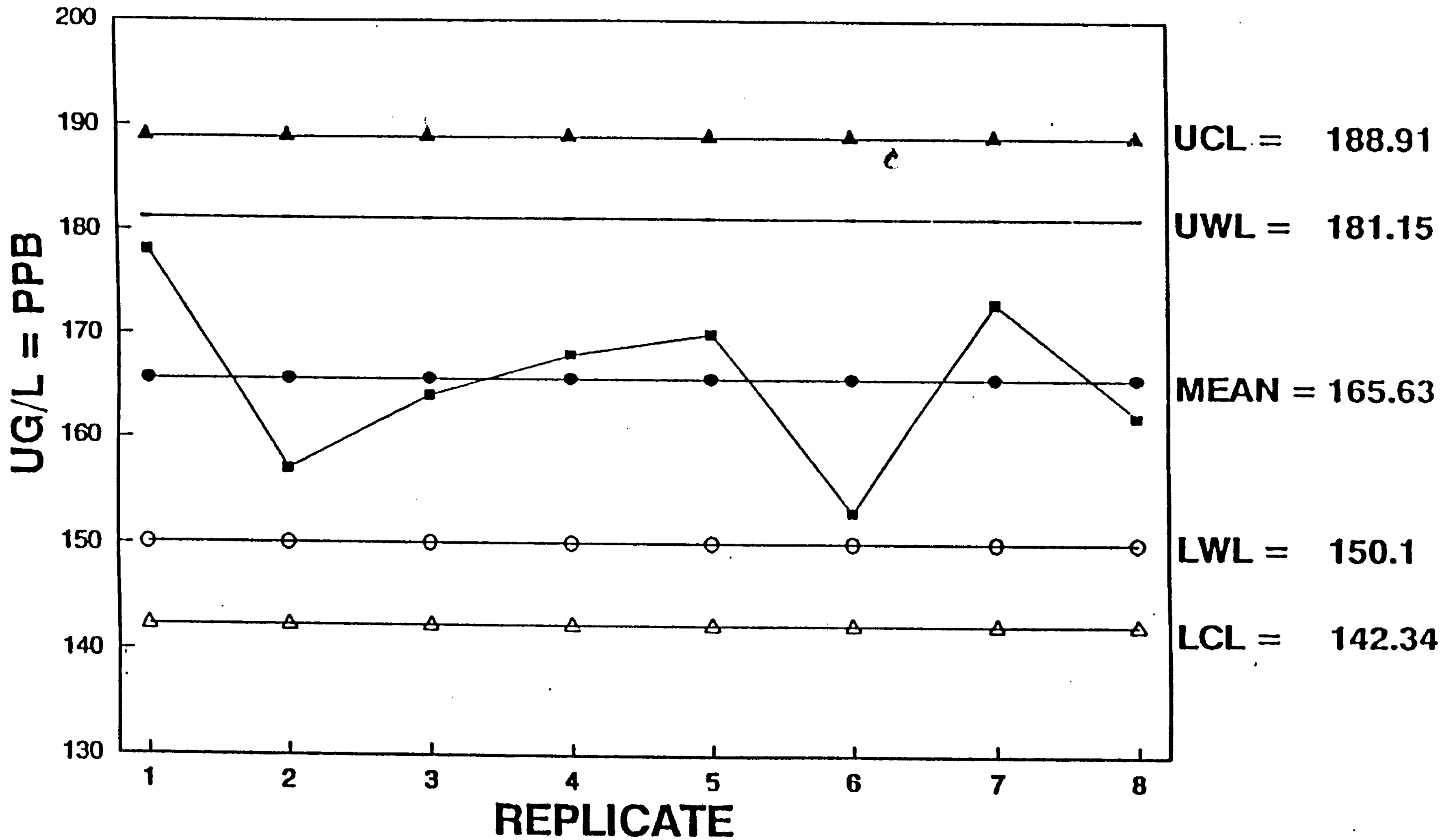
QUALITY CONTROL ANALYSIS - CSU
ARSENIC - COLORADO LOW POOL



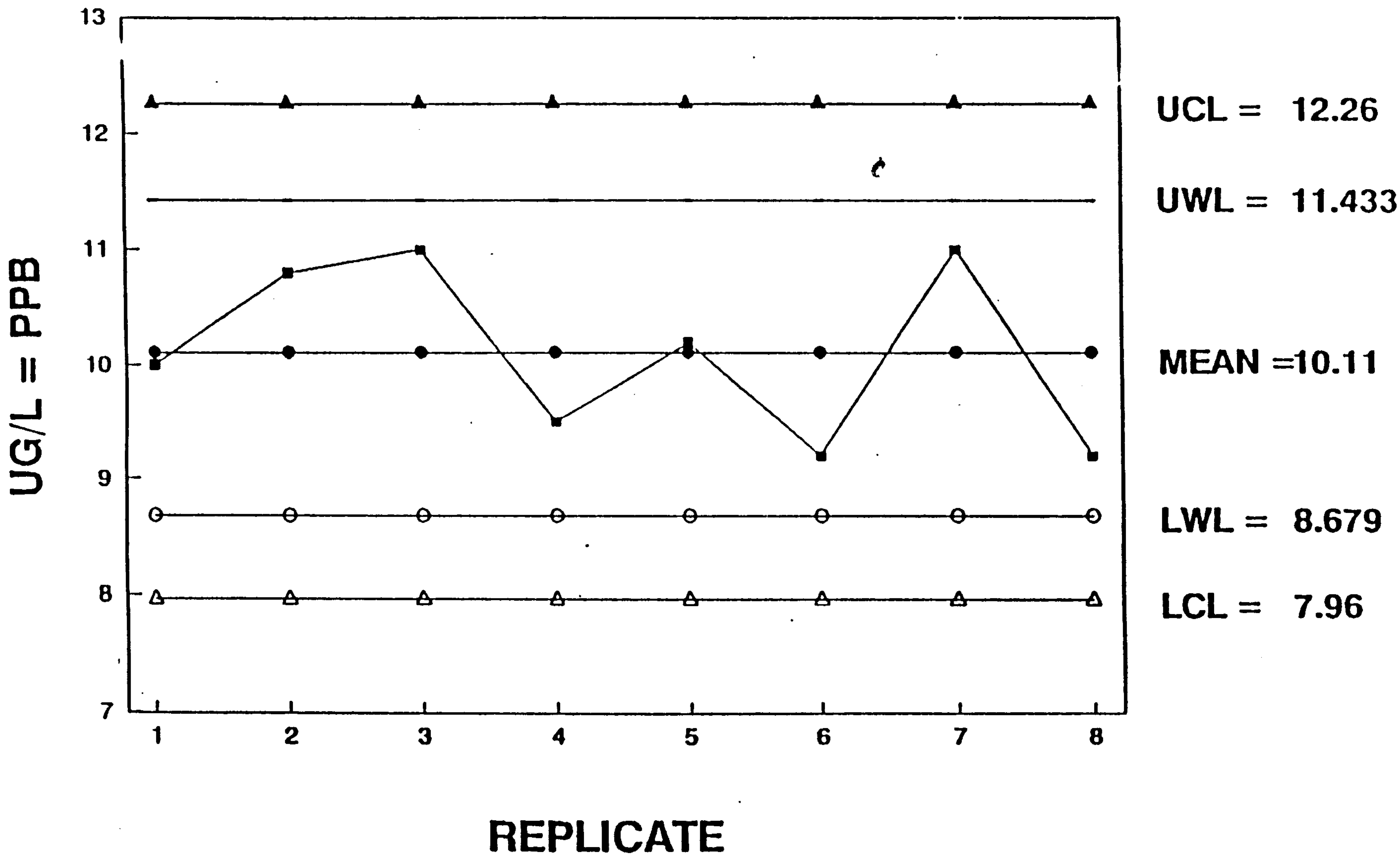
QUALITY CONTROL ANALYSIS - CSU
BIORAD LYPHOCHEK - HIGH SPIKE MERCURY



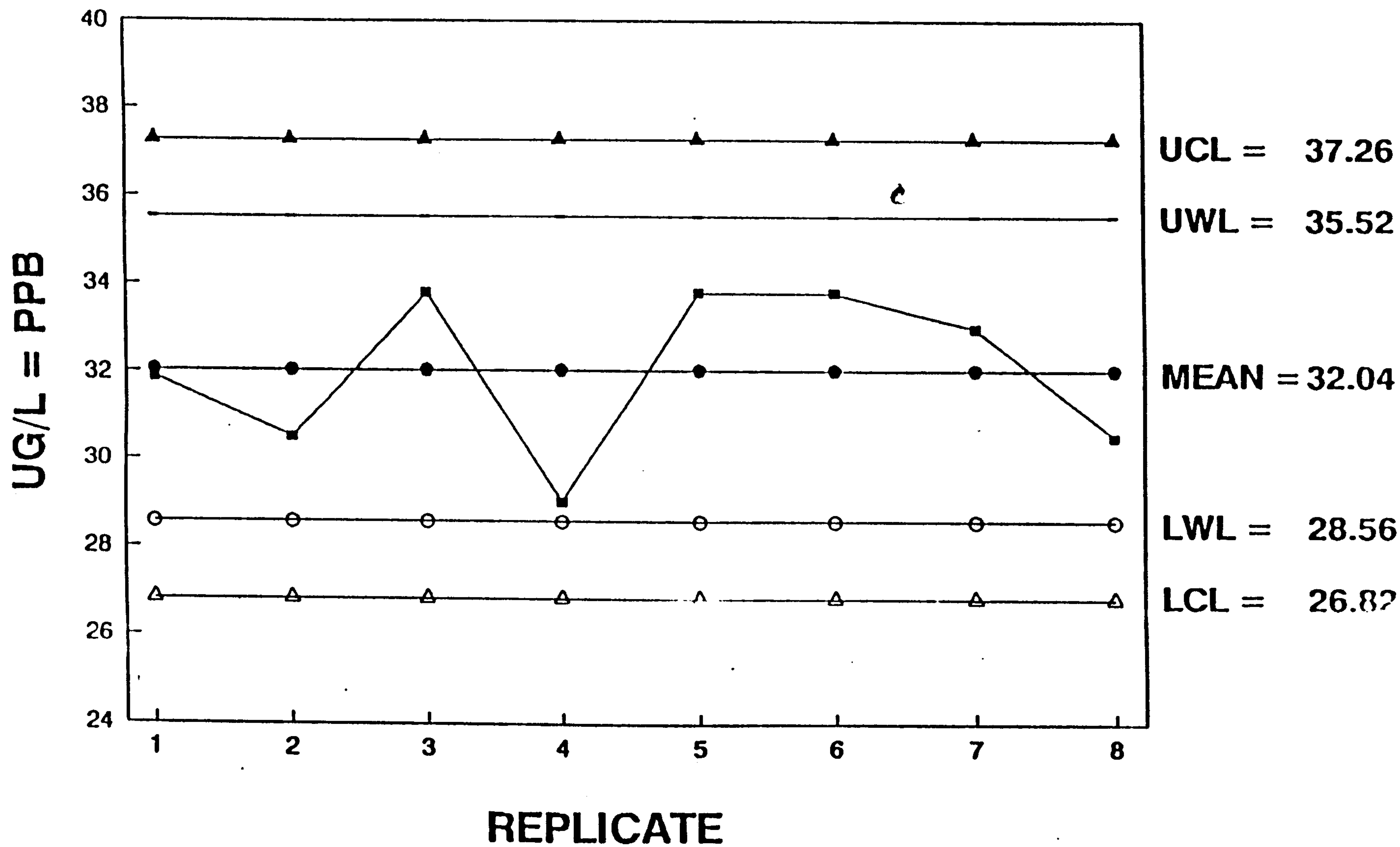
QUALITY CONTROL ANALYSIS - CSU
BIORAD LYPHOCHEK - HIGH SPIKE ARSENIC



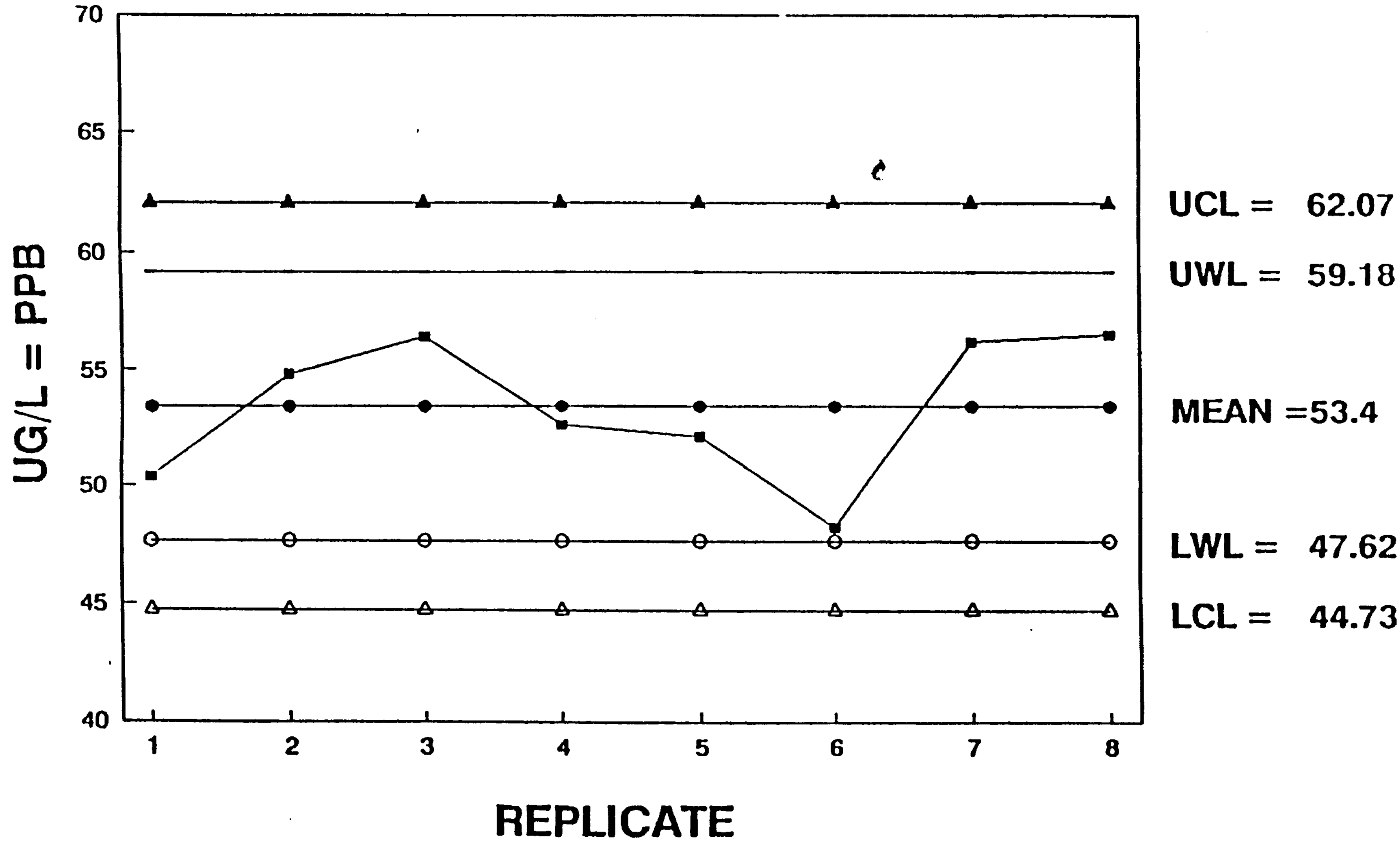
QUALITY CONTROL ANALYSIS - CSU
BIORAD LYPHOCHEK - LOW SPIKE MERCURY



QUALITY CONTROL ANALYSIS - CSU
BIORAD LYPHOCHEK - HIGH SPIKE MERCURY



QUALITY CONTROL ANALYSIS - CSU
BIORAD LYPHOCHEK - LOW SPIKE ARSENIC



Arsenic Duplication of Urine Samples

ANALYSIS TIME

(PPB)

SAMPLE NO.	FIRST	SECOND
935	10.9	8.0
940	11.5	10.7
983	24.4	22.7
03	31.7	26.3
13	13.9	14.8
21	20.2	19.2
22	11.2	10.5
49	13.7	13.0
58	16.8	15.4
60	14.1	12.7
62	11.4	11.5
71	18.2	16.6
96	12.7	12.3
109	11.6	12.0
111	11.0	13.1
127	16.0	8.7
[illegible]4	23.0	16.7
	18.9	16.8
	23.9	25.3
1[illegible]	13.8	12.4
18	23.2	12.5
1[illegible]	13.1	13.6
2[illegible]	12.2	11.4
[illegible]	11.4	9.7
	21.7	7.0
43[illegible]	14.5	15.9
	53.3	47.8
	20.1	20.1
49	18.0	12.4
50	18.6	18.6

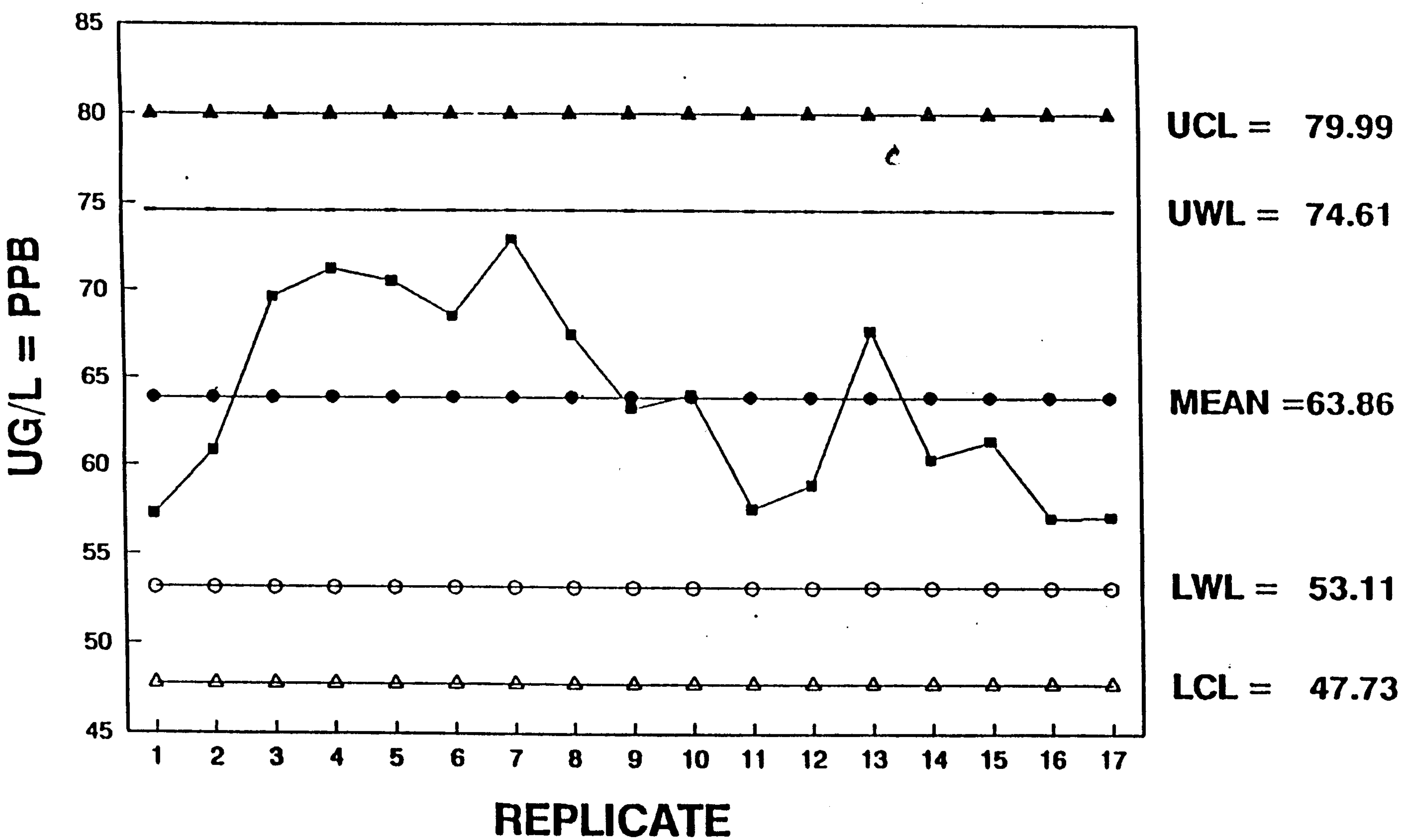
HIGH SPIKE — 63.9 = MEAN

1	63.2
2	63.7
3	59.3

BIO SPIKE — 53.7 = MEAN

1	59.0
2	63.9
3	49.3

QUALITY CONTROL ANALYSIS - CSU
ARSENIC - COLORADO HIGH POOL

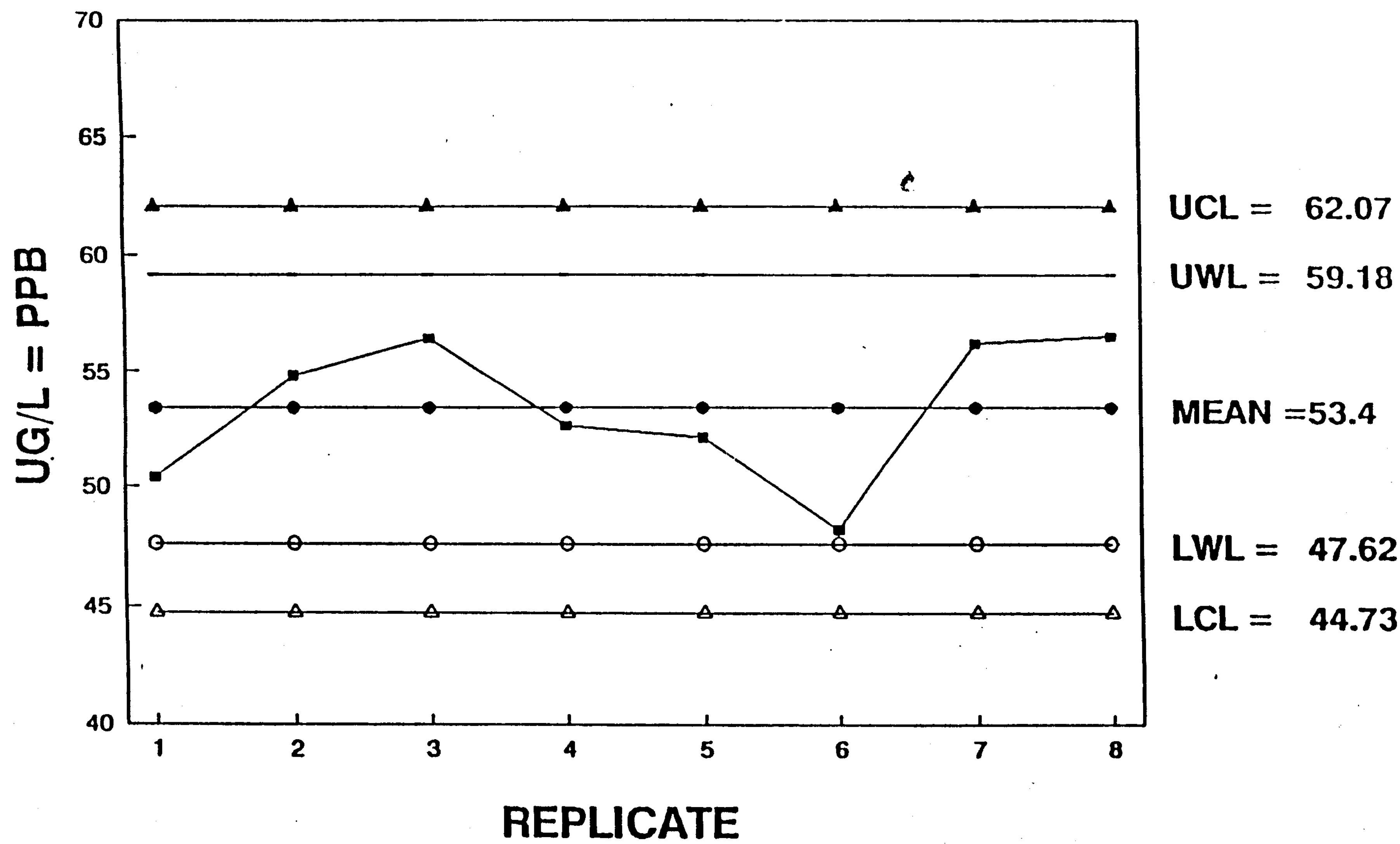


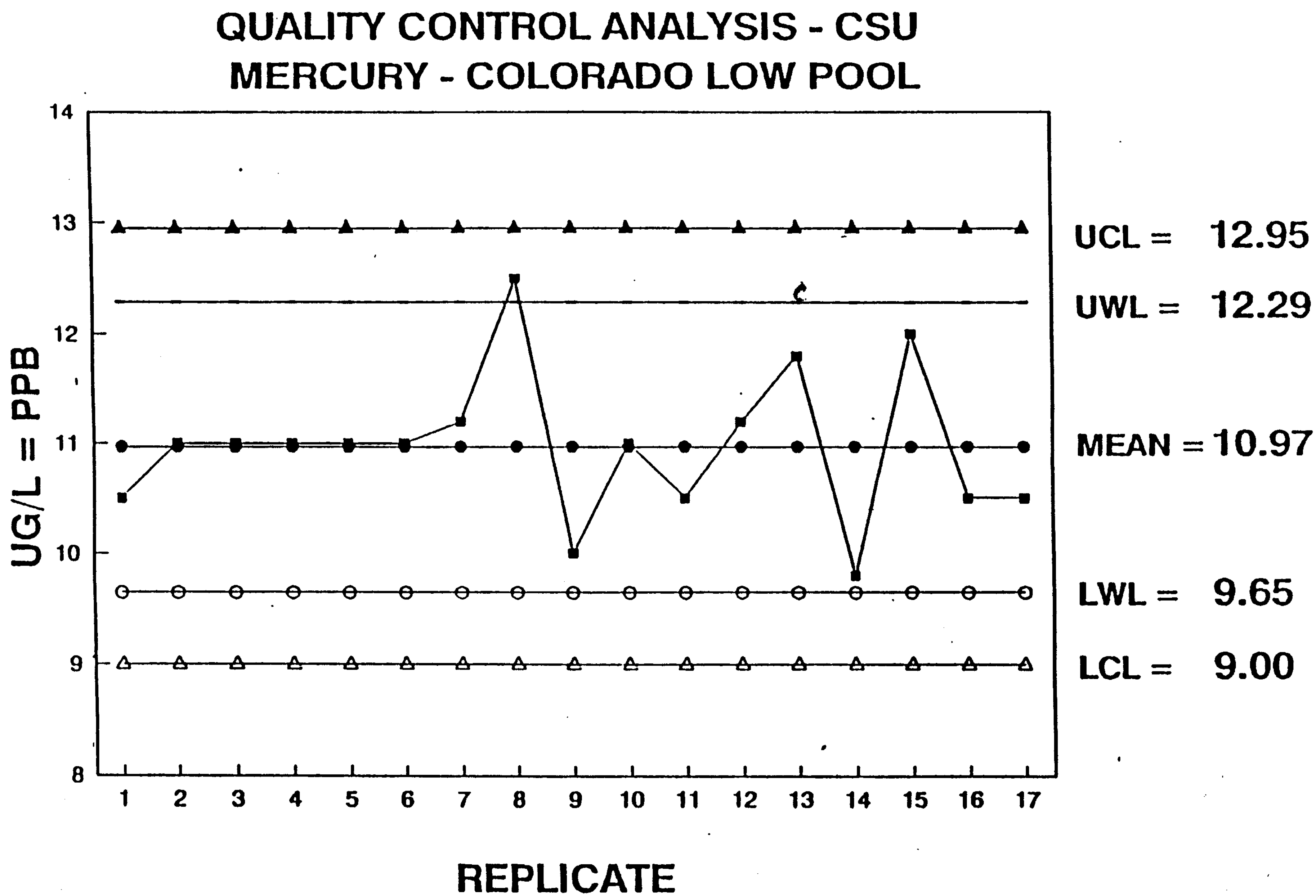
ARSENAL STUDY 1989 CSU
BIORAD LYPHOCHEK URINE METAL CONTROL
HIGH SPIKE ARSENIC QA/QC
DL = 10 PPB BIORAD RANGE 105-159 MEAN = 132 PPB

REPLICATE NUMBER	CSU'S PPB	MEAN	UCL	UWL	LWL	LCL
1	178	165.63	128.91	181.15	150.1	142.34
2	157	165.63	188.91	181.15	150.1	142.34
3	164	165.63	188.91	181.15	150.1	142.34
4	168	165.63	188.91	181.15	150.1	142.34
5	170	165.63	188.91	181.15	150.1	142.34
6	153	165.63	188.91	181.15	150.1	142.34
7	173	165.63	188.91	181.15	150.1	142.34
8	162	165.63	188.91	181.15	150.1	142.34

8 AVG = 165.625
S = 7.761081
UWL = 131.1472 UCL = 188.9082
LWL = 150.1028 LCL = 142.3418

QUALITY CONTROL ANALYSIS - CSU
BIORAD LYPHOCHEK - LOW SPIKE ARSENIC




QUALITY CONTROL ANALYSIS - CSU
MERCURY - COLORADO LOW POOL
UG/L = PPB
14
13
12
11
10
9
8
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
REPLICATE
UCL = 12.95
UWL = 12.29
MEAN = 10.97
LWL = 9.65
LCL = 9.00

March 22, 1991

Participant's name
Address

Dear :

Last winter you participated in the Rocky Mountain Arsenal Exposure Study. If you provided us with a sample of urine at that time, you were sent a letter in January of this year. The letter informed you of the results of the analyses for arsenic and mercury in your urine sample.

We are writing to you now to tell you how the results of these measurements came out for the entire group of people who participated in the study. You may wish to compare your results with those of the rest of the study participants.

The laboratory detected mercury in 31 out of 470 urine samples. The detection limit was 5 parts of mercury per billion parts of urine (ppb). The average mercury level in urines where it was detected was 7 ppb. The amounts of mercury ranged between 5 ppb, the detection limit, and 16.1 parts per billion.

The laboratory detected arsenic in 44 out of 470 urine samples. The detection limit was 10 ppb. The average arsenic level measured in urines where it was detected was 15.5 ppb. The range was between 10 ppb and 53.3 ppb.

If you have any questions about these laboratory measurements or the study, please do not hesitate to call me at 331-8621. Thank you for your participation.

Sincerely,

Theodora A. Tsongas, Ph.D., M.S.
Study Director

TAT/rn